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INDIAN
FOREST ECOLOGY

FOREST is a peculiar organism of unlimited kindness and benevolence that makes no demand for its sustenance and extends protection to all beings, offering shade even to the axeman who destroys it''.....

.....*Gautama Buddha.*

ECOLOGY is the science treating of reciprocal relations of organism and the external world.....

.....*E. Haeckel*

INDIAN FOREST ECOLOGY

A Comprehensive Survey of Vegetation and its Environment in the Indian Subcontinent

by

G. S. PURI

Vol. I

Complete in 2 Volumes

with Foreword by
Prof. W. H. PEARSALL, M.A., D.SC., F.R.S.,
University of London, England

Preface by
Prof. SIR HARRY G. CHAMPION, M.A., D.SC., I.F.S. (Retd.),
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This book is dedicated

to

my Mother and Father.

FOREWORD

By

PROF. W. H. PEARSALL, M.A., D.SC., F.R.S.,

Professor of Botany, University of London.

I write a short foreword for this book with great pleasure, as well as with appreciation and expectation. I am pleased to see how a former colleague, Dr. G. S. Puri, has been able to profit by the almost limitless opportunities for ecology in the Indian sub-continent to develop this subject of forest ecology and to bring together in this book such an impressive mass of data. To most European Ecologists, the extent of the information available about Indian Forests, their vegetation and ecology, will come as a surprise and the integration of this material in book form will be generally appreciated. Most Ecologists will also appreciate the possibilities now presented for future work and we may hope that abundant opportunities will arise for Indian Ecologists to develop a subject of such great interest alike to the scientists and to the practical foresters. Ecology is a fundamental basis of successful forestry as all other forms of land-use. It is, therefore, fitting that a work of this character should have come from the Forest Research Institute at Dehra Dun, which has done and is doing so much for forestry in general and Indian forestry in particular.

PREFACE

By

PROF. SIR. HARRY G. CHAMPION, M.A., D.SC., I.F.S. (Retd.)

Professor of Forestry, Oxford University,
Formerly Central Silviculturist, Forest Research Institute, Dehra Dun.

It is a matter of great interest and indeed satisfaction to me that the compilation of a comprehensive survey of the vegetation of the Indian sub-continent in its ecological aspects has now been undertaken. The vastness of the area to be covered, and still more, the unparalleled range of environmental conditions and associated types of vegetation, are such that very few individuals have had the opportunities for acquiring enough first-hand knowledge even to contemplate a general survey. Over the century, however, there have been many individuals with keen interest in the vegetation of the areas in which they worked or which were accessible to them and with the passage of years from Wallich, Royle and Hooker's time onwards, one region after another had come under study. Naturally in the early days, the emphasis was more on the taxonomic and floristic aspects, but the environment was always in mind and gradually began to receive increasing attention. Foresters, like myself, are proud of the leading part that their profession has played in these local studies. Many of these men such as Gamble, Hole and Haines, though strictly speaking, all amateurs in botany, achieved very high level of botanical work. Similar work was done by the Botanical Survey which began publication in 1893, but in view of the magnitude of its task was always starved of funds and staff. The build up of material was accelerated as Botanical Departments got going in the several Universities and the Indian Botanical Society was founded. Through its journal, the latter Society has, since 1919, contributed a very considerable number of papers bearing on Indian botanical ecology.

It is not surprising that the foresters, particularly, since the opening of the Forest Research Institute at Dehra Dun in 1914, have been the most keenly interested in this subject. for much of their professional work dealing with natural or semi-natural vegetation demands a knowledge and understanding of the growth of forests in relation to their environment. Moreover, the natural climax vegetation of almost whole of the country is forest or at least wood-land. It will be noted that hitherto the foresters, whether officially 'forest botanists' or 'silviculturists' have undertaken so much of this work because they needed it for practical application and because others better qualified for such studies were not doing it. The establishment of Forest Research Institute to serve the whole of India provided new opportunities, particularly in the silvicultural branch for some of its staff to become acquainted with the forest in all parts of the country, both at first hand and through their contacts everywhere. It thus became possible to get a general view and to put forward the first attempts at a connected story, pin pointing the major gaps and stimulating others to make improvements and extensions.

Meanwhile, ecology as a science in its own right, linking vegetation with environmental, biotic and especially human factors, has rapidly developed and the time was more than ripe for scientists trained as ecologists to take over the task. The recent (1955) establishment by the Government of India of the Indian Council of Ecological Research under the Chairmanship of Shri C. R. Ranganathan, Inspector General of Forests, with the author of this book as Secretary, marks not only a significant advance in Indian ecology, but official recognition of the importance of the subject to the general welfare of the country. It is most appropriate that the author should be the first Forest Ecologist at the Forest Research Institute and one who brings high qualifications in botanical ecology to this field. The chapters dealing with the influence of soil variations with the related solid geology and those on the grasslands, deserts, aquatic vegetation will be of special interest, since these are some of the fields in which most earlier studies have been markedly deficient.

I am confident that Dr. Puri's monumental work will be of the greatest value to all who are concerned with India's vegetation whether from the view point of pure science or from that of the application to it of the arts and sciences involved in agriculture, animal husbandry, forestry, soil conservation, etc. He would be the last to claim finality and the labour he has put into it will be well repaid if it encourages others, as I am sure it will, to make further contributions towards extending and deepening our knowledge of the whole complex interaction of vegetation and environment in India.

AUTHOR'S PREFACE

This book is a companion volume of the "Indian Manual of Plant Ecology" by R. Misra and G. S. Puri. It contains a critical summary of most of the important botanical and ecological literature, so far published on Indian Vegetation and is intended to serve as a reference book for teachers and research workers engaged on different aspects of ecological research. In its preparation, interests and requirements of foresters, agriculturists, botanists, geographers, soil scientists, ecologists and other specialists in Indian vegetation* have been kept in view; yet the book contains in every chapter, description of some parts of the subject in a popular language to interest graduate students and amateurs, who may not have technical knowledge of ecology.

The book is divided into 3 sections. In section A. basic facts about the Indian flora, vegetation and its environment are given. The geographical and geological histories of Indian vegetation would be of special interest to geo-botanists, plant geographers and palaeobotanists. The chapter on the classification of Indian and tropical vegetation would be of a great value to forest typologists in tropical countries.

In Section B, a fairly complete and comprehensive description of Indian vegetation as represented in the forests, grasslands, deserts, mangroves, savannahs, scrubs, lakes and plantations is given. In its preparation, Champion's classification of Indian vegetation as given in his "Forest Types of India" has been used, with some modifications. A large amount of published material not given in 'Forest Types of India' and nearly all the material published after 1938 have been incorporated in this book. It must be admitted that this section is still far from complete; but if it serves to focus the attention of research workers on important aspects of vegetation that have yet to be studied, the purpose of preparing this would be fulfilled.

On account of the absence of a sufficient amount of data on a number of important vegetation types, it has not been possible to completely revise the preliminary classification of Prof. Champion. However, basic defects in that classification have been remedied and all types of vegetation of the Indian sub-continent have been for the first time, properly arranged in ecologically distinct, climatic, edaphic and biotic types. It has been assumed that the original vegetation of India is a forest of some kind or the other and all other types have been considered as natural or artificial variations of the forest climax. The existence in this country of only four climaxes, viz. alpine, temperate, tropical and sub-tropical has been accepted, though it has not been possible on the data available at present, to ascertain clearly how far climate alone has been responsible in delimiting the various sub-types. The edaphic and biotic types have been considered as seral, in accordance with Clement's terminology and the use of the terms edaphic climax, physiographic climax or biotic climax has been dropped, as unsound. It has been pointed out that on account of the monsoonic climate, the climatic zones of India

*Treated here only in geographical and not political sense.

are determined by changes in moisture, which show gradation from south-east to north-west; as well as temperature, which changes predominantly from south to north. The role of the Arabian sea branch of monsoon in the Deccan brings in further complications in the latitudinal vegetational zonation concept. On this basis, homogenity, rather than heterogenity, of the northern and southern sub-types has been emphasized. The differences in the composition and structure of vegetation in the reorientated climatic zones have been shown to be due to edaphic and biotic factors, rather than normal small changes in temperature or rainfall from place to place. Some of the concepts used here may not be acceptable to all ecologists but it is hoped that future work will clarify further the concepts used in the systematic classification of Indian vegetation. Botanical nomenclature is another difficult task to keep up-to-date. Recently, there have been a number of changes in plant names. By substituting old names with new ones while quoting previous references would have in many cases been misleading. Moreover, all plant name changes have not so far been brought out in Indian flora and before the book is out many more changes may be necessary. Therefore, to avoid confusion, in most cases, old names mentioned by various authors quoted have been followed in this book. In more latest botanical studies some new names have, however, been used.

Section C, including the study of environment of Indian vegetation is the major section of the book. Chapters on climate, micro-climate, geology and soils contain fairly good details of normal, spatial and seasonal variations of these natural factors and their relationship with vegetation. The paucity of exact data on environment from various types and sub-types of Indian vegetation has made it difficult to present any finer correlations of vegetation with the complex of the environmental factors, however. These chapters, it is hoped, would direct attention of research workers for collecting the much needed fundamental data for the above purposes. Much of the older works on Indian vegetation lacked data on geology and soils. Even now detailed soil data in many parts of India on profile basis are not available. Works on forest soils are extremely rare. The need for such studies to establish a closer relationship between vegetation and soils has been emphasized. The importance of the biotic factor in shaping the various types of Indian vegetation has been, for the first time, clearly appreciated, though earlier workers like Champion have taken notice of this. The role of man and his domesticated animals in vegetational development and succession, has been stressed. The role of such environmental factors as volcanoes, mud flows, earth-quakes, etc. will be of considerable interest.

Ecology, as an independent subject has not so far been pursued in this country in any University. The ecological studies of the Indian vegetation so far published have been made more as a hobby and as a side line by officers of the forest and agricultural departments, who normally lacked proper facilities and opportunities for detailed studies of all aspects of the vegetation and its environment. Their works have been of different standards from those of the University men, who have in a few cases, made complete studies of vegetation in relation to its environment. This has presented difficulties in critically examining all the relevant literature on a uniform standard. While trying to include all known facts any ambiguity that could not be resolved, has been left out of this book. Nevertheless, it will be difficult to claim finality in a work of this nature and any important omission would be included in the next edition,

CHAPTER 1.

INTRODUCTORY 1-12

Natural Vegetation of India – 1, What is a Forest – 1, The Study of a Forest – 1, Plant Ecology and Forest Ecology – 2, History of plant ecology, forest ecology and Silviculture – 2, Plant Geography and Plant Ecology – 3, Forestry and Forest Ecology – 3, Forest Ecology, Silvics and Silviculture – 4, Basic concepts of Forest Ecology – 4, Forest Ecology and Forest Management – 5, Other applications of Forest Ecology in India – 5, History of Forest Ecology in India – 6, Forest Ecological problems of India – 6, The Aim and Scope of Forest Ecological Research In India – 9, References – 9.

SECTION A

CHAPTER 2.

INDIAN FLORA – ITS COMPOSITION AND ENDEMISM 14–27

Areas under forest vegetation in India – 14, Salient features of Indian Flora – 15, Endemic Flora of India – 16, Non-endemic elements in the Indian Flora – 19, Malayan Element in Burmese and Indian Floras – 19, Chinese element in Burmese and Indian Floras – 20, Australian element in Indian flora – 20, The Malayan, N. African, Tropical, Subtropical, Mediterranean and European elements in Indian floras – 21, Exotic weeds in Indian flora – 23, List of endemic and non-endemic dicots in Indian flora – 23.

CHAPTER 3.

BOTANICAL REGIONS OF INDIA 28–69

Western Himalayas – 28, Eastern Himalayas – 29, Indus Plain – 30, Gangetic plain – 31, Central India – 31, The West Coast of the Malabar – 31, The Deccan – 32, Assam – 32, Andamans – 32, Laccadive and Minicoy Group of Islands – 32, Geographical distribution of some south Indian flora – 33, Parasnath hill in Chota Nagpur Plateau – 33, Mahendra Giri hills in South Orissa – 33, Jaspur and Sarguja in M.P. – 33, Hills of Bihar, Orissa and neighbouring states – 34, Sholas of the Nilgiris – 35, Malabar – 35, Geographical distribution of Abor land flora – 36, Phyto-geographical patterns of some important Indian trees – 40, Theories to explain the discontinuous distribution of some Indian forest trees – 62, Himalayan glaciation theory – 62, Southern route across Indian Ocean theory – 62, Deccan Traps theory – 62, Continuous Range theory – 62, Satpura Hypothesis – 62, Burkill's views regarding the discontinuous distribution of plants in India – 63, References – 68.

CHAPTER 4.

GEOLOGICAL HISTORY OF FOREST VEGETATION OF INDIA 70–84

Traces of forest plants in pre-Tertiary-vegetation of India – 70, Dipterocarpoxylon garoense – 72, Cynometroxylon – 72, Glutaxylon – 72, The modern distribution of the Tertiary vegetation and its significance in phyto-geography of India – 74, Inter-trappean Flora of the Deccan – 74, Rajasthan Flora – 74, Kasauli Flora in the Himalayas – 75, Eastern Indian Flora – 75, Pleistocene vegetation of India – 75, The Liddarmarg Flora – 75, The Laredura Flora – 76, The Ningal Nullah Flora – 76, Modern distribution of the Pleistocene Flora and its phyto-geographical importance – 76, Kashmir Valley Flora – 78, Changes of climate and vegetation in the Kashmir Valley since the Pleistocene – 79, Himalayan uplift during the Pleistocene – 79, Post-glacial vegetation of India – 80, Historical records of climate and vegetation in India – 81, Sanskrit names – 82, Botanical names – 82, References – 83.

CHAPTER 5.

CLASSIFICATION OF INDIAN VEGETATION 85–102

The basis of classification of Indian vegetation – 85, Climate – 85, Temperature – 85, Rainfall – 88, Temperature and rainfall – 88, Types of Indian vegetation – 88, Tropical climax types – 89, Tropical edaphic types – 89, Biotic types – 90, Sub-tropical Forest – 91, Temperate forests – 92, Alpine Forests – 92, Objection to the climatic classification of Indian vegetation – 92, Classification of Indian Vegetation – 93, Moist Tropical Forests – 93, Climatic – 93, Primary Edaphic – 94, Subsidiary Edaphic – 94, Secondary edaphic – 94, Biotic – 94, Dry tropical forests – 94, Climatic – 94, Primary edaphic – 95, Subsidiary edaphic – 95, Biotic – 95, Montane subtropical forests – 95, Climatic – 96, Biotic – 96, Montane temperate Forests – 96, Climatic – 96, Subsidiary-Edaphic – 96, Biotic – 96, Alpine Forests – 96, Climatic – 96, Subsidiary edaphic – 96, Biotic – 96, Classification of tropical vegetation – 97, Burtt Davy's classification for tropical vegetation – 97, Woodland – 97, Grassland – 97, Desert – 97, Tropical Woodland – 97, References – 102.

SECTION B.

CHAPTER 6.

ALPINE VEGETATION OF INDIA. 104–115

Alpine Stony Deserts – 104, Alpine Scrub – 104, Open flats – 105, On Moraines and Screes – 105, Alpine meadows or pastures – 107, Colour scheme in Alpine pastures – 108, Alpine forests – 110, Alpine fir-birch forest – 110, Birch-Rhododendron forest – 113, Ecological status and successional relationship – 113, Stony deserts – 114, Alpine scrub – 114, Alpine meadows – 114, Alpine Forests – 114, References – 114.

CHAPTER 7.

TEMPERATE FORESTS OF INDIA 116–146.

Himalayan Moist temperate forests – 116, Southern Wet temperate forests – 118, Northern wet temperate forests – 120, Associations – 122, Consociations – 122, West Himalayan temperate forests – 125, Forest management types of temperate vegetation – 130. Hardwood sub-type – 131, Taxus sub-type – 131, Arundinaria sub-type – 131, Indigofera-Desmodium sub-type – 131, Spiraea-Viburnum sub-type – 131, Plectranthus rugosus sub-type – 131, Senecio sub-type – 131, Bracken sub-type – 131, Iris sub-type – 131, Strobilanthes-balsam sub-type – 131, Quercus incana – Rhododendron arboreum – Pinus excelsa community –133 Pinus excelsa secondary community – 133, Pinus excelsa – Picea smithiana secondary community – 133, Quercus incana – Quercus dilatata community – 133, Quercus dilatata – Pinus – Picea – Abies community– 133, Aesculus indica – Picea smithiana community – 133, Pinus excelsa – Picea smithiana community – 133, Secondary scrub community – 133, Secondary scrub community – 134, Quercus dilatata community – 134, Cedrus deodara community – 134, Cedrus deodara – Picea smithiana community – 134, Succession of forest communities in the zone of high monsoon rainfall – 134, Quercus semecarpifolia – 134, Succession in Quercus incana zone – 140, Vegetation of dry temperate zone of the Himalayas – 142, Quercus ilex community – 143, Cedrus deodara – Quercus ilex community – 143, Degenerate Quercus ilex scrub – 143, Quercus ilex – Pinus gerardiana community – 143, Pinus gerardiana – Quercus ilex community – 143, Cedrus deodara – Pinus gerardiana – Quercus ilex community – 143, References – 145.

CHAPTER 8.

TROPICAL FORESTS OF INDIA 147–174.

Moist tropical wet evergreen forests – 147, Southern tropical wet evergreens – 147, Tropical forests of North Kanara – 153, Tropical forests of Kerala – 155, Regeneration of Tropical forests – 155, Succession of forest communities in tropical forests – 155, Northern tropical wet evergreens – 155, Dipterocarpus forests of India – 162, Tropical forests of Assam – 162, Succession in wet evergreen forests – 165, Other features of wet evergreen forests – 165, Moist tropical semi-evergreen forests – 167, Southern moist tropical semi-evergreens – 167, Moist tropical forests of Kerala – 171, Northern moist tropical semi-evergreens – 171, Tropical forests of Kalimpong – 172.

CHAPTER 9.

TROPICAL MOIST DECIDUOUS FORESTS 175–199.

Southern tropical moist deciduous forests – 175, Succession in southern tropical moist deciduous forests – 177, Teak forests of India – 177, The teak Forest of Saurashtra – 177, Teak Forests in Central India – 179, The Teak Forests of Poona and Bombay – 179, Teak in Madhya Pradesh – 180, Succession of forest communities in some teak forests – 180, Sandal forests – 183, Northern tropical moist deciduous forests – 184, Succession in northern tropical moist deciduous forests – 184, The sal forests of India – 188, Natural Regeneration of Sal forests – 189, Dry tropical forests – 192, Southern tropical dry deciduous forests – 192, Northern tropical dry deciduous forests – 192, Succession in northern tropical dry deciduous forests – 192, References – 198.

CHAPTER 10.

MONTANE SUB-TROPICAL FORESTS 200–211.

Southern sub-tropical wet hill forests – 200, Sub-tropical forests at Mahabaleshwar – 200, Sub-tropical forests of Bhimashankar – 202, Sub-tropical forests of Coorg – 203, Sub-tropical evergreen forests of Central. India, Parasnath hills – 203, Bailadila range in Bastar State – 203, Kenahandi State – 204, Northern – sub-tropical wet hill forests – 204, Sub-tropical forests of the Eastern Himalayas – 204, Middle hill forests of the Kalimpong forest division – 206, Darjeeling Hills forests – 206, Aka Hills forests in Assam – 206, Sub-tropical pine forests – 207, Mussoorie pine forests – 207, Chir pine forests of Kangra, Hoshiarpur and Mandi – 209, Chir pine community of Garhwal Himalayas – 209, Pinus Khasya forests of Assam – 209, Sub-tropical dry evergreen forests – 210, Referrences – 210.

CHAPTER 11.

EDAPHIC FORESTS OF INDIA 212–233.

Riverain forests of India – 212, Plains of the Ganges and Brahmaputra – 212, Moist . tropical – 212, Moist riparian forest consisting of Lagerstroemia and Terminalia – 212, Gangetic tropical moist deciduous riverain forests – 212, Evergreen riverain – 213, Cane brakes – 214, Northern moist bamboo brakes – 214, Northern (Assam) tropical secondary evergreen forest – 214, Dry tropical – 214, Khair-sissu forest – 214, Aegle forests – 214, Peninsular India – 217, Moist tropical – 217, Southern tropical moist deciduous riverain forest – 217, Southern wet bamboo brakes – 217, Southern moist bamboo brakes – 217, Kanara bamboo forests – 217, Dry tropical – 217, Southern dry tropical riverain forest – 217, Inundation babul forest – 218, Andamans – 218, Southern tropical semi-evergreen riverain forest – 218, Himalayas – 218, Moist Temperate riverain forest – 218, Alder woods – 218, Temperate Hippophae scrub – 218, Moist temperate deciduous forest – 218, Succession in riverain habitats – 218, Mangrove forests of India, – 222, Beach forests – 223, In the Coco group of Islands – 223, Beach forest of Andamans – 224, Tidal forests – 224, Low mangrove forest – 224, Tree mangrove forest – 224, Sunderbans forests – 224, Mangroves of the Bombay Presidency – 225, Mangroves forests of Andaman – 226, Salt water Heritiera forest – 227, Fresh-water Heritiera forest – 227, Mangroves of Chakaria Sunderbans – 227, Tropical valley fresh water swamp forests – 228, Swamp forest of Mothronwala – 228, Swamp forest of the Brahmaputra valley – 228, Physiology of mangroves plants – 228, Geographical distribution of mangrove plants – 231.

CHAPTER 12.

TERRESTRIAL EDAPHIC FOREST COMMUNITIES 234–245.

Edaphic types of the plains of the Ganges and Brahmaputra – 234, N. Indian moist deciduous forest – 234, North Indian moist Terminalia forest – 234, E. Himalayan moist deciduous forest – 234, E. Sub-Himalayan wet mixed forest – 235, Wet plains sal forest – 235, Secondary moist bamboo brakes – 235, Moist deciduous sal forest on Siwalik clay – 235, Sal forest on dip slope of Siwalik clay – 235, Sal forest on conglomerate – 235, Sal forests on red clayey soils in Central India – 235, Edaphic types of the Peninsular India – 238, Western laterite semi-evergreen

forest – 238, Secondary evergreen Dipterocarp forest – 238, Coastal sal forest – 238, Southern tropical secondary moist deciduous forest – 238, Teak Community on the Basalt – 238, Evergreen forests on ferruginous clay – 240, Acacia catechu community on amygdaloid – 240, Edaphic types of the Andamans – 240, Andamans moist deciduous forest – 240, Edaphic types of the Himalayas – 240, Cypress forest – 240, Dry temperate deciduous forest – 241, Temperate Bamboo brakes – 241, High level blue pine forest – 241, Chir Pine on Siwalik Conglomerate – 241, Chir Pine on the Siwalik Sandstones – 241, Chir Pine community in the Middle and Inner Himalayas – 241, Silver Fir community on Moraines – 241, Deodar Communities in the Himalayas – 243, Blue Pine communities of the Karewas of Kashmir – 243, Forest communities on Dip and Scarp slopes in the Himalayas – 243, References – 244.

CHAPTER 13.

BIOTIC FORESTS OF INDIA 246–270.

Dry evergreen forests – 246, Dry evergreen forest of Sriharikota Island – 246, N. Indian tropical secondary moist deciduous forest – 246, Thorn forests – 247, Southern thorn forests – 247, Thorn forests of Dhond – 247, Thorn forests of Walhe and Trap hills near Khadakwasla – 250, Thorn forests of Khandesh – 250, Semi-desert vegetation of the Anamalai Hills – 251, Northern Thorn forests – 251, Euphorbia Scrubs – 251, Scrubby Vegetation of Kathiawar – 251, Scrubby vegetation of Dwarka – 253, Scrubby vegetation of Bet Dwarka – 253, Thorny scrub Jungle of Cutch – 254, Scrub vegetation of N. India – 254, Dry deciduous scrub – 254, Lower blue pine forest – 254, Oak scrub – 254, Secondary temperate scrub 254, Thatch park land – 255, Scrub Vegetation of the Himalayas – 255, Open Pasture – 255, Pinus excelsa Secondary Community – 255, Secondary Scrub Community – (Dry type) – 255, Secondary Scrub Community (Moist type) – 258, Degenerate Quercus ilex Scrub – 258, Savannah vegetation – 258, N. Indian upper alluvial Savannah – 258, N. Indian lower alluvial Savannah – 258, Dry Savannah – 258, Nilgiri subtropical hill Savannah – 259, Ecological status of savannah in India – 259, Desert vegetation of India, – 259, The Origin of the Indian desert – 261, Desert vegetation of Rajputana – 262, Sand Communities – 262, Gravel Communities – 263, Rock Communities – 264, Desert vegetation of Ajmer-Jaipur Region – 262, Desert vegetation of the Jhelum district – 266, Characters of Xerophytic desert plants – 267, Water storing cells – 267, Glandular hairs – 267, Secretory organs – 267, Pericycle – 268, Vegetation of the Gangetic valley – 268, Aquatic stage – 268, Wet meadow stage – 269, Dry meadow stage – 269, Thorn scrub stage – 269.

CHAPTER 14.

GRASSLAND VEGETATION OF INDIA 271–298.

Xerophilous grasslands – 271, Mesophilous grasslands – 271, Hygrophilous grasslands – 271, Main grassland types of India – 271, Dichanthium – Cenchrus – Elionurus type – 272, Dichanthium – Cenchrus – Elionurus sub-type – 272, Cenchrus – Elionurus sub-type – 272, Cynodon–Eleusine sub-type – 273, Aristida – Eragrostis sub-type – 273, Schima-Dichanthium type – 273, Sehima – Dichanthium sub-type – 273, Chrysopogon – Bothriochloa sub-type – 273, Heteropogon – Eremopogon

sub-type - 274, Aristida - Eragrostis, etc. sub-type - 274, Phragmites - Saccharum type - 274, Phragmites karka sub-type - 274, Phragmites - Saccharum sub-type - 274, Imperata cylindrica sub-type - 274, Sporobolus - Paspalum sub-type - 274, Succession of Grassland Communities - 275, Grass Ecology - 275, Grassland types of the Punjab - 276, Grassland types of U.P. - 285, Grassland vegetation of Central India- 285, Grassland types of Assam - 289, Tropical habitats - 289, Sub-tropical habitats - 289, Temperate habitats, Grass and vegetation of Kathiawar - 290, Desert Grasslands - 291, Cutch grasslands - 292, Grasses of Bhopal - 292, Grasslands of South India - 292, Grasslands of Nilgiris and Anamalai Hills - 292, Grassland - 293, Lower grassland subtype - 293, Upper grassland sub-type - 293, Grassland Vegetation of Bombay - Deccan - 293, High Rainfall Grassland - 293, Low rainfall Grasslands - 294, Succession of Deccan grasslands - 296, Grasslands and Wheat rust problem - 296.

CHAPTER 15.

BIO-EDAPHIC FORESTS OF INDIA 299-307.

Anogeissus pendula forest - 299, Inland dune scrub - 299, Gangetic saline scrub - 300, Dry Bamboo brakes - 300, Peninsular India - 300, Hardwickia - 300, Boswellia - 300, Butea - 300, Babul - 302, Laterite thorn forest - 302, Secondary dry deciduous - 305, References - 305.

CHAPTER 16.

ARTIFICIAL FORESTS OF INDIA 308-318.

Tectona grandis - 308, Shorea robusta - 310, Pinus roxburghii - 310, Deodar and other conifers - 311, Eucalyptus - 311, Cryptomeria japonica - 314, Casuarina equisetifolia - 314, Khair and Sissoo plantations - 315, Other plantations of indigenous and exotic plants - 315, Techniques of raising artificial forests - 315, Irrigated plantations - 316, Unirrigated - 316, Taungya system - 316, Ecological techniques of the introduction of Exotic plants in India - 317, References - 317.

which would be possible to present with the expanded programme of ecological research of the Indian Council of Ecological Research, that has recently been established by the Government of India.

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18, New Forest, Dehra Dun. **G. S. PURI.**

LIST OF FIGURES AND MAPS

Fig. No.		Page No.
1	East Mediterranean Influence on Indian Flora. ...	23
2	Vegetation zones in the Western and Eastern Himalayas (diagrammatic).	41
3	Distribution of *Terminalia arjuna*.	42
4	Distribution of *Terminalia tomentosa*.	42
5	Distribution of *Gmelina arborea*.	43
6	Distribution of *Adina cordifolia*, Anogeissus Latifolia. ...	43
7	Distribution of *Careya arborea*.	44
8	Distribution of *Eugenia Jambolana*.	44
9	Distribution of *Lannea grandis*.	45
10	Distribution of *Ougeinia dalbergioides*.	45
11	Distribution of *Hymenodictyon excelsum*.	46
12	Distribution of *Tectona grandis*.	46
13	Distribution of *Mesua ferrea*.	47
14	Distribution of *Xylia xylocarpa*.	47
15	Distribution of *Michelia champaca, Michelia excelsa*. ...	48
16	Distribution of *Lagerstroemea flos-raginae, Lagerstroemea hypoleuca*.	48
17	Distribution of *Hardwickia binata, Hardwickia pinnata*. ...	49
18	Distribution of *Hopea odorata, Hopea parviflora, Hopea wightiana*.	49
19	Distribution of *Podocarpus nerifolia*.	50
20	Distribution of *Homalium tomentosum*.	50
21	Distribution of *Terminalia bialata, Terminalia manii*. ...	51
22	Distribution of *Terminalia paniculata*.	51
23	Distribution of *Chickrassa tabularis Chloroxylon swietenia*.	52
24	Distribution of *Calophyllum inophyllum, Calophyllum spectabile, Calophyllum tomentosum*.	52
25	Distribution of *Artocarpus chaplasha, Artocarpus integrifolia, Artocarpus hirsuta*.	53
26	Distribution of *Dipterocarpus marcrocarpus Dipterocarpus turbinatus*.	53
27	Distribution of *Carallia integerrima, Carapa moluccensis*, ...	54
28	Distribution of *Grewia tiliaefolia*.	54
29	Distribution of *Dillenia pentagyna*.	55
30	Distribution of *Cedrela toona*.	55
31	Distribution of *Betula atnoides, Ulmus wallichiana*. ...	56
32	Distribution of *Acer campbellii, Acer oblongum*. ...	56

33	Distribution of *Bischofia javanica.*	57
34	Distribution of *Engelharditia spicata, Juglans regia.* ...	57
35	Distribution of *Abies webbiana, Taxus bacata.* ...	58
36	Distribution of *Picea morinda, Cedrus deodara.* ...	58
37	Distribution of *Pinus longifolia, Pinus excelsa, Pinus khasya.*	59
38	Distribution of *Dalbergia sissoo.*	59
39	Distribution of *Diospyros assimilis, Diosypros embryopteris, Diospyros marmorata, Diospyros melanoxylon.* ...	60
40	Distribution of *Acacia arabica, Acacia catechu, Acacia ferruginea.*	60
41	Distribution of *Bombax malabaricum, Boswellia serrata.* ...	61
42	Distribution of *Albizzia lebbek, Albizzia odoratissima.* ...	61
43	Distribution of climatic types.	86
44	Vegetational types of India and their variations with rainfall and altitude.	87
45	Relation between Forest communities and geological features in the Beas Valley near Naggar.	142
46	Relation between Surface geology and Vegetation. ...	142
47	Relation between Vegetation and geology in Parbatti Valley, Kulu.	142
48	Relation between geological features & forest communities.	142
49	Relation between tree communities and surface deposits at Pulga.	143
50	Arid Regions of the world.	261

LIST OF PHOTOGRAPHS

Photo No.		Chapter No.
1	Glaciers, alpine meadows on glacial moraines together with silver fir and blue pine forest above Pulga, Kulu (H. G. Champion).	6
2	*Saxifraga stracheyi* growing on rocks at Choor peak, 11,500 ft. in Sirmoi state (C. E. Parkinson).	6
3	*Juniperus recurva* growing on rock in Hazara, N.W.F.P. Pakistan. (R. S. Troup).	6
4	*Betula cylindrostachys* and *Rhododendron Mccabeanum* forest at Naga hills, Assam (N. L. Bor).	6
5	A view of glacial moraine above 9,000 ft. in Kulu Himalayas above Pulga, showing a grassy meadow with *Viola, Trillium, Fragaria, Indigofera*, etc. (G. S. Puri). ...	6
6	*Primula nivalis* and *Fragaria* at Monali, Kulu Himalayas at 12,000 ft. (N. L. Bor).	6
7	*Rhododendron campanulatum* community in *Abies pindrow-Betula utilis* areas at 11,200 ft., below Harangate in the Bashahar Himalayas (M. V. Laurie).	6
8	*Rhododendron hypenanthum* Balf. f. at 12,500 ft. Panch Chulhi Range with peak 22,650 in the background (K. C. Sahni).	6
9	*Anemone polyanthes* D. Don. at 13,500 ft., Panch Chulhi (K. C. Sahni).	6
10	*Sambucus niger* community near Sonmarg Glacier (B.S.I.).	6
11	Evergreen sholas confined to damp nallas & sheltered sites on steep slopes in the Nilgiris, above Avalanche (F.R.I.). ...	6
12	Sholas and grasslands in the Anamalai Hills, Madras (J. M. Seet).	6
13	Temperate evergreen sholas with *Ilex wightiana, Myrsine wightiana, Eugenia* sp., *Mahonia*, etc. and a fringe of *Eupatorium glandulosum* at Ootacamund, Madras (H. G. Champion).	6
14	Temperate Oak forest at 6,000 ft. with *Quercus lineata, Castanopsis*, etc., with many *epiphytes*, orchids and ferns in Sikkim (H. G. Champion).	6
15	Undergrowth in conifer forests of Sikkim (H. G. Champion).	6
16	*Arisaema intermedium* "Cobra plant" Common in undergrowth of the E. Himalayan moist temperate forests. Lepchajagat, Darjeeling Division, Bengal (M. V. Laurie). ...	6
17	Climatic climax *Quercus semecarpifolia* Community at the summit of Huttoo peak, 10,000 ft. Narkunda, Simla hills. (F.R.I.).	7

18	A community of *Juglans regia-Ulmus wallichiana*-Acer in Silver fir, spruce forest above Monali in the Kulu Himalayas (T. V. Dent).	7
19	Undergrowth consisting of *Adiantum, Viola, Fragaria, Lastraea,* etc., in coniferous forest at Konain, Chakrata Himalayas (H. G. Champion).	7
20	*Quercus semecarpifolia* climax forests at 9,500 ft. at Hutto peak, Simla hills (T. V. Dent).	7
21	*Quercus semecarpifolia* heavily lopped trees at Huttoo, Simla hills (T. V. Dent).	7
22	Snows from Khadrala showing Blue pine on warmer S.E. slopes and spruce Silver fir association on colder N.W. in Lower Bashahar division, Punjab (M. V. Laurie). ...	7
23	A Young *Cedrus deodra* forest in Bashahar Himalayas (A. L. Griffith).	7
24	Mixed forests of *Pinus excelsa, Cedrus deodara, Abies pindrow* and *Picea morinda* on schists at Makhidhank, Bashahar Himalayas, (A. L. Griffith).	7
25	*Virgin Picea Smithiana* and *Abies pindrow* forest at Kaisdhar in the Kulu Himalayas (H. G. Champion). ...	7
26	A young silver fir- spruce forest in the Kulu Himalayas, R. . Troup).	7
27	A view of young deodar on flood plain deposits of the Parbatti Valley in Kulu (G. S. Puri).	7
28	Conifers in the Kasol Valley. Deodar on flood plain deposit, blue pine on Scarp and deodar on dip slopes of schists (G. S. Puri).	7
29	Silver fir community on moraines at 9,000 ft. above Pulga, Parbatti, Kulu (G. S. Puri).	7
30	*Pinus gerardiana* forest on abandoned cultivation. Undergrowth scanty, short grass, with very occasional trees of *Quercus ilex.* Below Chini, Bashahar Himalayas (F.R.I.). ...	7
31	Evergreen rain forests of *Cullenia - palaquium* at Palghat division, Madras (M. V. Laurie).	7
32	Evergreen forest of *Palaquium, Dipterocarpus, Hopea, Mesua, Garcinia* etc. at Karekette, Mysore State. The bare hillsides have been disforested and are preserved as poor pasture lands. (G. S. Puri).	7
33	Evergreen forest in Valleys, viewed from the ghats on Agumbe–Udipi Road, of Dipterocarpus, Garcinia, *Mesua,* etc. (G. S. Puri).	7
34	A large buttressed tree of *Elaeocarpus tuberculatus* at Agumble (G. S. Puri).	7
35	A community of ferns along seepage planes of rocks in Agumbe forest (G. S. Puri).	8
36	Tree Ferns in evergreen forests of Agumbe (G. S. Puri).	8
37	*Arisaema* in the undergrowth of evergreen forest at Agumbe (G. S. Puri).	8
38	A pure Community of *Sonchus* in an open place, along a stream in evergreen forest at Agumbe (G. S. Puri). ...	8

39 A beautiful fragrant, pink coloured epiphytic orchid, *Rhynchostylis retusa* (Fox tail orchid), Agumbe—Shringeri Road (G. S. Puri). 8

40 *Dendrobium* on a tree along Sirisi Jog Falls Road (G. S. Puri). 8

41 Epiphytic orchid and the fern *Drynaria* in evergreen ghat forests (G. S. Puri). 8

42 Epiphytic orchid *Cymbidium* in evergreen ghat forests (G. S. Puri). 8

43 Geologyne epiphytic orchids in evergreen forest on the ghats (G. S. Puri). 8

44 Large bunches of Aerides, epiphytic orchids in ghats forests of Mysore (G. S. Puri). 8

45 Evergreen forest at Nilambur, foot of the Nilgiris (H. G. Champion). 8

46 Evergreen rainforest with epiphytic ferns and Aroids at Manantody Chandanathode Rd. Madras. 8

47 Jog Falls in North Kanara. The siliceous rocks bear a thick dense evergreen forest full of leeches and cobra (G. S. Puri). 8

48 Evergreen forest, with *Lagerstroemia lanceolata* tree in the foreground Near Yellapur (G. S. Puri). 8

49 A robust woody climber in an evergreen forest, in Jog Falls Forest (G. S. Puri). 8

50 An evergreen forest in the vicinity of Yellapur. In the fore-ground is a large tank. The main species are *Lagerstroemia*, *Vitex*, *Holigarna*, *Actinodaphne*, *Garcinia*, etc. (S. K. Jain). 8

51 *Calycopteris floribunda* climber with conspicuous large and white flowers in evergreen forest of Yellapur. (S. K. Jain). 8

52 Dense growth of *Melastoma* along ponds and streams in evergreen forests, near Yellapur (G. S. Puri). ... 8

53 A flowering branch of *Careya arborea* (G. S. Puri). ... 8

54 Evergreen forest at Deviar, Kerala, with *Vateria*, *Dipterocarpus*, *Terminalia*, etc. and a thick undergrowth (G. S. Puri). 8

55 A large tree of *Tetrameles nudiflora* with buttressed stem (G. S. Puri). 8

56 Tea Estates in evergreen forest zone at Munnar, Kerala (G. S. Puri). 8

57 Stem of *Baccaurea courtallensis* covered densely with red coloured inflorescences. Poringal evergreen forests (G. S. Puri). 8

58 *Dipterocarpus alatus* trees at the edge of paddy fields with dense *Calycopteris* undergrowth. Bhimoriaghona, Coxa Bazar, Bengal (F.R.I.). 8

59 Tropical wet evergreen forests at Makut, South Coorg with pure reed undergrowth. Trees are *Calophyllum elatum*, *Dipterocarpus indicus* and *Artocarpus hirsuta* (M. V. Laurie). 8

60	Tropical evergreen forests of *Myristica* sp., *Dipterocarpus indicus* at Makut, South Coorg (M. V. Laurie). ...	8
61	Buttressed tree in evergreen forest of Kerala (G. S. Puri).	8
62	Evergreen forest with large lianes and evergreen undergrowth Kerala (G. S. Puri).	8
63	Moist tropical forest in Kerala. The main species here are *Holigarna, Ostodes, Cinnamomum, Baccaurea,* etc., (G. S. Puri).	8
64	A dense community of ferns and tree ferns in evergreen forest in Kerala. (G. S. Puri).	8
65	Teak forest of Allapalli, Chanda division, M. P., (M. V. Laurie).	9
66	Teak forests developed on trap rock of Junagad (G. . Puri).	9
67	Teak forest in Central India, Manpur Ghats, near Indore. Teak, *Boswellia, Sterculia, Terminalia* are common associates in these forests (G. S. Puri).	9
68	Teak tree in moist deciduous forest in Manghat, near Indore (G. S. Puri).	9
69	Dry mixed teak forest of Alirajpur state. Other species are *Ougeinia dalbergioides, Terminalia tomentosa, Anogeissus latifolia, Lagerstroemia parviflora, Sterculia urens* and *Emblica officinalis* (A. L. Griffith).	9
70	Teak forests at Dhimba in the Poona District. ...	9
71	*Clematis triloba* a common climber in teak forests. Its white flowers are very conspicuous during rainy months (G. S. Puri).	9
72	Grassy undergrowth in teak forest at Pokhari ghat. *Apluda varia, Cymbopogon martinii, Heteropogon contortus, Arundinella tenella* are some of the common grasses (G. S. Puri).	9
73	Teak-Sandal community on trap near Poona (G. S. Puri).	9
74	I quality *shorea robusta* forest in Haldwani Division, U.P. (E. A. Smythies).	9
75	*Shorea robusta* coppice forest in Gorakhpur division U.P. (A. L. Griffith).	9
76	*Shorea robusta, Pinus roxburghii* and *Quercus incana* forest Landsowne, U. P. (Basti Ram).	9
77	*Anogeissus latifolia* forest at Ramnagar Division U.P. on S.W. aspect on disintegrated sand stone(A.E. Osmaston).	9
78	Wet type *Shorea robusta* forests with *Alpinia, Amoora rohituka,* and *Leea* at Jalpaiguri, Bengal (H.G. Champion).	9
79	Wet type *Shorea robusta* forest with an undergrowth of *Calamus tenuis* Haldwani division, U.P. (E. C. Mobbs). ...	9
80	Sal forest of the wet mixed type at Buxa division, Bengal (J. R. P. Gent).	9
81	Evergreen forest of *Eugenia, Memecylon, Actinodaphne* at Mahableshwar. Venna lake in the foreground (G. S. Puri).	9

82	A degraded *Eugenia-Memecylon* community at Mahableshwar.	9
83	Thick undergrowth of *Pogostemon parviflorus* in dense evergreen forest. Near Hirda bunglow, Mahabaleshwar (G. S. Puri).	9
84	Sub-tropical forest of *Eugenia-Memecylon* at Bhimashankar (G. S. Puri).	9
85	Buttresssed stem of *Eugenia jambolana* at Bhimashankar (G. S. Puri).	9
86	*Memecylon* community in Sub-tropical forest of Bhimashankar (G. S. Prui).	9
87	A thick undergrowth of *Carvia* in *Eugenia* forest at Rajpura (G. S. Puri).	9
88	*Carvia* undergrowth in the open, Rajpura, (G. S. Puri). ...	10
89	*Curcuma* in the undergrowth of evergreen forest at Bhimashankar (G. S. Puri).	10
90	*Cynoglossum denticulatum* and *Carvia* in the undergrowth of evergreen forest (G. S. Puri).	10
91	Ferns in the undergrowth of evergreen forest at Bhimashankar (G. S. Puri).	10
92	A riverain forest of *Lagerstroemia parviflora* with *Bombax* along Sankos river, in Goalpara division, Assam. ...	10
93	Typical growth of *Eugenia jambolana* and *Barringtonia acutangula* in the bed of a small river in Gorakhpur division, U.P. Photo taken in April when all water dried up and ground covered with ferns (R. G. Marriot). ...	10
94	A tarai stream with leafless *Trewia, Machilus, Acacias, Phragmites, Alangium* and *Croton* along the Bania River, Buxa Division, Bengal (N. G. Champion).	10
95	*Cane brake* in sal-evergreen community in the Dun Valley (G. S. Puri).	10
96	Typical good quality *Dendrocalamus strictus* in mixed forest at Palamau division (F. C. Osmaston).	10
97	*Shorea robusta* - *Bambusa arundinacea* community in Angul division, Orissa, (A. L. Griffith).	10
98		
99	An *Elaeocarpus tuberculatus* community in Mysore (G. S. Puri).	10
100	Epiphytic orchids Aerides in riverain community at Agumbe, (G. S. Puri).	10
101	A close up of *Arisaema* in ground flora community in riverain community in *Agumbe* (G. S. Puri). ...	10
102	A community of *Polygonum* on riverain alluvium in Kanara (S. K. Jain).	10
103	A community of *Echinops* on riverain alluivium (S. K. Jain).	10
104	Bamboo forests of N. Kanara (S. K. Jain).	12
105	A bamboo community with *Terminalia* and *Lagerstroemia* at Kulgi (S. K. Jain).	12

106	Bamboo forest, 6 miles South of Yellapur. N. Kanara, (G. S. Puri).	12
107	Bamboo brakes in Kanara (S. K. Jain).	12
108	*Acacia arabica* in Cutch (S. K. Jain).	12
109	*Populus euphratica* forest in Hyderabad Sind (A.L. Griffith).	12
110	Tropical evergreen forests in the Andamans. Trees are *Canarium euphyllum, Terminalia bialata, Pterocarpus dalbergioides* in front of right end edge (M. V. Laurie). ...	12
111	Temperate deciduous forest at 4,000 ft. of *Betula cylindrostachys. Eurya, Aesculus, Acer* with an undergrowth of *Strobilanthes*. Kurseong, Bengal (H. G. Champion). ...	12
112	A community of *Saccharum—Cyperus—Tamarix* along a nala at Nadibag, Bhuj, (S. K. Jain).	12
113	*Dalbergia Sissoo-Holoptelea integrifolia* community in the Dehra Dun Valley (H. P. Bhatnagar).	12
114	A *Tamarix* community developed on sandy soil in Bhuj (S. K. Jain).	12
115	*Salmalia, Adina, Eugenia* developed in a disturbed grassy riverain community, Dun Valley (G. S. Puri).	12
116	A *Zizyphus* community on shingle island in the Dun Valley (G. S. Puri).	12
117	*Pinus roxburghii* on quartzite and riverain soil, Parbatti valley, Kulu Himalayas (T. V. Dent).	12
118	Deodar, Chirpine and blue pine reproduction coming up in Chir forest at an altitude of 6,000 ft. Chakrata Division, U. P. (R. S. Troup).	12
119	*Casuarina equisetifolia* along sea beach at Karwar. *Spinifex* colonising sea sand (G. S. Puri).	12
120	Palms and other plants on sea shore. Thick patches of *Ipomea biloba* binding sea sand in the foreground Karwar (S. K. Jain).	12
121	Tidal forest of Sunderbans (G. S. Puri).	12
122	Tidal forest of the Sunderbans (G. S. Puri).	12
123	*Nipa fruticans* at Gewa Khali Sunderbans division, Bengal (M. V. Laurie).	12
124	*Heritiera minor* forest, showing very dense pneumatophore growth and buttressing of trees in wet depression at Sunderbans, Bengal (M. V. Laurie).	12
125	*Rhizophora* in mangrove vegetation on Western Coast at Udipi (G. S. Puri).	12
126	Mangrove forests of the West Coast at Bombay (S. K. Jain).	12
127	Mangrove forest of *Rhizophora mucronata* at Austin straiht Andamans, showing typical arching root habit (M. V. Laurie).	12
128	*Typical Bruguiera gymnorhiza* forest at Austin strait, N. side, Andamans, showing pneumatophores and buttresses and typical straight cylindrical boles, (M. V. Laurie). ...	12

129	Swamp vegetation of *Alpinia* sp. and *Pandanus* sp., under *Eugenia* etc. on the hill behind is *Bombax* over *Phoenix* and grass. Gudalur Vaitri Ghat Road, Nilgiri, Wynaad, Madras.	12
130	Fresh water swamp forest with *Eugenia jambolana* over cane and Ferns a Pilibhit Division (A. E. Osmaston).	12
131	A mixed sal forest on thin layer of clay overlying conglomerate, Siwaliks (G. S. Puri).	12
132	Sal forest on dip slope of Siwalik clay. Note the preponderance of cane and ferns in the undergrowth. Dehra Dun Valley (G. S. Puri).	12
133	Deciduous forest, with little or no sal present on conglomerate, Siwaliks (G. S. Puri).	12
134	*Sal* forest on red clayey soil. Note good growth of *sal* tree. Bihar (G. S. Puri).	12
135	Grass community of *Cymbopogan, Themeda, Arundinella* etc., in undergrowth of an open teak forest on basalt, Baudhan Hill (G. S. Puri).	12
136	*Cupressus torulosa* on lime stone cliffs (in foreground) at Jaunsar, U. P. Trees far background chiefly Deodar (R. S. Troup).	12
137	Chirpine community on conglomerate in the Saharanpur Siwaliks (G. S. Puri).	12
138	*Pinus roxburghii* forest on quartzite in the Parbati valley, Kulu Himalayas (T. V. Dent).	12
139	Deodar community on flood plain deposits in the Parbati valley. Note communities of *Pinus excelsa* on dip slope of schists and chir pine quartzite at high level (G. S. Puri). ...	12
140	A patch of *Spinifex squarrosus* growing on sandy, dry soil on Madh Island in a dry evergreen forest (G. S. Puri). ...	13
141	A semi-desert community of *Phoenix* on dry, sandy, gravelly soil along Saklespur—Hassan Road, Mysore (G. S. Puri).	13
142	A close-up of flowering Asclepiadaceae climber on *Euphorbia* shrubs, Outram Ghat, Chalisgaon (S. D. Mahajan).	13
143	Dense undergrowth of *Chlorophytum* species (*C. attenuatum & C. undulatum*) in the shade of *Boswellia* tree over slope of Takya hill, Laling (Khandesh) (G. A. Tatke). ...	13
144	*Acacia sundra* on red shallow soils but good rainfall with grass and *Gardenia gummifera* near North Mangalore Division, Madras (H. G. Champion).	13
145	*Euphorbia* clumps with *Acacia, Grewia,* at Jamnagar (G. S. Puri).	13
146	*Euphorbia* clumps abundant in deciduous scrub, Haripur. Boulders of trap rock in foreground (G. A. Tatke). ...	13
147	*Euphorbia antiquorum* clumps forming extensive stretches at Bet Dwarka (G. S. Puri).	13
148	A large clump of *Euphorbia nivulia* on Taranga Hill, Cutch, (S. K. Jain).	13
149	Clumps of *Euphorbia* in scrubby vegetation of Paud Road, Poona (S. K. Jain).	13

150	Communities of *Orthocnemum indicum* growing on saline soils at Surendar nagar (G. S. Puri).	13
151	A dense community of *Fagonia cretica* on saline soils in Saurashtra (G. S. Puri).	13
152	Scrub jungle of *Acacias* and *Euphorbias* in Bhujia Hill, Cutch (Gangurde).	13
153	Community of *Acacia senegal—Balsamodendron mukul—Euphorbia* at Mevo Rakhal, Cutch (Gangurde). ...	13
154	Savannah in the making. The effect of water erosion on a high forest of *Sal* in the Dun Valley. Note the growth of grasses and bushes in bouldery habitat (G. S. Puri). ...	13
155	A sand dune being colonised by shrubby vegetation of *Aerua, Crotalaria, Leptadenia*, etc.—Near Barmer (G. S. Puri).	13
156	A well developed community of *Calotropis gigantea* on sandy soil in Rajasthan (G. S. Puri).	13
157	Community of *Elyonurus* on sandy calcareous soil in Rajasthan (G. S. Puri).	13
158	A large bush of *Grewia populifolia* in *Acacia—Grewia—Zizyphus* community on calcareous sandy plains—Jaisalmere (G. S. Puri).	13
159	*Capparis decidua* with Cucurbitaceous plants in Jaisalmere (G. S. Puri).	13
160	A view of gravel habitat near Jaisalmere (G. S. Puri). ...	13
161	A *Heliotropium* community on sandy, gravelly soil in Rajasthan (G. S. Puri).	13
162	A community of *Prosopis spicigera—Capparis—Salvadora*, etc. in Rajasthan (G. S. Puri).	13
163	Closed area on rocky plateau near Jodhpur. Note the luxuriance of grassy undergrowth (G. S. Puri). ...	13
164	Scrubby vegetation in un-fenced areas of Sand stone rock near Jodhpur. Scattered clumps of *Euphorbia*, bushes of *Capparis*, etc. are present (G. S. Puri).	13
165	Limestone hills in the Jaisalmere area. Note the situation of villages in sheltered sites between two continuous hill blocks (G. S. Puri).	13
166	Fort built of limestone rocks near Jaisalmere. *Calotropis* and *Acacia* are seen in the picture (G. S. Puri). ...	13
167	Barmer Hills with *Euphorbia, Capparis, Zizyphus*, etc. (G. S. Puri).	13
168	A large tree of *Salvadora oleoides* near Barmer (G. S. Puri).	13
169	Heavily exploited forest in Ajmer, Marwara (M. V. Laurie).	13
170	Heavily grazed area with *Euphorbia nivulia, Acacia rupestris, Anogeissus pendula, Acacia* etc. in Ajmer (H. G. Champion).	13
171	*Prosopis spicigera* and *Prosopis glandulosa* in riverain forests in Hyderabad, Sind (A. L. Griffith).	13
172	Inland forest in Sind, showing *Prosopis spicigera, Tamarix dioica, Tamarix articulata* and on the ground *Blumea* spp. with some *Capparis aphylla* and *Salvadora persica*. The grass is *Saccharum arundinacea* (A. L. Griffith). ...	13

173	Desert vegetation of *Euphorbia nivulia, Salvadora persica, Capparis aphylla* near Karachi, Sind (A. L. Griffith). ...	13
174	Trees in Sind desert of *Acacia senegal, Euphorbia neriifolia,* and in the field *Prosopis spicigera* and *Salvadora oleoides* ..	13
175	Free floating plant association of *Azolla, Limnanthemum cristatum* (rooted) and submerged plants of *Potamogeton crispus, Ceratophyllum demersum*—Calcutta (G. S. Puri). ...	13
176	Floating leaves species of *Limnanthemum, Aponogeton monostachyon* and attached emersed plants of *Eleocharis plantaginea,* Sagar Lake (G. S. Puri).	13
177	Emersed aquatic stage plants *Nelumbium speciosum* and *Eleocharis,* Sagar Lake (G. S. Puri).	13
178	A community of *Ipomea* in a lake on Paud Road (G. S. Puri).	13
179	Wet meadow stage showing *Oryza sativa, Coix lachryma-jobi, Ischaemum rugosum, Themeda, Cyperus,* etc. along the bank of Sagar Lake (G. S. Puri).	13
180	*Caesulia axillaris* community in ponds in the Deccan (G. S. Puri).	13
181	*Typha latifolia* community, (Gangurde).	13
182	*Eichhornia-Ipomea* community in Panvel Lake I (Prabhakar).	13
183	*Polygonum glabrum* community in a pond on Paud Hill (G. S. Puri).	13
184	*Capparis aphylla* community with *C. horrida, Calotropis* and *Zizyphus,* traversed by Ganges Canal with *nim* shade line. District Aligarh U.P. F. R. I.	13
185	*Phoenix sylvestris* with *Butea* on usar land clayey loam over kankar in Badaun Distt. U.P. (A. E. Osmaston). ...	13
186	*Dichanthium annulatum* community growing on a moist alluvial soil (G. S. Puri).	14
187	*Echinochloa* on drying mud in a dried pond in Cutch (S. K. Jain).	14
188	Extensive *Elyonurus hirsutus* community, heavily grazed at Pokhram (G. S. Puri).	14
189	*Aristida* community on decomposed amygdaloid soil on Paud Road (G. S. Puri).	14
190	*Panicum antidotale* community on sand dunes at Barmer (G. S. Puri).	14
191	Community of *Chloris tenella* in Deccan grasslands (S. K. Jain).	14
192	*Themeda-Cymbopogon* community on the Deccan trap Country (G. S. Puri).	14
193	*Chrysopogon montanus* community in the riverain soil (G. S. Puri).	14
194	*Heteropogon contortus* community in the Deccan grassland (G. S. Puri).	14
195	*Eragrostis - Sporobolus - Aristida* community on dry soil in the Deccan (G. S. Puri).	14
196	*Saccharum munja* community in drier soil conditions in the Deccan (S. K. Jain).	14

197 Annually burnt, grassland at Ul nadi, Pilibhit division, U.P., *Saccharum spontaneum* (large variety) on left *Anthistiria* behind with little *Phargmites karka* in front of it (A. E. Osmaston). 14

198 *Coix lachryma-jobi* community along a running stream in Deccan (G. S. Puri). 14

199 Patches of *Sacciolepis interrupta* in Panvel Lake (G. S. Puri). 14

200 Sholas and grasslands on the Nilgiris at Ootacamund (G. S. Puri). 14

201 Extensive patches of heavily grazed and burnt grasslands at Ootacamund (G.S. Puri). 14

202 Evergreen forest and grassland in the Western Ghats in Mysore (G. S. Puri). 14

203 *Dysophylla stellate* community in pools at Bhimashankar (G. S. Puri). 14

204 *Arundinella tenella* community in mud hole at Bhimashankar. (G. S. Puri). 14

205 *Cyathocline lutea* community on somewhat dry soil near Pokhari (G. S. Puri). 14

206 A community of *Ischaemum* in a depression, Paud Road (G. S. Puri). 14

207 *Themeda* community in *Themeda—Cymbopogon* grassland in low rainfall areas of the Deccan, (G. S. Puri). ... 14

208 *Bothriochloa* community in deeper soil in low rainfall areas of the Deccan, (G. S. Puri). 14

209 *Anogeissus pendula* forests on hills slopes in Shahabad, (S. K. Jain). 15

210 *Leptadenia spartium* community in Rajasthan (G. S. Puri). 15

211 A community of *Tephrosia purpurea* in Rajasthan (G. S. Puri). 15

212 A community of *Dinebra retroflexa* in Tikkar Rann, Saurashtra (G. S. Puri). 15

213 *Heteropogon contortus* community in saline scrub area near Lucknow (G. S. Puri). 15

214 Grassy undergrowth of *Bothriochloa*, etc. in a saline scrubby vegetation, near Lucknow, (G. S. Puri). ... 15

215 A heavily lopped tree of *Hardwickia* in forests of Khandesh at Laling (G. S. Puri). 15

216 *Boswellia serrata* community on shallow, undecomposed gneissic soil (G. S. Puri). 15

217 Deciduous forest of *Boswellia serrata* over the slopes of Takya hill, Laling (S. D. Mahajan). 15

218 *Butea* community in Central India with stunted, lopped trees and heavy grazing (G. S. Puri). 15

219 A mixed *Butea* community on Bhopal Road (G. S. Puri). ... 15

220 *Acacia arabica* community at Bhirandyra, Cutch (G. S. Puri). 15

221 Laterite scrub with bushes of *Gardinia, Ixora, Randia* and grasses near Kumta (G. S. Puri). 15

222	A young plantation of teak raised after felling a moist deciduous forest in Top Slip area (G. S. Puri). ...	16
223	A young plantation of teak at Vincholi, N. Kanara (G. S. Puri).	16
224	30 years old plantation of *Pinus roxburghii* at the New Forest Estate, Dehra Dun (Silviculturist F.R.I.). ...	16
225	Plantation of *Cedrus deodara* at Nogli. Bashahr Himalayas (A. L. Griffith).	16
226	A grove of large *Cupressus torulosa* trees round the temple Wan, Garhwal Himalayas, U.P. (E. C. Mobbs). ...	16
227	*Araucaria* trees planted in the Indian Botanical Gardens, Sibpur, Calcutta (G. S. Puri).	16
228	A beautiful grove of *Eucalyptus* in Lucknow (G. S. Puri). ...	16
229	*Cryptomeria* plantations at Darjeeling (V. S. Rao). ...	16
230	*Casuarina* plantations Shri Hari Kota Islands on sandy soil (G. S. Puri).	16
231	*Casuarina* trees in the Indian Botanic garden, Sibpur (G. S. Puri).	16
232	*Populus nigra* (Lombardy poplar) at Jari, Parbati Valley, Kulu Himalayas (T. V. Dent).	16
233	A single line plantation of *Populus nigra*, serving as wind break at Mardan, N.W.F.P., Pakistan (A. L. Griffith).	16
234	A plantation of *Trewia nudiflora* and *Anthocephalus cadamba* near Sukna, Kurseong (M. V. Laurie). ...	16
235	Palms in Sibpur Botanical gardens, Calcutta (G. S. Puri).	16
236	Tea plantations at Munnar, Kerala (G. S. Puri). ...	16
237	Rubber Plantation (Rubber Research Institute). ...	16
238	Plantations of *Prosopis juliflora* in Cutch (G. S. Puri). ...	16

1

INTRODUCTORY

Natural Vegetation of India: The natural vegetation over the greater part of India is one or the other kind of a forest. However, by continued exploitation and maltreatment of plants for centuries by man and his domesticated animals the forest climaxes have been destroyed, replacing them at places by grasslands, scrubs, savannahas, swamps, deserts and such other biotic or bioedaphic communities that may represent post-climax, pre-climax or subclimax stages. There also occur relict communities that are quite unlike the surrounding types of vegetation. There are no climax grasslands in India, though some types on the Nilgiris and in the Rajasthan are considered to be climatic climax by some workers (Ranganathan, 1938). Some of the vegetation types of India, may not conform to the conventional definition of a forest: it is therefore, necessary to define this term.

What is a Forest: The word forest is derived from the Latin root *foris*, meaning out of doors, and etymologically, it is "a large uncultivated tract of land covered with trees and under wood." (Chamber's Twentieth Century Dictionary, p. 359, 1943). In common language, it denotes a group or stand of trees in a closed canopy. Willis (1951) defines forest as "a closed assemblage of trees allowing no break in the overhead canopy; homogenous of one species, or diversified."

The term woodland is frequently used by English ecologists for forest. Schimper (1923), however, distinguishes between the two terms. Woodland is the vegetation of woody plants; and trees growing in a closed condition constitute a forest.

In the British Commonwealth forest terminology (1953) forest is defined as "a plant community predominantly of trees and other woody vegetation usually with a closed canopy". This definition is a slight modification of the term adopted by the Society of American Foresters. The definition of a forest given in Indian Forest Record (new series), Vol. 2(1) published in 1936 reads as "an area set aside for the production of timber and other forest produce or maintained under woody vegetation for certain indirect benefits which it provides, e.g., climatic or protective".

Ecologically, the term forest signifies a complex organism, composed of distinct biological units called forest communities, that have come into being by the combined action, reaction, and co-action of a variety of organisms with the complex factors of the habitat that themselves change, both in space and time. According to Toumey and Korstian (1947, p vii), "forest vegetation is composed of plant communities or units of vegetation developed and arranged in accordance with definite biological laws and is not an aggregation of trees and other plants brought together by chance".

The study of a Forest: The study of a forest is done from a number of angles. If one confines oneself, for example, to the enumeration of plant species that make up a forest then the approach is floristic. For a country like India, where the number of plant species, varieties and forms

composing a forest is very large and varied the early studies in ecology have been necessarily floristic.

The next step that logically follows any floristic study is the classification of species in the forest into groups of plants, occupying distinct habitats. This approach is vegetational and is examplified in the preparation of forest working plans.

The third approach in ecological studies is phyto-geographical, in which the distribution of species, genera or orders of plants composing a forest is studied, both in space and time.

A study of the causal relationship between vegetation and its environment is a pre-requisite for application of ecological knowledge in various biological problems. Of these, silviculture and forest management are simple forms of applied ecology. In afforestation, erosion and flood control, soil and water conservation and proper land use, the problems are much more complex.

PLANT ECOLOGY AND FOREST ECOLOGY

Plant ecology is defined as the study of organisms in reciprocal relationship with their environment. Accordingly, therefore, forest ecology should be the study of a forest in reciprocal relationship with its environment. This definition of forest ecology, however, is inadequate in practical forestry and since forests are to meet both physical and economic needs of the population, forest ecology combines in itself the study of all these factors that affect both natural and economic importance of forests. Forest management, not known in plant ecology, becomes an important environmental factor in forest ecology. In this important respect forest ecology differs from plant ecology and may, with advantage, be considered as an applied plant ecology.

Forest ecology had developed earlier to plant ecology itself; though its early development has been mostly of an applied nature. As a science, forest ecology is related both to plant ecology and silviculture. Since forest provides an excellent type of vegetation for plant ecological studies, plant ecologists and foresters in this country have worked side by side, enriching both these sciences.

Forest ecology like plant ecology, overlaps a number of sciences; therefore, a certain knowledge of basic sciences, like physics, chemistry, geology, meteorology, soil science, taxonomy of plants, etc., is essential for work in forest ecology.

Plant geography is closely associated with plant ecology and its study along with forest ecology has obvious advantages, when working in applied forest ecology.

Phytogeography was sub-divided by Warming into floristic plant geography and ecological plant geography. While the former may form a part of plant ecology, the latter inevitably is a part of forest ecology.

Like plant ecology, forest ecology may be studied in two subdivisions, namely aut-ecology and syn-ecology, which are defined, respectively, as the study of an individual forest tree or tree species and of a group of forest trees or forest communities.

History of plant ecology, forest ecology and silviculture: A statement showing the historical development of plant ecology, forest ecology and silviculture, as given in table 1, may be useful in order to appreciate the relationship of these overlapping sciences with one another.

Table 1.

THE HISTORICAL DEVELOPMENT OF ECOLOGY AND FORESTRY.

(Mainly after **Boerker, 1916**)

Plant Geography and Plant Ecology	Forestry and Forest Ecology
Before 1838, there was an era of plant *geography*, and general studies of vegetation and geographical distribution of individual plants were done.	1346–1758. During this period forestry practice was based upon empericism and the development of silviculture proceeded mainly by practice, with little reference to the fundamental natural laws involved in it.
1838–1895 was the period dealing with the study of plant formations. A plant formation was recognized as the fundamental unit of vegetation and the corner-stone of plant ecology was laid. This period marked the division of vegetation into units and the beginning of the study of plant succession.	1758–1870. During this period there developed the study of biological phases of forestry, such as forest botany, forest pathology, morphology and physiology of woody plants; and the theory of light and shade in the forest was elaborated.
1895–1916. This may be called the period of *modern plant ecology*, when the study of the habitat along with the exact determination of physical factors, etc. was made, Ecology allied itself with plant physiology. The whole field of plant ecology was divided into aut-ecology and syn-ecology. The works of Schimper, Drude, and Warming are characteristic of this period.	1870–1916. This was the period of *modern forest ecology* in which the forest experimental stations were established in Europe and America, and studies in experimental ecology and the measurement of habitat factors were made. Forest experimental stations in addition took to the study of forest soils, forest influences, forest litter, forest climatology, seed provenance studies; and the ecological basis for thinnings was established. Works of Wagner, Mayr, and Duesberg are the highest expressions of the application of modern forest ecology to the practice of silviculture.
After 1916, ecological research greatly expanded by the establishment of ecological societies and publication of ecological journals. Experimental plant ecology, gen-ecology, etc. developed in Europe and America. Cowles and Clements brought in the dynamic aspect of plant ecology in the forefront. After the second World War, the UNESCO started Desert and Arid zone studies. Numerous Regional ecological stations have since been set up.	After 1916, applied forest ecology developed rapidly. The application of forest ecology was early recognised in soil conservation works in the U.S.A.; then flood control, desert afforestation were treated as ecological problems. Numerous books on soil conservation, water-shed management, etc. were published. After the second World War, the FAO established forestry wing and World studies on soil conservation were initiated. Forest ecology as an applied science is actively expanding in all countries since then.

Boerker (1916) who has made a special study of this subject considered that "while plant ecology and forest ecology developed independently (the former along purely scientific lines, the latter along applied lines), we are witnessing to-day a period in which they are becoming mutually helpful. Modern plant ecology will have the tendency to make forest ecology a more orderly science".

In the early part of the 18th century, developments in forest botany, entomology, plant anatomy, physiology, etc. everywhere had "helped to lift forestry out of the shackles of empericism and to make scientific treatment of forest possible. Physics, chemistry and biology put our knowledge of the soil upon a scientific basis and thereby revolutionised many silvicultural practices. In fact, the whole field of forestry experienced a renaissance; forestry was remodeled, as it were, according to modern standard. Thus, was born the science of forest ecology" (Boerker, 1916, p. 405).

In recent years, the importance of ecology has become so evident in forestry that Bor (1942 a) considers it to be the fundamental of forestry. In India, the introduction of forest working plans towards the end of the last century offered a great scope for the development of this subject. However, fundamental knowledge of forest ecology, without which application of ecological techniques in forestry cannot be accomplished, has not progressed far, due to lack of facilities in this science in most of the Indian Universities.

The establishment of forest experimental stations in Europe, during the early part of this century, however, gave a great fillip to the study of forest ecology and it rapidly began to be applied to forestry operations in most of the European countries, especially Sweden, Finland, Denmark and Germany, where silviculture has been strictly based on ecological classification of vegetation.

Forest Ecology, Silvics and Silviculture: Forest ecology is related to silvics and silviculture and such other branches of forest biology as forest botany, forest mycology, forest genetics, forest zoology, forest entomology, etc.

Silvics is the scientific basis for the practice of silviculture and derives material from plant ecology, plant geography and is the fundamental of forest ecology. It is defined by the Society of American Foresters as "that branch of ecology which treats the life of trees in forest and the life history and general characteristics of forest trees and stands with particular reference to environmental factors". British Commonwealth Forestry Terminology (1953) defines silvics as "the study of the life history and general characteristics of forest trees and crops, with particular reference to environmental factors, as the basis for the practice of silviculture". Silviculture is defined as "the art and science of cultivating forest crops". Silviculture is applied forest ecology, such as soil conservation, desert control, flood control, pasture management, agriculture and land use planning are.

Basic concepts of Forest Ecology: Forest ecology, like plant ecology, recognises as the basis of the development of forest vegetation the actions, reactions and coactions of trees and other organisms to the complex of the environment. But since forests have the dual purpose of protection and production, forestry operations, such as management, silvicultural treatments, forest hygienic operations, forest protection, selective fellings, planting, etc., introduce yet another factor, generally not fully appreciated in plant ecology and plant geography of natural tracts of vegetation. Forest ecology has thus to contend itself very often with quasi-natural conditions, rather than natural.

In India, with a very old civilisation, the historical treatments of vegetation in the form of shifting cultivation, pasturing, protection or destruction of plants on religious, or socio-political grounds, have made important changes in the structure and composition of plant communities. The time factor thus assumes a great importance in shaping the forest ecological environment. The original climatic climax vegetation has long since been converted into relicts or secondary seres over a large part of the country. In such a disturbed vegetation complex in India the concepts of plant succession, climax and plant indicators in forest ecology become somewhat different than what they are understood in plant ecology. For this reason the maintenance of permanent ecological preservation plots and successional or plant indicator transects in different types of forest vegetation becomes an important part of forest ecological research, besides surveys by temporary transects, for finding out exact trends in vegetational changes. The basic concepts of climax become rather different in forest ecology for the reason that apparent stable community is not natural but is maintained in that condition by numerous forestry practices.

The original concept of forest types, developed by Cajander (1926) in virgin forests of Finland does not apply strictly to Indian forests under management, in which ground flora species have been greatly modified by continued silvicultural and other operations. The original concept has thus to be modified to suit the particular conditions, and vegetation is to be classified into cover types or management types. The so called climatic types over parts of India, are in fact, bio-edaphic, or edaphic types, Thus, the basic concepts of plant ecology are applicable to forest ecology only to a limited extent, and need necessary modifications.

Forest Ecology and Forest Management: Forest ecology ordinarily forms the basis for forest management practices. The methods of management depend partly upon ecological conditions of the crop, including its successional behavior and partly on economic considerations. Forest management as already stated, is one of the important ecological factors in shaping the growth and development of the future generations of forest crops.

Forest ecology has helped in the selection of a management system in conifer forests of the Himalayas. It was found necessary ecologically that the retention, or in some cases the introduction, of broad leaved deciduous species in conifer communities was desirable for the maintenance of suitable conditions for the reproduction of silver fir. Foresters in *sal* areas now favour an uneven canopy; and the retention of a certain percentage of associated species of *sal*, in areas with deficient *sal* regeneration, is recommended. Management very often has to be based on economic considerations as well, such as the ease of working in concentrated units, and. therefore, a departure from pure concepts of plant ecology is made, and forest ecology has essentially to adjust itself to such needs on the one hand and to basic concepts of plant ecology on the other.

It has to be appreciated, therefore, that forest ecology has necessarily made certain departures from plant ecological concepts so that both the protective and productive roles of vegetation are properly balanced. Forest ecology thus deals invariably with non-climax units of vegetation that are as much shaped by the human hand as climate and soil.

Other applications of Forest Ecology in India: Principles, techniques and methods of forest ecology find application in all those fields of human endeavour in which living plants are used as working material, whether singly or in groups. Thus, afforestation, soil

conservation, desert and flood control, land use, town planning, river training, pasture and range management, nature conservancy, etc. are all applied forest ecological problems (Bor, 1942 a; Aggarwal, 1955, Puri; 1955). Besides forestry, plant ecological methods find application in agriculture, animal husbandry, sociology, anthropology, human economics and even politics.

History of Forest Ecology in India: Forest ecology is of recent origin in India. A history of plant ecology has recently been given by Puri (1954) and a complete bibliography for India, Burma, Pakistan and Ceylon is found in the paper of Misra and Puri (1955). A very brief account is given here.

In the north and north-west Himalayan forests, Mohan (1933), Suri (1933), Gorrie (1933), Glover (1930–31), Trevor (1917) and others made notable contributions on the distribution and classification of oak and conifer communities. Taylor, Mahendru, Mehta and Hoon (1936), Puri (1950), Puri and Gupta (1951), Mohan and Puri (1954) studied the relationship of forest vegetation with geology, soil and other factors of the habitat.

Champion's monographs on *Shorea robusta* (1933) and forest types (1938) are landmarks in forest ecology of India, besides a number of other contributions by him. In the eastern and central India, Bor (1938–1942), Mooney (1933–1938), Hewetson (1941), Kulkarni (1951), Waheed Khan (1953), Tiwary (1941), Puri (1954–1955), Misra and Joshi (1952), Bhatia (1954) and others have written on forest ecology of *Sal*, teak and grasslands. These authors have also worked in mixed deciduous forests and evergreens. Bor's studies on relict vegetation of the Shillong plateau is an important contribution in that region.

In south Indian forests, Ranganathan (1938) made valuable contributions on shola forests and grasslands. In the Andamans, Changapa (1944) made ecological observations and Kadambi wrote on western ghat forests in the Mysore State. Brief ecological observations on forests are usually given in forest working plans, which now cover almost all the important forests of the country.

Forest Ecological problems of India: Since Hole (1914–1916) brought in the forest ecological approach in the study of *sal* regeneration in U.P. the necessity of ecological research has become apparent in forestry practices in the country. In 1926, Troup gave a comprehensive statement of the various forestry problems in which ecological research could be directed and since then some work has been conducted to fill in gaps in our knowledge of forest ecology by Champion, Bor, Mooney, Hewetson and others.

In 1948, the states forest and agricultural departments were consulted in the compilation of a list of outstanding ecological problems of India. The list reproduced in table 2 for different zones is the result of that enquiry.

The object of giving this comprehensive list is to focus attention of workers on filling up gaps in our knowledge of tropical ecology, which is now emerging as distinct from temperate ecology. Our neighbours in the south in Ceylon have made notable contributions in the tropical ecology of that island but the problems outlined in table 2 could be common for India, Burma, Ceylon and Pakistan.

Table 2.

FOREST ECOLOGICAL PROBLEMS OF INDIA

(Mainly based on enquiry made in 1948 from State Forest Departments)

ZONE I:—ANDAMANS, ASSAM, BENGAL.

1. Study of the ecology of different types of forest communities found in the Andamans, with particular reference to the association of species and their beneficial inter-related factors.

2. Ecology of grassy areas in the forests of Assam and Bengal for purposes of afforestation.

3. Ecological factors governing the formation of *Ceriops roxburghiana* scrub in forest areas and means of converting the community into forests.

4. The study of succession in flooded areas of Assam, and factors responsible for the existence of blanks in semi-consolidated mud and ways of restocking these with forest trees in Bengal.

5. The ecology of *Phoenix paludosa*—studded river banks and ways to improve the land for better purposes.

6. Succession in riverain vegetation of Midnapur, Nanda and Burdwan districts of West Bengal so that the surrounding denuded areas be successfully planted with firewood species and safeguarded against erosion.

ZONE II:—BIHAR, ORISSA, MADHAYA PRADESH.

7. Ecological study of bamboo crops in Monghyar and Hazaribagh divisions, with reference to aspect, rock formations, hereditary and biotic influences and the effect of bamboo in the understorey in *sal* and teak forests in relation to the regeneration of these species in M.P.

8. Study of the competition between forest crops and agricultural crops and competition in mixed forest stands in relation to the problem of *sal*, mixed forest and miscellaneous forest, etc.

9. Afforestation of eroded areas and a general ecological study of the suitability of the species to be planted.

10. Possible seral retrogression in the different types of forests in Bihar as a result of fire (in Hazaribagh) and excessive grazing (in Palamau).

11. Ecological study of the problems of *sal* regeneration in Banjor range and causes of grassy blanks, with special reference to the water content of the soil, types of soil and biotic influences.

12. Ecological study of the problem of regeneration of *Boswellia, Salmalia* and other species.

13. Correlation of forest types and undergrowth with soil types.

14. The effect on edaphic factors of the main silvicultural systems practised in Madhya Pradesh and Berar.

15. Natural succession of grasses under grazing closures in representative edaphic conditions and the effect of early and late fires.

ZONE III:—BOMBAY, MADRAS, ANDHRA, MYSORE, KERALA.

16. Natural regeneration of species and succession in wet semi-evergreen and teak forests.

17. The problem of eradicating *Loranthus* and *Lantana* from moist mixed teak and semi-deciduous forests.

18. The problem of bamboos and grasses in teak plantations, and the natural regeneration of teak "*de novo*" in high forests.

19. Ecological aspects of the forest types in the Nilgiris and the causes of the existence of sholas, such as Karian sholas, in the midst of deciduous forests surrounded by grassland as in the *Ibex* hills of south Coimbatore Division.

20. Causes of bare areas in Bellary and Anantapur districts which are gradually changing into grassland, climatic causes including wind, humidity, temperature and biotic causes may need emphasis, and for the formation of bare areas in sub-climax vegetation in coastal regions of Guntur, Krishna and Godawary districts.

21. Regressive succession in Dhone and Pauyam Reserves (grass replacing higher forms of vegetation), in the Kurnool District.

22. Ecological aspects of areas suitable for the plantation of teak, wattle, *Eucalyptus, Evodia, roxburghiana, Melia composita, Salmalia malabarica, Ailanthus excelsa, Ochroma lagopus, Sterculia campanulata, Terminalia myriocarpa, Albizzia stipulata,* etc.

23. Ecological conditions necessary for successful regeneration and development of *Hardwickia binata, Pterocarpus santalinus, Santalum album,* and the slow growth, development and recent unexplicably heavy casualties in *Casuarina* plantations.

24. Ecological survey of tropical evergreen species, especially their regeneration, under a system of canopy manipulation, so as to obviate artifical means of nursery formation and planting.

25. Ecological consequences of felling of teak and other species in different parts of the state.

ZONE IV:—RAJASTHAN, NORTH WESTERN PARTS OF BOMBAY (KUTCH, SAURASHTRA), DELHI

26. Ecological survey of Saurashtra and Rajasthan deserts to find suitable species for afforestation purposes.

ZONE V:—HIMACHAL PRADESH, JAMMU AND KASHMIR, PUNJAB, UTTAR PRADESH.

27. The ecological factors which determine the attack by *Arceuthobium* on blue pine in the dry zone of the upper Bashahr and measures of controlling the attack.

28. The measures to ensure reproduction of deodar forests in the dry zones of upper Bashahr and any conifer regeneration in the tension belts of deodar, spruce, fir and deodar-fir areas.

29. Management types ensuring fir or any coniferous regeneration in fir forests.

30. The study of secondary succession in conifer forests of the Kulu area after grazing and incendiary fires and progression after ordinary regeneration fellings.

31. Ecological study of the so called moribund *sal*, i.e. Champion's A_2 type or a transition stage from B_3 to A_2.

32. Studies of succession in ravine areas and other vegetation types of the states.

These problems were discussed in the VIII Silvicultural Conference (Puri, 1951) and recently as a result of discussions held at Baroda on vegetation types of India, an organisation for conducting ecological studies in different zones on a co-ordinated basis has been set up (Ranganathan, 1955; Annon, 1955).

The Aim and Scope of Forest Ecological Research in India: Forest ecological studies in India should in the future aim at (1) gathering basic knowledge of vegetation and its environment, recognizing the forest management and other forestry operations as an additional biotic factor, and (2) applying the forest ecological knowledge to problems in forestry and related fields.

The scope of such studies is unlimited for India. Information on ecology of Indian species can be collected on the following broad headings prepared by Puri and Misra (1954) after consulting various English and American schemes for such studies:—

1. Distribution:
   (i) Geographical; (ii) Geological.
2. Autecology:
   (i) Seed output; (ii) Seed dispersal; (iii) Viability of seed and its germination; (iv) Seedling growth; (v) Vegetative propagation; (vi) Vegetative growth; (vii) Reproductive growth; (viii) Indicator value of the species.
3. Synecology:
   (i) Community: Structure & pattern; (ii) Composition: (a) Tree layer; (b) Shrub layer; (c) Ground layer; (iii) Successional status of the community; (iv) Regeneration of the community; (v) Types of communities: (a) Progressive (Primary), (b) Retrogressive (Secondary).
4. Community environment:
   (i) Physical environment: (a) Climate, (b) Geology, (c) Soil; (ii) Biotic environment.
5. Physiological nature of the community.
6. Community stability and survival.
7. Applied ecology.

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SECTION A

In this section are described some interesting features of the Indian flora, namely, its composition, endemism distribution in space and in time, and its formation into different types of vegetation. Various methods of classification of Indian vegetation and tropical vegetation are also given.

2

INDIAN FLORA
ITS COMPOSITION AND ENDEMISM.

Areas under forest vegetation in India: The forests of India, though varied in composition and character, do not occupy in relation to population sufficiently large areas that are generally required for proper maintenance of climates and physical features of the subcontinent. From the data given in table 3, the extent of forest area per head in India is only 0.52 acres, which is inadequate for an agricultural country, with a monsoonic climate.

Table 3.

RELATIONSHIP OF POPULATION TO FOREST AREAS IN DIFFERENT COUNTRIES OF THE WORLD.

(Compiled from various sources.)

Country	Population (millions)	Forest area (million acres.)	Forest %	Forest per head (acre)
United Kingdom.	48	3.0	5	0.07
France.	41	26.2	19	0.64
Netherlands.	9	0.5	6	0.06
Germany.	69	31.5	27	0.45
Switzerland.	4	2.2	22	0.52
Italy.	44	14.5	19	0.33
Sweden.	6	57.8	51	9.12
Finland.	4	60.2	64	16.18
Europe.	392	331.5	26	0.85
U.S.S.R.	178	2400	45	13.6
India.	388	206.5	19	0.52
China.	452	165	8	0.36

The forests of the country which are under the control of the forest department constitute an area of 116,666 sq. miles i.e. roughly a little more than 1/10th of the total area of India. They are scattered over the entire country from the Kashmir Himalayas in the north to Cape Comorin in the south, Saurashtra in the west and Assam in the east of India. They exhibit a great variety of forms, which is due to a variety of factors of climate, physiography, geology, soil, water conditions and biota. In the world classification of forests the major part of the Indian vegetation is classified as monsoon and dry forests, thorn bush and savanna. The desert area in Rajasthan comes under semi-desert, and desert category; and much of the scrubs in the western region, touching Pakistan, is called steppe forest.

The Indian region lies roughly between 10°N–36°N and of the total areas occupied by different types of vegetation in the world at various latitudes shown in table 4 it would appear that the total area occupied

by Indian forests is not large enough to be of sufficient value for the protection of physical features of this heavily populated region of the World.

Table 4.

AREAS UNDER SEVERAL TYPES OF VEGETATION AT DIFFERENT LATITUDES IN THOUSANDS OF SQUARE MILES.

	No Vegetation.	Arctic-alpine.	Temperate.	Subtropical.	Tropical.	Total
80° - 90° N.	112	...	...	...	...	112
60° - 80° N.	729	5,417	...	...	...	6,146
40° - 60° N.	895	2,137	8,493	...	...	11,525
20° - 40° N.	921	1,487	2,318	7,485	...	12,211
0° - 20° N.	1	24	326	1,188	6,571	8,110
0° - 20° S.	17	193	261	1,583	5,551	7,605
20° - 40° S.	110	180	652	4,266	...	5,208
40° - 60° S.	28	63	404	...	...	495
60° - 80° S.	...	...	...	...	...	...
80° - 90° S.	...	...	...	...	...	...
Total	2,813	9,501	12,454	14,522	12,122	51,412
Northern hemisphere.	2,658	9,065	11,137	8,673	6,571	38,104
Southern hemisphere.	155	436	1,317	5,849	5,551	13,308

Salient features of Indian Flora: The *flora* of a region represents the sum total of different types and kinds of plants. The *vegetation* represents the total effect produced by abundance or scarcity of plants. In a floristic study the number and quantity of plants in an area need not be estimated but this is necessary in vegetational analysis. The flora of India is made up of well over 30,000* species of higher plants under 174 natural orders and an over all picture of the vegetation of India may be presented by calling it monsoon tropical. There are over 600 species of ferns and pteridophytes. Although, politically, India is now a smaller unit for the present floral and vegetational analysis Indian region includes Pakistan and Burma.

Of the total number of higher plants Dicotyledons alone are represented by 11,124 species, belonging to 1,831 genera. The largest family of flowering plants in India is the Orchidaceae, with nearly 1,700 species. In order of abundance we may classify the ten dominant families in Indian flora as under:—

Orchidaceae, Leguminosae, Gramineae, Rubiaceae, Euphorbiaceae, Acanthaceae, Compositae, Cyperaceae, Labiatae and Urticaceae.

Except, for the Labiatae and the Compositae, which are more temperate than tropical, the rest of the families have largely tropical species. The low position in India of the Compositae, which is the richest family of flowering plants in the World and which usually tops the list in floras of many countries, is surprising. If the Himalayan and the Alpine species of the Compositae are excluded this family will not come even in the first ten dominant families in the Indian vegetation.

* Since all information about Indian Species is not available this is the nearest estimate.

In the Indian flora, Monocotyledons occupy a fairly prominent place, there being for every seven Dicotyledonous species one Monocot. There are well over 100 species of Bamboos, and 25 species of conifers occuring in India.

Endemic Flora of India: Although, India is connected by land with a number of countries, with distinct floral elements, it has a large proportion of endemic flora. Considering only the Dicots, Chatterjee (1939) shows as many as 61.5% endemic to the Indian region. Excluding Burma at least 47% of the Dicots of India are endemic (table 5.)

Table 5.

DICOTYLEDONOUS FLORA OF INDIA.

(After Chatterjee, 1939).

Total No. of Dicot. spps.	Total No of. Dicots Genera.	No. of Dicots wides.	No. of Dicots endemics.			
			Continental India.	Himalaya with Assam.	Burma.	General Area.
11,124	1,831	4,273	2,045	3,169	1,071	533
Percentage.	...	38.5	18.2	28.8	9.6	4.9
					61.5	

The highest number of endemic Dictots occurs in the Himalayas and the least in general area of the country. This number of endemism in Indian flora is quite high as compared to neighbouring countries in the Southern continent. For example, the percentage of endemism is 30 in Ceylon, 72 in New-Zealand, 80 in Australia and 82 in Hawaii Islands.

The reason for the presence of such a high percentage of endemic plants in India is the presence of lofty mountains of the Himalayas on the north, north-east and north-west of the mainland and sea on other directions.

The following list from Chatterjee gives the distribution of plant genera that are endemic to India and Burma:—

Papaveraceae: *Cathcartia* Hook. f. E. Himalaya. (Reduced to *Meconopsis*, Vig. by G. Taylor in his monograph. 1934).

Cruciferae: *Lepidostemon* Hook. f. and T. E. Himalaya (Sikkim)
Arcyosperma Schultz. E. and W. Himalaya.
Douepia Camb. S. W. Punjab.

Capparidaceae: *Hypselandra* Pax et Hoffmann (Fedde Burma. Repert. XLI, 1936, 128).
Borthwickia W. W. Smith. (Trans. Proc. Burma (Upper). Bot. Soc. Edin. XXIV (1911) 175.

Flacourtiaceae: *Gynocardia* R. Br. E. Himalaya, Assam, Burma, Chittagong.

Guttiferae: *Poeciloneuron* Bedd. S. India (Malabar).

Malvaceae: *Decaschistia* W. and A. S. India.

Sterculiaceae: *Mansonia* Drummn. Burma (Lower).

Tiliaceae: *Erinocarpus* Nimmo. S. India.
Plagiopteron Griff. Burma (Lower).

Linaceae: *Anisadenia* Wall. C. and E. Himalaya, Khasia. Now found in extreme South China.

Rutaceae: *Chloroxylon* DC. S. India (Nilgiri, Ceylon).

Meliaceae: *Beddomea* Hook. f. S. India (Malabar).

Sapindaceae: *Otonephelium* Radlk. S. India (Malabar).
Zollingeria Kurz. Burma (Lower).

Anacardiaceae: *Solenocarpus* W. and A. S. India (Malabar).
Drimycarpus Hook. f. E. Himalaya (Sikkim). Khasia.
Nothopegia Bl. S. India (Malabar, Ceylon).

Papilionaceae: *Stracheya* Benth. C. Himalayan, Tibet.
Neocollettia Hemsl. Burma.
Ougeinia Benth. W. Himalaya, S. W. Punjab.
Dicerma DC. Burma.
Phyllodium Desv. Burma.
Catenaria Benth. Burma.
Cochlianthus Benth. C. Himalaya.
Butea (Royal). Koen. India, Burma.
Mastersia Benth. E. Himalaya (Mishmi Hills).

Caesalpinaceae: *Wagatea* Dalz. S. India (Malabar).

Phizophoraceae: *Blepharistemma* Wall. S. India (Malabar).

Myrtaceae: *Meleoromyrtus* Gamble. S. India (Malabar).

Cucurbitaceae: *Biswarea* Cogn. (Syn. *Warea* Clarke.) E. Himalaya (Sikkim)
Dicaelospermum Clarke. S. India (Malabar).
Edgaria Clarke. E. and W. Himalaya.

Umbelliferae: *Vicatia* DC. E and W. Himalaya.
Meeboldia Wolff. W. Himalaya.
Polyzygus Dalz. S. India (Malabar).
Pleurospermopsis Norman. E. Himalaya (Sikkim).
Cortia DC. E. and W. Himalaya.

Araliaceae: *Pentapanax* Seem. India.
Woodburnia Prain. Burma.
Gamblea Clarke. E. Himalaya (Sikkim).
Tupidanthus Hook. f. Khasia.

Cornaceae *Toricellia* DC. E. and W. Himalaya.

Caprifoliaceae: *Pentapyxis* Hook. f. E. Himalaya (Sikkim).

Rubiaceae: *Clarkella* Hook. f. W. Himalaya.
Polyura Hook. f. Khasia, E. Himalaya (Mishmi).
Parophiorrhiza Clarke. Khasia.
Carlemannia Benth. E. Himalaya (Sikkim), Khasia.
Silvianthus Hook. f. Khasia, (Sylhet).
Octotropis Bedd. S. India (Malabar).

Valerianaceae: *Nardostachys* DC. E. and W. Himalaya. Also recently recorded from South China.

Compositae *Lamprachaenium* Benth. S. India (Malabar).
Adenoon Dalz. S. India (Malabar).
Nanothamnus Thoms. S. India (Malabar).
Caesulia Roxb. Punjab, Chittagong, Deccan.
Glossocardia Cass. C. India, and S. India.
Goniocaulon Cass. C. India, and S. India.
Catamixis Thoms. W. Himalaya.

Campanulaceae: *Leptocodon* Hook. f. and T.E. Himalaya. Now recorded from South China.

Vacciniaceae: *Pentapterygium* Klotzsch. E. Himalaya (Sikkim Khasia.)
Corallobotrys Hook. f. Khasia, E. Himalaya (Bhutan).

Ericaceae: *Diplarche* Hook. f. and T. E. Himalaya (Sikkim)

Pyrolaceae: *Cheilotheca* Hook. f. Khasia.

Primulaceae: *Bryocarpum* Hook. f. and T. E. Himalaya (Sikkim to Mishmi).

Myrsinaceae: *Sadiria* Mez. E. Himalaya (Bhutan), Khasia.
Antistrophe A. DC. S. India (Malabar, 1 sp.) Khasia (1 sp.)
Hymenandra A. DC. Assam.
Amblyanthus A. DC. Khasia.
Amblyanthopsis Mez. E. Himalaya (Bhutan), Assam.

Styracaceae: *Parastyrax* W. W. Smith. Burma (Upper).

Asclepiadaceae: *Brachylepis* W. and A. S. India (Nilgiri).
Utleria Bedd. S. India (Deccan).
Decalepis W. and A. S. India (Deccan).
Pentabothra Hook. f. Assam (Kamrup).
Adelostemma Hook. f. Burma.
Lygisma Hook. f. Burma.
Treutlera Hook. f. E. Himalaya (Sikkim).
Dittoceras Hook. f. E. Himalaya (Sikkim).
Oianthus Benth. S. India (Deccan).
Frerea Dalz. S. India (Malabar).

Gentianaceae: *Parajaeschkea* Burkill. E. Himalaya (Sikkim).
Jaeschkea Kurz. E. and W. Himalaya. Now recorded from S. China.

Boraginaceae *Lacaita* Brand. E. Himalaya (Sikkim), Burma (Upper).
Actinocarya Benth. E. and W. Himalaya, Tibet.
Micvoula Banth: Himalaya and Tibet.

Convolvulaceae: *Blinkworthia* Choisy. Burma.

Scrophulariaceae: *Bythophyton* Hook. f. Khasia.
Hemiphragma Wall. E. Himalaya, Khasia, Burma. Now recorded from S. China.
Picrorhiza Royle. E. and W. Himalaya.
Oreosolen Hook. f. E. Himalaya (Sikkim).
Falconeria Hook. f. W. Himalaya.

Gesneraceae: *Platystemma* Wall. W. Himalaya.
Boeica Clarke. E. Himalaya, Burma (Upper).
Tetraphyllum Griff. Assam and Chittagong.
Trisepalum Clarke. Burma (Lower).
Phylloboea Benth. Burma (Lower).
Jerdonia Wight. S. India (Deccan).
Leptobaea Benth. E. Himalaya (Sikkim, Mishmi Hills,), Khasia.

Acanthaceae: *Ophiorrhiziphyllon* Kurz. Burma (Lower).
Meyenia Nees. S. India (Deccan).
Petalidium Nees. S. W. Punjab and S. India.
Aechmanthera Nees. E. and W. Himalaya.
Stenosiphonium Nees. S. India.
Calacanthus Anders. S. India (Malabar).
Phlogacanthus Nees. Himalaya, Assam, Burma.
Diotacanthus Benth. S. India (Malabar).
Cystacanthus Anders. Burma.
Haplanthus Nees. S. India (Malabar), Burma.
Asystasiella Lind. Khasia.
Phialacanthus Benth. N. Assam.

Odontonemella Lindau. Khasia.
Sphinctacanthus Benth. Assam.

Labiatae: *Craniotome* Reich. E. and W. Himalaya, Khasia.
Eriophyton Benth. E. and W. Himalaya.
Roylea Wall. W. Himalaya.
Notochaete Benth. E. Himalaya Burma,

Amarantaceae: *Banalia* Moq. S. India.
Stilbanthus Hook. f. E. Himalaya (Sikkim), Khasia.

Podostemaceae: *Griffithella* Warming. S. India (Malabar).
Willisia Warming. S. India (Nilgiri).

Cytinaceae: *Sapria* Griff. E. Himalaya (Mishmi Hills).

Lauraceae: *Syndiclis* Hook. f. E. Himalaya (Bhutan).
Purkayasthea Purkayastha. Khasia.
Dodecadenia Nees. Himalaya, S Assam, Burma.

Loranthaceae: *Helicanthes* Danser. S. India.

Santalaceae: *Phacellaria* Benth. Manipur and S. Burma.

Euphorbiaceae: *Pseudoglochidion* Gamble. S. India (Malabar).
Neopeltandra Gamble. S. India (Malabar).
Prosorus Dalz. S. India (Malabar).
Platystigma R. Br. Assam.
Lasiococca Hook. f. E. Himalaya (Sikkim).

Non-endemic elements in the Indian Flora: There are as many as 38.5% of the total Dicots in India which are widely distributed. Geographically, the Wide's element seems to be made up of a number of distinct groups of plants, which have migrated from the neighbouring regions. These are the Burmese, Malayan, the Mediterranean and European, the African, the Australian and American, the Tibetan and Siberian in alpine belts, and a number of Chinese and Japanese species occuring in temperate regions of India. As many as 570 European species form a part of the Indian flora, and as many are believed to have mid-eastern affinities. The Malayan element is, however, dominant in India; its migration having been facilitated by land connection between the two countries. Due to the High Himalayan barrier the Tibetan and Sino-Japanese elements are not well represented. Australian and American elements are, however, still less represented due to sea barriers.

Malayan Element in Burmese and Indian Floras: Discussing the distribution of flora in the S.E. Asian region Kingdom Ward (1921) gives the following distribution of the Burmese forests:—

(1) Forests upto 5,000 ft. in Burma are made up entirely of Indo-Malayan forms such as *Dipterocarpus, Shorea, Hiptage, Elaeocarpus, Engelhardtia, Garcinia, Caryota, Calamus, Ficus, Mussaenda, Aroids, Raphidophora, Pothos*, tree ferns and in the under growth many Zingiberaceae, Acanthaceae and Gesneraceae.

(2) Temperate rain forests between 5,000 and 8,000 ft. are characterised by *Schima, Gordonia, Bucklandia, Quercus, Magnolia, Acer, Rhododendron*, Araliaceae, *Ficus*, epiphytic ferns, Orchids, *Aeschynanthus* and there is a striking development of mosses. There are a few lianes of temperate genera of *Clematis, Hydrangea, Aristolochia.* Small herbs abound, especially, Urticaceae, *Impatiens* and *Strobilanthes.*

(3) Conifer forests above 8,000 ft. comprise of *Abies, Juniperus, Tsuga.* There are also a number of shrubs of *Rhododendron, Euonymus, Ribes, Rubus, Pieris, Echinanthus, Rosa, Philadelphus, Deutzia, Hydrangea, Buddleia, Schizandra, Akebia* and *Smilax.* Bamboos are present.

(4) Between 9,000 and 11,000 ft. alpine meadow is developed in marshy places in which species of *Nomocharis, Thalictrum, Epipactis, Allium, Lilium, Meconopsis,* Compositae and Umbelliferae are present along with *Rhododendrons, Potentilla fruticosa,* species of *Spiraea, Pyrus, Berberis* and bamboo. From rocks and screes *Primula, Cremanthodium, Lloydia, Pedicularis, Saxifraga, Gentiana, Cassiope, Androsace* are described.

The above flora is a mixture of the Himalayan, Indo-Malayan, the Chinese and Burmese endemic forms. The presence of Indo-Malayan types at low altitudes is due to the penetration of the Burmese mountain ranges in the Indo-Malayan region in the south and west.

The Himalayan flora is more common at intermediate altitudes and in the Alpine regions in Burma. The reason for the presence of the Himalayan flora in Burma has been ascribed by Kingdom Ward to be due to the presence of temperate climate in southern and eastern Tibet. The Himalayan uplift in the Eocene times converted Tibet into a desert and the flora migrated to these mountains.

Chinese element in Burmese and Indian Floras: The Chinese element in the flora of Burma and India is quite conspicuous. In the Burma-Yunnan area identical species of *Rhododendron,* and *Candelabra, Primulas,* Celastraceae and Gesneraceae are present. This flora is highly endemic and typical. Chinese flora occurs at higher altitudes and includes a number of Alpine plants such as *Polygonum forsterii, Primula serratifolia, Cassiope palpebreta* and a number of sub-alpine plants as *Primula sonchifolia* and *Nomocharis.* In Alpine regions species of *Rhododendron, Primula,* etc. are endemic.

A number of plants that are both Himalayan and Chinese show a wide distribution across eastern Asia, occurring in Japan and sometimes even in North America. An example of this may be *Clitoria mariana.* A number of plants from the Himalayan foot hills representing the Indo-Malayan element are found in the Burman-Yunnan area.

The relationship between the flora of the Himalayas and the western China has been explained by Kingdom Ward (1921) on the presence of the North East Frontier belt in this area. This belt has acted as a barrier as well as a bridge between the Himalayan ranges to the west and the Chinese ranges to the East, which have got closely related floras. He states that "the three areas, Himalaya, North East Frontier and western China form a sort of letter Y, the three limbs of which, each composed of parallel ranges, are separated from one another, but connected independently with the desert plateaux of Central Asia, and it will probably be found that while the eastern most range of the N.E. Frontier belt shows a closer relationship with the western China limb, the western most range shows a closer relationship with the Himalayan limb.

To sum up, the N. E. Frontier belt, and more especially the Mekong-Salween divide, is primarily a barrier, botanical and zoological marking the eastern limit of the Indo-Malayan, or Oriental region, for at least 750 miles.

Secondarily it is, or has been connected in the north with the Himalayan ranges on the one hand and with the great China divide on the other, serving both to keep them apart and to link them up to a common centre."

Australian element in Indian flora: The Australian element is largely made up of such genera and species, which are exclusively endemic in the southern hemisphere. Some of these are *Backea, Laptospermum*

Melaleuca, Leucopogon, Stylidium, Helicia, Eucalyptus and *Casuarina.* The genus *Oxybaphus* in the Himalayas is greatly American and *Pyrularia edulis* is described from Java and North America. *Vogelia* comes from South America and Socotra.

Of the conifers there are again eastern and western elements. *Agathis loranthifolia* and *Dacrydium elatum* are Malayan extensions, and *Podocarpus neriifolia* and *Pinus merkusii* are more Malayan than Indian. *Juniperus communis* and *Taxus baccata* are European, although the latter extends as far east as to the Sino-Tibetan border. Two species of *Juniper* and one each of *Picea, Taxus, Tsuga* and *Pinus roxburghii* are common both in the eastern, and the western ranges of India.

The Malayan, N. African, Tropical, Subtropical, Mediterranean and European elements in Indian floras: The extent to which exotic elements from the above regions have entered Indian flora can be best studied in the Indus delta and the adjoining desert of Rajputana. The following account of the geographical distribution of plants occurring in the Indus Delta is given after Blatter and Sabnis (1928):

1. Endemic species. *Gossypium bakeri, Periploca sp., Convolvulus sp., Andrachne sp., Asparagus gharoensis, Asparagus deltae.*

2. The following are found in various parts of India and extend sometimes into Ceylon.

Nymphaea rubra, Maerua arenaria, Cadaba indica, Tamarix dioica, Triumfetta rotundifolia, Indigofera uniflora, I. viscosa, Tephrosia tenuis, Mimosa hamata, Kedrostis rostrata, Corallocarpus epigaea, Pluchea tomentosa, Echinops echinatus, Volutarella divaricata, Daemia extensa, Trichodesma indicum, Rivea hypocrateriformis, Linaria ramosissima, Lindenbergia urticaefolia, Clerodendron phlomoides, Suaeda nudiflora, Polygonum plebejum, Euphorbia caducifolia, E. clarkeana, Ficus glomerata, Crinum asiaticum, Pandanus tectorius, Urochloa setigera, Oryza coarctata.

3. The following is the Indo-Malayan element, some of the species extending to Australia and Polynesia.

Crotalaria juncea, C. medicaginea, Indigofera cordifolia, Pongamia glabra, Ceriops roxburghiana, Sonneratia acida, Scaveola frutescens, Oxystelma esculentum, Heliotropium paniculatum, Solanum xanthocarpum, Bonnaya veronicaefolia, Avicennia officinalis, Cyperus haspan, Fimbristylis ferruginea, Coix lachryma - jobi, Eragrostis amabilis.

4. The following species belong to the N. African - Indian Desert, and those which are found in the Indian desert only are also included in this list:

Farsetia jacquemontii, Ochradenus baccatus, Polycarpaea spicata, Tamarix troupii, Tamarix articulata, Gossypium stocksii, Tribulus alatus, Commiphora mukul, Zizyphus rotundifolia, Crotalaria burhia, Indigofera anabaptista, Tephrosia petrosa, Alhagi camelorum, Prosopis spicigera, Cucumis prophetarum, Citrullus colocynthis, Orygia decumbens, Pluchea lanceolata, Gnaphalium pulvinatum, Inula grantioides, Pulicaria angustifolia, P. stocksii, Launaea chondrilloides, L. nudicaulis, Statice stocksii, Salvadora oleoides, Periploca aphylla, Sarcostemma stocksii, Leptadenia spartium, Heliotropium calcareum, Heliotropium undulatum (also Mediterranean and tropical Asia), *Convolvulus scindicus, C. rottlerianus, C. microphyllus, Lycium barbarum, Schweinfurthia sphaerocarpa, Cistanche tubulosa, Tecomella undulata, Blepharis sindica, Salvia aegyptiaca* (also Mediterranean), *Aerua tomentosa, A. pseudo-tomentosa, Atriplex stocksii, Suaeda monoica, Salsola foetida, Euphorbia granulata, E. jodhpurensis, Ephedra foliata, Asparagus dumosus, Cyperus arenarius, Saccharum griffithii, Cymbopogon jwarancusa,*

Digitaria pennata, Cenchrus biflorus, Sporobolus arabicus, Heleochloa dura, Eragrostis ciliaris, Chloris villosa (also Mediterranean), *Eleusine flagellifera, Aeluropus villosus* (also Mediterranean).

5. The Tropical and N. African - Indian Desert Element is distributed in Kordofan, Darfur, Sennar, Etbai, Abyssinia, Yemen, Hadramaut, and the Island of Socotra, and number of its representatives are present in India, especially in the N.W. parts. In the Indus Delta only the following species belonging to this group are present:

Cocculus pendulus, Cleome brachycarpa, Capparis decidua, Polygala irregularis, Bergia odorata, Sida grewioides, Abutilon muticum, A. fruticosum, Senra incana, Grewia populifolia, Corchorus antichorus, Melhania denhami, Zygophyllum simplex, Acacia arabica, A. senegal. Vernonia cinerascens, Dicoma tomentosa, Salvadora persica, Calotropis procera, Pentatropis cynanchoides, Cordia myxa, Cordia rothii, Heliotropium ophioglossum, H. ovalifolium (also Mediterranean), *Convolvulus rhyniospermus, Solanum albicaule, Lindenbergia abyssinica, Ruellia patula, Barleria acanthoides, B. hochstetteri, Leucas urticaefolia, Aristolochia bracteata, Andrachne aspera, Commelina albescens, Cenchrus catharticus, Aristida funiculata, Eleusine aristata.*

6. This group has 13 species which are commonly distributed to tropical Africa and India. *Nymphaea stellata, Grewia asiatica, G. villosa, Triumfetta pentandra, Ruellia prostrata, Justicia heterocarpa, Nothosaerua brachiata, Arthrocnemum indicum, Typha elephantina* (Also in N. Africa), *Cyperus tegetum, Pennisetum cenchroides* (Also Mediterranean), *Desmostachya cynosuroides* (Also in Syria).

7. Common to the Tropics of the Old World are 39 species. *Portulaca quadrifida, Bergia ammannioides, Abutilon polyandrum, Thespesia populnea, Corchorus tridens, Gymnosporia montana, Indigofera pauciflora, Sesbania aculeata, Aeschynomene indica, A. aspera, Alysicarpus vaginalis, Rhizophora mucronata, R. conjugata, Ceriops candolleana, Bruguiera gymnorhiza, Momordica charantia, Coccinia indica, Melothria maderaspatana, Vernonia cinerea, Enicostema littorale* (also W. Indies), *Merremia chryseides, Ipomaea eriocarpa, I. aquatica, Physalis minima, Limnophila gratioloides, Barleria prionitis, Ocimum canum, Boerhaavia verticillata, Pupalia lappacea, Alternanthera nodiflora, Phyllanthus reticulatus* (also in China), *Cyperus stoloniferus, C. alopecuroides, Saccharum spontaneum, Dichanthium annulatum, Phragmites karka* (also in Japan), *Eragrostis interrupta, Diplachne fusca.*

8. 19 species are common to tropics. *Cleome viscosa, Gynandropsis pentaphylla, Abutilon indicum, Corchorus acutangulus, Rhynchosia minima, Acacia farnesiana, Trianthema monogyna, Blainvillea rhomboidea, Merremia aegyptia, Ipomaea biloba, Datura fastuosa, Amarantus viridis, Achyranthes aspera, Euphorbia hypericifolia, Phyllanthus niruri, Cocos nucifera, Eleocharis atropurpurea, Paspalidium geminatum, Chloris barbata.*

9. The following 22 species are distributed in most warm countries:

Portulaca oleracea, Sida spinosa, Tribulus terrestris, Fagonia cretica, Mollugo hirta, Eclipta erecta, Sonchus Oleraceus, Scaevola plumieri, Cressa cretica, Amarantus polygamus, Alternanthera triandra, Vallisneria spiralis, Cyperus rotundus, Hemarthria compressa, Digitaria sanguinalis, Eriochloa ramosa, Echinochloa colona, E. stagnina, Setaria verticillata, Aristida adscenscionis, Tragus racemosus, Cynodon dactylon.

10. 6 Species of this area are found in the tropical and subtropical regions of the Old World or of the whole world. *Grangea maderaspatana, Lippia nodiflora, Ocimum sanctum, Boerhaavia diffusa, Euphorbia hirta, E. pilulifera.*

11. In the warm parts of the Old World there are 3 species: *Ammannia baccifera, Fimbristylis dichotoma, Eleusine aegyptiaca.*

12. One species *Zannichellia palustris* is common to the temperate and subtropical regions.

13. Mediterranean - Oriental in distribution are the following two species: *Withania somnifera, Saccharum ravennae.*

14. Oriental 5 species are the following: *Taverniera cuneifolia, Nerium odorum, Suaeda fruticosa* (also in Europe, N. Africa, and America), *Haloxylon recurvum, Populus euphratica.*

15. One species *Erodium cicutarium* is European.

16. Cosmopolitan 6 species are: *Convolvulus arvensis, Solanum nigrum, Chenopodium murale, Sagittaria sagittifolia, Scirpus maritimus, Echinochloa crusgalli.*

Chatterjee (*loc. cit.*) has made an interesting study of evaluating the influence of the mediterranean element on the dicotyledonous flora of India. As shown in fig. 1 the *Cruciferae* and the *Caryophyllaceae* are mainly Mediterranean, while the other four families in the Indian flora are partly Mediterranean in origin.

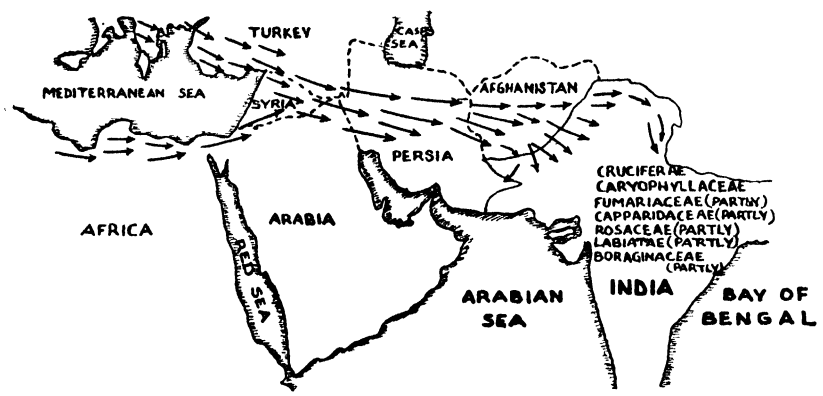


FIG. 1. EAST MEDITER—RANEAN INFLUENCE ON INDIAN FLORA
(after Chatterjee, 1947)

Exotic weeds in Indian flora: A number of plants from foreign lands have in recent years established themselves so firmly in India that they appear to be a part of the Indian flora. For example, *Eichornea* has become a very serious pest in Bengal, and *Lantana* and *Croton sparsiflorus* have established themselves to the exclusion of anything else in most bare areas in South India. Another plant which is seen to be spreading from east is *Eupatorium odoratum. Ageratum conyzoides, Mikania scandens, Argemone mexicana, Suaeda maritima, Opuntia dillenii* and *Evolvulus nummularius* are slowly becoming common in this country. The use is made of several foreign grasses and Kudzu vine for checking erosion in several parts of India.

LIST OF ENDEMIC AND NON-ENDEMIC DICOTS IN INDIAN FLORA.

The number of endemic and non-endemic plants among the Indian dicotyledonous flora is given in table 6 family-wise after Chatterjee.

Table 6.

THE DISTRIBUTION OF DICOTYLEDONOUS FLORA OF INDIA.

(From Chatterjee, 1939).

	Total No. Sp.	Total No. Gen.	Wide spp.	Endemic spp.			
				Cont. I.	Himalayas.	Burma.	G. Area.
Ranunculaceae.	162	21	61	13	80	5	3
Dilleniaceae.	15	3	10	3	0	1	1
Magnoliaceae.	36	7	5	0	24	6	1
Schizandraceae.	5	2	4	0	1	0	0
Anonaceae.	129	22	52	28	11	29	9
Menispermaceae.	42	17	30	6	4	1	1
Lardizabalaceae.	5	4	1	0	4	0	0
Berberidaceae.	35	4	1	1	28	3	2
Nymphaeaceae.	11	6	7	3	0	0	0
Cruciferae.	174	43	78	8	86	0	2
Fumariaceae.	66	4	18	0	47	1	1
Papaveraceae.	43	7	15	0	25	3	0
Capparidaceae.	65	10	30	18	2	12	3
Resedaceae.	4	3	4	0	0	0	0
Violaceae.	25	3	14	1	7	3	0
Bixaceae.	1	1	1	0	0	0	0
Cochlospermaceae.	1	1	1	0	0	0	0
Flacourtiaceae.	21	5	10	4	1	3	3
Pittosporaceae.	8	1	4	2	2	0	0
Polygalaceae.	32	4	25	4	1	2	0
Xanthophyllaceae.	7	1	5	1	1	0	0
Frankeniaceae.	1	1	1	0	0	0	0
Caryophyllaceae.	107	18	44	2	57	1	3
Portulacaceae.	6	2	5	1	0	0	0
Tamaricaceae.	8	2	4	2	1	0	1
Elatinaceae.	6	2	5	1	0	0	0
Hypericaceae.	26	3	11	1	11	1	2
Guttiferae.	40	6	20	13	3	4	0
Ternstroemiaceae.	39	13	18	8	7	4	2
Dipterocarpaceae.	51	8	16	15	2	17	1
Ancistrocladaceae.	5	1	4	1	0	0	0
Malvaceae.	111	22	81	18	4	6	2
Sterculiaceae.	80	19	47	18	9	5	1
Tiliaceae.	78	9	42	21	4	6	4
Elaeocarpaceae.	42	2	27	4	7	3	1
Linaceae.	8	5	5	0	3	0	0
Erythroxylaceae.	6	1	5	0	1	0	0
Malpighiaceae.	17	2	10	2	4	0	1
Zygophyllaceae.	9	5	9	0	0	0	0
Geraniaceae.	28	4	16	0	11	0	1
Oxalidaceae.	14	3	9	3	2	0	0
Balsaminaceae.	242	2	21	77	112	26	6
Rutaceae.	71	24	48	9	7	5	2
Simarubaceae.	15	7	11	1	3	0	0

Table 6. (Contd.)

	Total No. Sp.	Total No. Gen.	Wide spp.	Endemic spp.			
				Cont. I.	Hima-layas.	Bur-ma.	G. Area.
Ochnaceae.	9	2	5	3	0	1	0
Burseraceae.	13	5	3	9	0	0	1
Meliaceae.	62	19	27	17	11	4	3
Dichapetalaceae.	3	1	3	0	0	0	0
Olaceae.	18	6	13	2	2	0	1
Icacinaceae.	25	12	7	10	2	5	1
Opiliaceae.	4	3	3	0	0	1	0
Aquifoliaceae.	34	1	21	3	4	4	2
Celastraceae.	84	10	24	22	22	10	6
Hippocrateaceae.	27	3	13	6	5	2	1
Rhamnaceae.	53	11	25	10	15	2	1
Ampelidaceae.	70	8	31	18	13	1	7
Leeaceae.	27	1	6	5	3	3	10
Staphyleaceae.	4	2	3	1	0	0	0
Hippocastanaceae.	2	1	2	0	0	0	0
Sapindaceae.	54	20	34	7	3	8	2
Aceraceae.	20	1	3	0	15	2	0
Sabiaceae.	19	2	5	1	10	1	2
Anacardiaceae.	67	20	25	20	8	9	5
Coriariaceae.	1	1	1	0	0	0	0
Connaraceae.	20	5	11	3	1	4	1
Papilionaceae.	862	112	372	176	147	108	59
Caesalpiniaceae.	125	23	78	21	5	15	6
Mimosaceae.	96	17	53	26	6	9	2
Rosaceae.	255	26	76	14	144	11	10
Saxifragaceae.	114	17	27	0	83	4	0
Crassulaceae	64	7	15	4	44	1	0
Droseraceae.	4	2	4	0	0	0	0
Hamamelidaceae.	7	7	3	0	4	0	0
Haloragidaceae.	14	5	10	3	0	0	1
Rhizophoraceae.	16	9	15	1	0	0	0
Combretaceae.	49	6	26	11	1	9	2
Hernandiaceae.	4	2	2	2	0	0	0
Myrtaceae.	116	9	59	44	4	4	5
Lecythidaceae.	12	2	7	1	0	4	0
Melastomaceae.	127	16	42	48	16	17	4
Lythraceae.	48	7	26	15	2	4	1
Crypteroniaceae.	3	1	1	0	1	1	0
Sonneratiaceae.	5	2	4	0	0	0	1
Onagraceae.	39	6	13	2	24	0	0
Samydaceae.	20	2	9	5	2	1	3
Passifloraceae.	7	2	4	0	3	0	0
Caricaceae.	1	1	1	0	0	0	0
Turneraceae.	1	1	1	0	0	0	0
Cucurbitaceae.	86	28	58	12	9	2	5
Begoniaceae.	71	1	16	7	26	18	4

Table 6. (Contd.)

	Total No. Sp.	Total No. Gen.	Wide spp.	Endemic spp.			
				Cont. I.	Himalayas.	Burma.	G. Area.
Datiscaceae.	2	2	2	0	0	0	0
Cactaceae.	6	3	6	0	0	0	0
Aizoaceae.	16	7	16	0	0	0	0
Umbelliferae.	180	43	49	23	101	4	3
Araliaceae.	55	15	23	7	20	4	1
Alangiaceae.	6	1	4	0	1	1	0
Cornaceae.	12	5	8	1	3	0	0
Nyssaceae.	2	1	1	0	0	1	0
Caprifoliaceae.	56	8	13	2	39	0	2
Rubiaceae.	555	68	187	170	101	66	31
Valerianaceae.	20	4	4	6	10	0	0
Dipsaceae.	17	4	3	1	12	1	0
Compositae.	697	126	330	102	219	23	23
Stylidaceae.	3	1	3	0	0	0	0
Goodeniaceae.	2	1	2	0	0	0	0
Campanulaceae.	71	13	24	4	38	4	1
Vacciniaceae.	68	4	4	1	39	21	3
Ericaceae.	144	9	18	0	78	44	4
Monotropaceae.	3	3	2	0	1	0	0
Diapensiaceae.	1	1	0	0	1	0	0
Plumbaginaceae.	8	6	5	2	1	0	0
Primulaceae.	208	7	31	2	159	16	0
Myrsinaceae.	92	10	29	12	37	9	5
Sapotaceae.	32	10	14	10	4	3	1
Ebenaceae.	58	2	18	18	11	10	1
Symplocaceae.	51	1	7	23	14	6	1
Styracaceae.	9	3	3	0	3	3	0
Oleaceae.	97	10	29	25	23	16	4
Salvadoraceae.	5	3	5	0	0	0	0
Apocynaceae.	84	36	30	17	14	17	6
Asclepiadaceae.	232	49	62	73	61	19	17
Loganiaceae.	40	8	20	3	9	3	5
Gentianaceae.	188	15	42	24	89	28	5
Menyanthaceae.	1	1	1	0	0	0	0
Polemoniaceae.	1	1	1	0	0	0	0
Hydrophyllaceae.	1	1	1	0	0	0	0
Boraginaceae.	145	39	62	27	47	4	5
Convolvulaceae.	177	24	90	43	12	20	12
Solanaceae.	58	14	42	7	6	0	3
Scrophulariaceae.	274	54	135	22	90	16	11
Orobanchaceae.	29	7	17	5	6	1	0
Lentibulariaceae.	30	2	13	9	5	3	0
Gesneraceae.	133	27	11	14	66	34	8
Bignoniaceae.	32	13	16	5	2	7	2
Pedaliaceae.	4	2	2	2	0	0	0
Acanthaceae.	508	50	88	188	107	99	26

Table 6. (Contd.)

	Total No. Sp.	Total No. Gen.	Wide spp.	Endemic spp.			
				Cont. I.	Himalayas.	Burma.	G. Area.
Verbenaceae.	115	15	60	18	18	8	11
Labiatae.	419	69	160	81	110	28	40
Plantaginaceae.	13	1	12	0	1	0	0
Nyctaginaceae.	8	3	4	2	1	0	1
Illecebraceae.	2	2	2	0	0	0	0
Amarantaceae.	47	17	31	9	4	1	2
Chenopodiaceae.	40	18	37	2	1	0	0
Phytolaccaceae.	2	2	2	0	0	0	0
Polygonaceae.	110	8	25	3	64	1	17
Podostemonaceae.	16	8	5	9	1	0	1
Nepenthaceae.	1	1	0	0	1	0	0
Cytinaceae.	1	1	0	0	1	0	0
Aristolochiaceae.	13	3	4	3	5	1	0
Piperaceae.	103	4	15	24	52	8	4
Chloranthaceae.	3	2	3	0	0	0	0
Myristicaceae.	14	4	5	6	1	0	2
Lauraceae.	171	18	33	45	63	19	11
Hernandiaceae.	1	1	1	0	0	0	0
Proteaceae.	7	1	2	2	0	2	1
Thymeleaceae.	22	10	12	0	7	0	3
Elaeagnaceae.	12	2	4	5	3	0	0
Loranthaceae.	73	13	26	24	11	9	3
Santalaceae.	15	7	3	3	4	4	1
Balanophoraceae.	6	2	1	0	4	0	1
Buxaceae.	6	2	2	1	2	1	0
Euphorbiaceae.	442	70	161	119	74	68	20
Ulmaceae.	16	5	10	1	1	2	2
Cannabinaceae.	2	2	2	0	0	0	0
Moraceae.	114	15	70	10	14	8	12
Urticaceae.	111	20	42	10	43	7	9
Platanaceae.	1	1	1	0	0	0	0
Juglandaceae.	4	2	4	0	0	0	0
Myricaceae.	1	1	1	0	0	0	0
Casuarinaceae.	1	1	1	0	0	0	0
Cupuliferae.	64	7	22	2	19	9	12
Salicaceae.	43	2	14	0	28	0	1
Ceratophyllaceae.	1	1	1	0	0	0	0

3

BOTANICAL REGIONS OF INDIA.

India is divided into a number of botanical regions by Clarke (1898), Hooker (1907) and Chatterjee (1939). The arrangements of the three authors is given in table 7.

Table. 7.

BOTANICAL REGIONS OF INDIA ACCORDING TO CLARKE, HOOKER AND CHATTERJEE.

C. B. Clarke.	J. D. Hooker.	D. Chatterjee.
(1) West Himalaya.	(2) Western Himalaya.	(8) Western Himalaya.
(2) India Deserta.	(3) Indus Plain.	(3) Indus Plain.
(3) Malabaria.	(5) Malabar.	(2) Malabar.
(4) Ceylon.	(7) Ceylon and Maldives.	...
(5) Coromandalia.	(6) Deccan.	(1) Deccan.
(6) Gangetic Plain.	(4) Gangetic Plain.	(4) Gangetic Plain.
(7) East Himalaya.	(1) Eastern Himalaya.	(6) Eastern Himalaya.
(8) Assam.	...	(5) Assam.
...	...	(7) Central Himalaya.
(9) Ava.	(8) Burma.	(9) Upper Burma.
(10) Pegu.	...	(10) Lower Burma.
(11) Malaya Peninsula	(9) Malaya Peninsula.	...

Since Burma is no longer a part of India the zones referring to it are excluded and Andamans as a distinct unit may be included. It is also necessary to include central India and the Laccadive and Minicoy group of Islands on the Western Coasts as two additional botanical regions of India. Since both these have not been studied adequately it would not be possible to give any complete account of vegetation of these now. A brief summary of vegetation characters in these regions is given below:—

1. **Western Himalayas.** Comprising of the Himalayan mountains from Kumaon to Kashmir is characterised by rainfall of 40" to 80" per annum, with considerable variations between the outer and the inner valleys. The inner valleys receive very low monsoon rainfall but high snowfall. The climate generally becomes drier and extreme towards west. The vegetation is divided into altitudinal zones, such as submontane zone upto about 5,000 feet; temperate zone from 5,000 to 11,000 or 12,000'; and Alpine zone above 11,000 or 12,000' to snowline. In fig. 2, (p. 39) a comparison between vegetation of different altitudinal zones of the Western and Eastern Himalayas is given.

The altitudinal zonation of the different types of vegetation is not strict and it has been found that geology and soils exercise a far greater influence on the distribution of vegetation than altitude or climate. The other important feature in the Himalayas is the role of man in delimiting the vegetation zones. Glaciation in the Pleistocene Period has intro-

duced still another important feature and there is a good deal of difference in the vegetation of glaciated and non-glaciated regions in the Himalayas.

The submontane zone comprising of the Siwaliks has *Shorea robusta* forests, broken according to geological, biotic or soil features by tracts of Savannah, riverain types, swamps, etc. In the Savannahs, trees of *Salmalia malabarica, Butea monosperma Lagerstroemia parviflora, Acacia catechu* with *Zizyphus, etc.* in a grassy, undergrowth are present. *Acacia catechu* and *Dalbergia sissoo* are the main trees in riverain tracts. Swampy areas have a vegetation of *Cedrela toona, Bischofia javanica, Albizzia procera, Ficus glomerata, Eugenia jambolana, Trewia nudiflora* and *Calamus tenuis,* with a thick undergrowth of evergreen bushes, ferns, etc.

In the Bhabar tracts, with low water table and drier soil conditions mixed deciduous forests of *Terminalias, Anogeissus, Stereospermum, Phyllanthus, Adina, Ougeinia,* etc. with or without *sal,* as the predominant tree, are present. The bamboo - *Dendrocalamus strictus* is found commonly at places. *Pinus roxburghii* comes in these forests on special habitats, such as quartzite and boulder conglomerate on top of hills. In burnt and heavily disturbed areas thorny species of *Zizyphus, Carissa, Acacia* and constituents of an open degraded forest, such as *Mallotus, Holarrhena, Ehretia laevis, Casearia tomentosa, Ficus bengalensis, Adina cordifolia* and even *Terminalias* and *Sal,* are found. In west of the Jamuna *Acacia modesta, Carissa spinarum, Dodonaea viscosa, Olea cuspidata,* etc. are present in degenerate forest communities. *Euphorbia royleana* may also be present in clumps in these heavily disturbed forests with dense grassy cover. In all these types, the ground flora is usually very scanty and is formed of a number of grass species.

In the temperate zone, forests of five species of Oaks - *Quercus semecarpifolia, Q. dilatata, Q. incana, Q. ilex, Q. glauca,* are present forming climax communities. *Q. ilex* occurs in inner dry valleys and *Q. incana* is the species of monsoon climate in the outer ranges. The oaks are associated with a number of deciduous broad leaved trees, such as *Acer, Aesculus, Populus, Ulmus, Alnus, Betula, Cornus, Prunus,* etc. *Rhododendron arboreum* at lower level and *Rhododendron campanulatum* at higher are common constituents in the Oak climaxes. In the inner dry valleys, *Fraxinus xanthoxyloides* and *Buxus* are present. In the zones of the Oaks, conifers forming pure or mixed forests constitute an important feature of forest vegetation. *Pinus excelsa,* and *Cedrus deodara* occur in outer monsoon zone, whereas *Picea smithiana* and *Abies pindrow* occur in areas with heavy snowfall at higher altitudes. *Pinus gerardiana* is present in the inner dry valleys.

The alpine vegetation generally consists of high level silver fir, *Betula, Juniper, Rhododendrons,* with a variety of plants, forming cushion like features. The vegetation of the glaciated regions differs considerably from the non-glaciated parts. In the glaciated parts of Kashmir, there are no oaks and laurels. Deodar is scanty. The alluvial Karewa Lake deposits are covered with *Pinus excelsa,* while glacial moraines to as low an altitude as 6,000 ft. bear *Abies webbiana* forest in Kashmir.

Geology and soil conditions have a powerful effect on forest distribution. Quartzite even at 9,000ft. above sea level carries *Pinus roxburghii* and riverain alluvium at 5,000ft. bears exclusively *Cedrus deodara,* showing that altitude has little effect on the distribution of these conifers in the Himalayas. There are numerous other examples that will be given in the text elsewhere from the works of Puri (1950).

2. **Eastern Himalayas:** The Eastern Himalayas constitute the humid region from Sikkim, eastwards. This is also divided into tropical, temperate and alpine zones according to altitude.

The eastern Himalayas is distinguished from the western parts by the higher monsoon rainfall, scanty snowfall, and higher temperature and humidity.

The tropical zone in the eastern Himalaya is also formed of *sal* forests, with patches of riverain forests, mixed deciduous forests, savannahs and swamps. This corresponds to the Siwaliks zone. The mixed deciduous forests consist of *Sterculia villosa, Lagerstroemia parviflora, Terminalia sp., Anthocephalus cadamba, Cedrela toona, Bauhinia, Stereospermum,* etc. These forests are also developed on the Siwalik formations and on account of the high rainfall and deep clayey red soils most of the constituents of the eastern *sal* forests are evergreen. The undergrowth in these is also more luxuriant than in western *sal* forests.

The savannahs in this part of the Himalayas are usually moist, with tall grasses and trees of *Albizzia procera, Bischofia javanica,* and *Salmalia.* The evergreen forests in this zone constitute a very important feature and are composed of *Aesculus punduana, Artocarpus chaplasha, Michelia champaca, Cinnamomum, Schima wallichii, Dillenia indica,* etc.

The common bamboo is *Dendrocalamus hamiltonii.*

The temperate zone is divisible into two, the lower and the upper. The vegetation in the lower is dominated by broad leaved species of oaks, such as *Quercus lamellosa, Q. lineata* and *Michelia excelsa, Pyrus, Symplocos, Eurya, Meliosma, Castanopsis,* etc.

The upper zone has conifers, such as *Abies webbiana, Picea spinulosa, Larix griffithii* and *Tsuga brunoniana* with *Junipers,* Willows and *Rhododendrons.* The common bamboo is *Arundinaria racemosa.*

In the alpine zone the commonest species are *Rhododendrons* and *Juniperus.*

The vegetation of the Eastern Himalayas broadly differs from that of the Western Himalayas by having less conifers and much more broad-leaved forests. There are more than 20 oaks here as against 5 in the Western Himalayas. The *Rhododendrons* have greater abundance and variety. There are tree ferns and Orchids which greatly outnumber here than in the Western Himalayas.

3. **Indus Plain** comprises of parts of the Panjab, Rajputana, Cutch, Delhi, in which rainfall is usually less than 30 inches. In most parts it is less than 20″, and in dry regions it may be anything between 2″ and 5″. The forests in this area are, no doubt, degraded from the past glory by the biotic interference and at present comprise of bushy, thorny plants. *Acacia arabica, Prosopis spicigera, Salvadora oleoides, Salvadora persica, Capparis aphylla, Tecomella* are the main species. *Acacia senegal* is the common plant on limestone soils. On sandstones of the *Aravallis, Anogeissus, Gymnosporia, Eugenia* and mango are common plants. On new alluvium or on abandoned cultivation *Dalbergia sissoo, Albizzia lebbek* and *Acacia arabica* are found.

On the Aravallis, e.g. at Abu, *Anogeissus pendula, Boswellia serrata Sterculia urens, Balanites roxburghii, Acacia senegal, Acacia catechu, Euphorbia nivulia* and *Grewia salvifolia* are present. On account of the adverse biotic interference grassy areas extend for miles on all sides. On sandy plains and sand-dunes *Calligonum, Aerua, Alysicarpus, Tephrosia purpurea* form extensive communities of plants. *Calotropis* is a conspicuous feature of the sandy areas. *Panicum antidotale, Elionurus hirsutum* are tall sand-binding grasses and extend for miles. On saline areas *Eleusine* and *Sporobolus* from extensive close communities.

Prosopis juliflora has been extensively planted all over the Indus plains and is doing extremely well. *Neem* and mango have good possibilities of use as forest forming trees.

4. **Gangetic plain** comprises of the Uttar Pradesh, parts of Delhi and plains of neighbouring States of Bihar, Orissa and Bengal. The forests have largely been destroyed from most of the area and in some tracts *sal* forests are left.

The sal forests have *Terminalia tomentosa, Terminalia belerica, Bauhinias, Eugenia, Phyllanthus, Woodfordia,* etc. These forests being open and having suffered greatly from fire, grazing, etc., have a grassy undergrowth in which seedlings of trees are not able to shoot up.

The important types here are Mangroves of Sunderbans and Delta forests in the Bay of Bengal. The latter are dominated by *Sonneratia apetala, Aegiceras majus, Cynometra ramiflora and Ceriops candolleana.*

5. **Central India:** The Central India comprising mainly of the Vindhyas, now included in Madhya Pradesh, is a distinct vegetation unit which has been very little studied. On granite and gneiss hills that rise upto an altitude of 1500–2000 ft. above sea level, teak and *Madhuca* are the dominant species. On account of intense biotic interference from the local population - the Bhils - *Madhuca* is retained in good patches, but teak is mainly poor stunted and badly coppiced small trees. *Terminalia tomentosa, Bauhinia,* mango, *Phyllanthus* are some other important trees. Rainfall being fairly good, between 60" to 80" epiphytic orchids are present in these forests. In the shrub layer are *Desmodium, Helecteres isora,* occasionally *Acacia* sp. The ground layer is mainly grassy with a number of legumes.

6. **The West Coast of the Malabar** is the region of very high rainfall stretching from Cape Camorin to parts of Gujarat in the north. Luxurient vegetation, more or less of virgin character, is present in this area and comprises of tropical evergreen or rain forests, mixed deciduous or monsoon forests and sub-tropical or temperate forests on the peninsular mountains.

The tropical evergreens have a luxurient vegetation forming several strata, and with very tall trees, often with buttressed stems. The north Kanara forests are composed of *Cedrela toona, Dysoxylum malabaricum, Dipterocarpus indicus, Hopea parviflora, Mesua ferrea, Mangifera indica, Canarium strictum, Sterculia alata, Calophyllum tomentosum, Artocarpus hirsuta, Vitex altissima* and *Hydnocarpus wightiana.* There is a dense second storey and undergrowth of many ferns and tall herbs.

The mixed deciduous or monsoon forests comprise of species which remain leafless during December to June. They are composed of *Terminalia tomentosa, Terminalia paniculata, Tectona grandis, Dalbergia latifolia, Lagerstroemia lanceolata, Xylia xylocarpa, Adina cordifolia, Grewia tiliaefolia, Stephegyne parvifolia.* Woody climbers may be present. The commonest bamboos are *Bambusa arundinacea* and *Dendrocalamus strictus.* These forests are usually developed on the Deccan trap.

The sub-tropical or temperate evergreen forests, commonly called sholas, occur in the Palni, Anaimalai and the Nilgiris, usually above an altitude of 5,000 feet. They are composed of *Eurya japonica, Gordonia obtusa, Michelia nilagirica, Ternstroemia japonica, Eugenia, Ilex, Meliosma, Symplocos* and various Lauraceae.

Mangrove forests, grasslands and dwarf forests also occur in this region. In the mangroves *Avicennia, Rhizophora,* etc. are common with

Acanthus as a common shrub. Common grasses are *Aristida, Heteropogon, Cymbopogon, Apluda, Themeda,* etc.

At altitudes of above 3000 ft. in this region an evergreen forest comprising of *Eugenia, Actinodaphne,* mango, *Sideroxylon,* etc. occurs. *Memecylon* is the commonest second storey species in these forests with *Carvia callosa* in the undergrowth. These forests are developed on red ferruginous clay and laterite at Mahabaleshwar, Matheran and Bhimashankar with rainfall above 200" per annum.

In the forests of this zone epiphytic orchids and ferns are common.

7. **The Deccan** including the major part of the peninsular India is a hilly plateau with rainfall of near about 40".

In the upper parts, the Satpuda ranges have a thick forest of *Hardwickia binata, Boswellia serrata,* Teak, numerous *Acacias* and a grassy undergrowth. In plains that are sandy and dry with low rainfall, the forests are of the dry open type with *Prosopis spicigera* and other thorn forest species, such as *Acacia planifrons* and *Acacia latronum.* In rocky areas with dry soil, *Capparis* sp. and *Euphorbia* are present. Small tracts carry forests of *Pterocarpus santalinus* in the Cuddapah and *Hardwickia binata* in Salem and north Arcot. The important Sandal forests occur in this zone. In areas with sufficient rainfall by far the commonest type is the teak forest which are not very elegant. *Anogeissus, Boswellia, Garuga, Buchanania, Diospyros* are common associates of teak in these forests on basalt. On amygdaloid type, however, *Acacias* are the most common with *Euphorbias.*

8. **Assam:** Comprises of the valleys of Brahmputra and Surma with hills of Naga, Manipur and Lushai. The rainfall is very heavy above 80 inches to 460 inches in Cherrapunji. The vegetation is luxuriant, composed of *Artocarpus chaplasha, Michelia champaca, Ficus elastica, Mesua ferrea, Vatica lanceaefolia, Alstonia scholaris, Sterculia alata, Morus laevigata* and *Stereospermum chelonoides,* etc.

The commonest bamboo is the *Dendrocalamus hamiltonii.* The thick undergrowth is formed of canes, climbers and evergreen bushes. The hill forests of Assam are similar to those of the east Himalayas with the exception that alpine zone is absent. The forests are dominated by *Alnus nepalensis, Betula alnoides, Carpinus viminea, Rhododendron arboreum, Pieris ovalifolia, Bucklandia populnea, Magnolia, Michelia, Prunus, Pyrus, Acer,* etc.

The pine forests are composed of *Pinus khasya.* The hill tops carry extensive grasslands as in the Nilgiris.

9. **Andamans:** The Andaman forests generally resemble forests of Burma, differing from the latter in specific composition. These are classified into Mangrove vegetation, beech forests, evergreen, semi-evergreen and deciduous forests. The mangroves are swamp types with *Rhizophora* spp. The beech forests have *Mimusops, Calophyllum,* etc. *Dipterocarpus* spp. are the most characteristic in the evergreen forests. *Terminalias* and *Lagerstroemia,* etc. are common species of deciduous and semi-evergreen forests.

10. **Laccadive and Minicoy Group of islands** along the Western Coast form a distinct botanical region, which is very little known. There is a scrub type of vegetation growing on rocky substrata and brief reference to the types of plants are given by Ellis (1724) in Gazetteer. In Agathi, the hottest of the Laccadive group has a dense undergrowth with scattered coconut trees. In Androth island there is a luxuriant growth of ferns. Coconuts, breadfruit, plantains and betel vines grow well. A

few limes and areca palms also grow. In Kalpeni and Cheriam, the area is covered with a dense Jungle of screw pine, Killi and Chonum. In the middle of the island bread fruit grows well. There are areca palms, tamarind and a few limes. In Suhelipar Island, there is a jungle with a few coconut trees, screw pines. One *Ficus bengalensis* occurs on which *Ipomea* creepers have been recorded.

Higher up on the west coast, there are a few small Islands. These were visited by the author recently. At Bet Dwarka along the Saurashtra Coast there occurs a scrubby vegetation of *Acacia senegal, Grewia populifolia, Euphorbia nivulea, Zizyphus xylopyrus.* There are a number of climbers among which *Ephedra* is present. Coarse grasses like *Aristida* and *Heteropogon* are present mainly in the undergrowth.

Geographical distribution of some south Indian flora: From the foregoing description of the botanical regions of India it may follow that the Himalayan flora is absolutely distinct from other parts of India. Actually a number of Himalayan species have been found in other parts of India, which has raised interesting phytogeographical problems.

The flora of some of the hills in Bihar, Orissa, Bastar state, Nilgiris and other regions in the Peninsular India has attracted attention since a number of species from the Eastern Himalayas, Western Himalayas and the Western Ghats have been found in isolated places in these hills. The main types are the following:—

(1) **Parasnath hill in Chota Nagpur Plateau:** The relationship of vegetation between Parasnath Hill and the Himalayan region was detected by Anderson as early as 1863, who stated that Hooker, already in 1848, had seen this resemblance. The following species from Parasnath Hills are distributed in the Himalayan region: *Clematis nutans, Thalictrum glyphocarpum, Berberis asiatica, Geranium nepalense.*

The flora of Parasnath also resembles the flora of the less elevated and dry mountain ranges of Central and Southern India. From both these areas the absence of Anonaceae, Ternstroemiaceae, Pittosporaceae, Rhamnaceae, (except *Zizyphus*), Rosaceae, Araliaceae, Myrsinaceae, Cornaceae, Apocynaceae, Lauraceae, Amarantaceae, Aroideae, Orchideae and Ferns greatly strengthens the botanical affinities in the two floras.

Olacineae, Terebinthaceae, Leguminosae, Combretaceae, Lythraceae, Rubiaceae, Compositae, especially the genera *Vernonia* and *Blumea*, Convolvulaceae, Cordiaceae and Gramineae are present in the floras of both the regions.

This relict flora according to recent studies of Biswas (1949) is more or less allied to Kurseong in the Darjeeling district. Clarke (1898) and Haines (1921-25) have suggested that these hills may have in the past served as stepping stones for the passage of plant species between the hills of the Peninsula and the Eastern Himalayas.

2. **Mahendra Giri hills in South Orissa:** Mukerjee (1935) studied this very interesting flora and found a number of West Himalayan, East Himalayan and South Indian hill plants from these hills at an altitude of 2,000 feet. The various elements from this flora are given in table 8.

There are in addition a number of species in Mahendra Giri hills that occur in other hilly tracts of India, some of these are: *Indigofera pulchella, Hamiltonia suavcolans, Viola patrinii, Peperomia reflexa, Reinwardtia trigyna, Carex speciosa,* etc.

3. **Jaspur and Sarguja in M.P:** Mooney (1944) has recently reported the presence of *Crataegus crenulata, Pyrus pashia, Berberis asiatica,*

Table 8.

DISTRIBUTION OF MAHENDRA GIRI HILL PLANTS.

(after Mukerji, 1935)

Western Himalaya	Eastern Himalaya	South Indian hills.
1. *Senecio nudicaulis.*	1. *Scutellaria discolor.*	1. *Balanophora polyandra.*
2. *Pogostemon plectranthoides.*	2. *Shuteria vestita.*	2. *Senecio corymbosus.*
3. *Clematis nutans.*	3. *Alectra indica.*	3. *Vernonia divergens.*
		4. *Plectranthus menthoides.*

Cudrania javanica at an altitude of 3,700 feet in Jaspur and Sarguja. *Rubus ellipticus* was recorded from Mayurbhanj hills. All these species are normally present in the temperate Himalayas from Kashmir to Bhutan, Khasi hills and Manipur.

4. **Hills of Bihar, Orissa and neighbouring states:** Mooney (1947) has recorded thirteen species of the Rosaceae belonging to *Pygeum, Rubus, Potentilla, Fragaria, Rosa, Pyrus* and *Crataegus* from hills of Bihar, Orissa and the neighbouring states.

Of these *Rubus ellipticus* is the most widely distributed, occurring from the Sameshwar hills on the borders of Nepal in the north of Champaran district to the southern extremity of Kalahandi. *Pygeum acuminatum* is more abundant within this area than *Rubus*, but is not so wide-spread. *Pygeum andersoni* is endemic in Chota Nagpur and south Orissa, and *Pygeum mooneyi* is endemic to the Bailadila Range. *Pyrus pashia* occurs only in Mainpat (3,500-3,600 feet) in Surguja, the only area south of the Himalayas. *Crataegus crenulata* is the only species recorded from the rocky banks above the stream at Newadih on Samripat, Surguja (3,700-3,800ft) in the South of the Himalayas.

About seven species out of twelve are absent from localities below an elevation of 3,500 ft., but are quite abundant at higher altitudes. These species are *Pygeum andersoni, Pygeum mooneyi, Potentilla kleiniana, Potentilla leschenaultiana, Rubus rugosus, Pyrus pashia,* and *Crataegus crenulata. Rubus ellipticus* and *R. lasiocarpus* are found at 3,000ft. *Pygeum acuminatum* occurs at about 2,000ft. *Rosa involucrata, Potentilla supina* and *Fragaria indica* are tolerant of low altitudes. *Fragaria indica* occurs along the foot of the Himalayas from the Punjab to Assam, and in South India it is found only above 3,500 ft. So except in the extreme north it prefers the higher altitude than 3,500 ft. This can also be added to the above mentioned seven species.

Table 9 gives the localities where species of the family Rosaceae are found in Bihar and Orissa.

Table 9.

DISTRIBUTION OF THE ROSACEAE IN BIHAR AND ORISSA.

(after Mooney, 1947)

Locality	Habitat conditions.	Species.
1. North Bihar.	Plains elevation less than 1000 ft.	*Rosa involucrata.*
		Fragaria indica.
	Above 2000ft. in Sameshwar Hill of Chamapran district towards the Nepal border.	*Potentilla supina.*
		Rubus ellipticus.
2. Parasnath Hill.	4,300 ft.	*Pygeum andersoni.*

Table 9. (Contd.)

Locality	Habitat conditions.	Species.
3. The pats of Chota Nagpur Jaspur & Surguja.	Favourable season. Rainfall 65-70 inches.	
(a) Mainpat.	3,500-3,600 ft.	*Pygeum andersoni.* *Fragaria indica.* *Rubus ellipticus.* *R. rugosus.* *Pyrus pashia.*
(b) Samripat.	3,600-3,800 ft., with small outlier of Lahsunpat, 4,016 ft.	*Pygeum andersoni.* *Potentilla Kleiniana.* *P. leschenaultiana.* *Rubus rugosus.* *Crataegus Crenulata.*
(c) Netarhat and Pakari Pat.		*Rubus rugosus.* *Potentilla kleiniana.* *P. leschenaultiana.*
4. The Singhbhum, Bonai, Pal Lahara and Mayurbhanj Hills.	General elevation 2,000-2,500 ft. Several peaks rise above 3,000 ft., rain fall 65"-70".	*Pygeum acuminatum.* *Rubus ellipticus.* *Rosa involucrata.*
5. The Kasipur Plateau in Kalahandi State.	2,500-4,200 ft. Frost is rare. Rainfall 80"-100".	*Pygeum acuminatum.* *Rubus ellipticus.* *R. lasiocarpus.*
6. The Bailadila Range in Bastar State.	3,000 to 4,000 ft., rainfall 80".	*Pygeum acuminatum.* *P. mooneyi.*
7. Mahendragiri Hill in South Orissa.	4,019 ft.	*Pygeum andersoni.* *P. acuminatum.*

The Rosaceae are generally inhabitants of North temperate zone and occur in the Himalayas. Their presence in the hills of the Peninsula India indicates the south-ward migration of the Himalayan species during the recent past.

5. **Sholas of the Nilgiris:** The temperate forests of the Nilgiris have affinities with the flora of the Naga hills, Manipur, Khasya and Eastern Himalayas. The following species are common to the Eastern Himalayas: *Hypericum hookerianum, Ternstroemia japonica, Hypericum nepalense, Eurya japonica, Rhamnus dahuricus, Photinia notoniana, Rubus ellipticus, R. lasiocarpus, Carallia brachiata, Rhododendron arboreum, Gaultheria fragrantissima* and *Gardneria ovata,* together with a species of *Kadsura, Berberis, Pittosporum, Elaeocarpus, Euonymus, Meliosma,* etc.

The species of *Thalictrum, Ranunculus, Cardamine, Geranium, Alchemilla, Fragaria, Scutellaria, Potentilla, Parnassia, Lysimachia, Swertia, Gentiana* and many Cyperaceae and grasses are common in the ground flora.

6. **Malabar:** The Malabar flora has a number of Malayan plants belonging to the families Guttifereae, Dipterocarpaceae, Myristicaceae, and many palms and bamboos. In families Sterculiaceae, Tiliaceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae, etc. many Malayan types occur in the Malabar. *Podocarpus altifolia* occurs in the Burma, Malaya and Tinnevelly hills. The flora of Travancore has affinities with Ceylon and Malaya. The Burmese genera such as *Dipterocarpus, Grewia, Dioscoria* and *Gaultheria* are found in this region.

Narayanaswami and Rao (1950) gave an account of the Indo-Burmese species of *Grewia* Linn., and state that "The genus *Grewia* is confined to the tropical and subtropical regions of the Old World only. The original home of *Grewia* appears to be Equatorial Africa from where the line of distributions has proceeded in an easterly direction as far as the Polynesian Islands, through India, Burma, Siam, Indo-China and Malaya."

Biswas (1949) stated that "a retrospect of the main vegetational features of the mountain ranges of Peninsular India shows that the flora is closely akin to that of Sikkim, Bhutan, Assam and Burma."

Geographical distribution of Abor land flora: Burkill (1924) has studied the vegetation of Abor hills, in the valley of Dihang and Brahmputra rivers. The vegetation of this area is interesting in that there are no pines in Abor land, however, *Pinus excelsa, P. longifolia, P. khasya, P. merkusii,* approach the area. There are several species of *Quercus* and *Castanopsis,* also of *Betula* and *Engelhardtia.*

The temperate forest in the Abor land stretches between an altitude of 3,000 and 4,000 feet. *Michelia punduana* forms a considerable part of the forest on the south face of Bapu. Here tree ferns are fewer. The dominant genera are *Quercus* and *Castanopsis.*

The Abor land vegetation has a very interesting distribution.

In table 10, Burkill gives the number of species from the Abor land flora that are common with the various neighbouring regions.

Table 10.

SPECIES OF ABOR LAND FLORA COMMON WITH NEIGHBOURING REGIONS.

(From Burkill, 1924).

	Species.
Abor Land and The Sikkim Himalaya.	635
,, ,, ,, The Khasia and Jaintea Hills.	631
,, ,, ,, Northern Burma.	540
,, ,, ,, The Naga Hills.	386
,, ,, ,, The Shan Hills to Doi Sutep which is in Northern Siam.	340
,, ,, ,, The N. W. Himalaya south of 32° N. ...	311
,, ,, ,, Lower Burma.	307
,, ,, ,, The centre of Nepal.	308
,, ,, ,, Java.	298
,, ,, ,, Tenasserim.	283
,, ,, ,, S.E. China.	272
,, ,, ,, Manipur.	268
,, ,, ,, Eastern Malaysia.	261
,, ,, ,, S. W. China.	257
,, ,, ,, The east of the peninsula of the Deccan. ...	253
,, ,, ,, Malabaria.	252
,, ,, ,, The north of the Malay peninsula.	247
,, ,, ,, The hills of N. Cachar.	238
,, ,, ,, Bhutan.	235
,, ,, ,, The Lushai Hills and Chittagong.	231
,, ,, ,, Ceylon.	220
,, ,, ,, Borneo.	190
,, ,, ,, The Dephla Hills.	176
,, ,, ,, N. W. Himalaya north of 32° N.	159
,, ,, ,, The east of the Malay Peninsula.	154

Table 10. (Contd.)

	Species.
Abor Land and The south of the Malay Peninsula.	154
,, ,, ,, The Mishmi Hills.	126
,, ,, ,, The north of the Deccan Peninsula.	109
,, ,, ,, Australia.	108
,, ,, ,, Tropical Africa.	103
,, ,, ,, Japan.	84
,, ,, ,, The Pacific Islands.	83
,, ,, ,, The Mascarene Islands.	80
,, ,, ,, The Garo Hills.	61
,, ,, ,, The American continents.	52
,, ,, ,, Europe and the mediterranean.	30
,, ,, ,, The Aka Hills.	22

These regions are grouped as belonging to east, west, south-east and south west directions. The gradual disappearance of Abor flora in the western Himalayas is due to the gradual drier conditions westwards. The number of Abor land plants which extends westwards to the Mediterranean region is only 30.

The Abor land species have strong Chinese affinities. In the Abor land flora 257 species were recorded from south-western China, 272 from South-eastern China and 5 from Japan. It was considered by Burkill that reason for the absence of the remaining species is due to our imperfect knowledge of the flora of this region.

The Abor land flora has many species common with Khasya hills, Naga hills, Garo hills, Manipur, Lushai hills, Chittagong and Sikkim Himalayas. The Malayan peninsula from Java to New Guinea has 366 species of Abor land plants, 108 species occur in Australia and 83 in Pacific Islands. The following species of Abor land finding the limit in the north of the Malayan Peninsula occur in Java: *Smilax odoratissima, Ophiorrhiza mungos, Engelhardtia spicata, Piper attenuatum, Cleidion javanicum, Calamintha gravilis, Blumea densiflora, Ecdysanthera micrantha, Marsdenia tinctoria, Paraphlomis rugosa, Laportea crenulata, Pratia nummularia, Pothos scandens, Spilanthes acmella, Gynostemma pedatum, Styrax serrulatum, Scleria elata, Clematis gauriana, Maesa indica, Blumea glomerata, Buddleia asiatica, Polygonum chinense, Atylosia scarabaeoides, Lophotocarpus guianensis, Trichosanthes palmata, Artemisia vulgaris, Zizyphus jujuba, Smithia sensitiva, Boehmeria platyphylla, Cassia tora, Deeringia amaranthoides, Cudrania javanica, Amaranthus gangeticus, Dichrocephala latifolia* and *Pycreus globosus.*

Of the Abor land species that occur in Deccan, 21 are recorded from the hills of Chota Nagpur, 22 from Ceylon and 24 from Malabar, 10 in the northern part of the Deccan. The species which reach Chota Nagpur region through the Bengal plains are the following:- *Curcuma amada, Amomum dealbatum, Natsiatum herpeticum, Amorphophallus bulbifera, Randia fasciculata, Gouania leptostachya, Callicarpa arborea, Albizzia procera, Plectranthus ternifolius, Dioscorea glabra, Heteropanax fragrans, Blumea laciniata, Belamcanda chinensis* and *Dopatrium junceum* - mostly herbs.

The species which occur in Malabar or/and Ceylon but do not occur in the hills of Chota Nagpur are given below: *Alpinia allughas, Typhonium trilobatum, Mallotus albus, Mesua ferrea, Geodorum purpureum, Solanum ferox, Pothos scandens, Polygonum runcinatum, Scleria elata, Ficus heterophylla, Ilysanthes ciliata, Cyathula prostrata, Centotheca lappacea, Paspalum conjugatum, Sonchus arvensis, Cyperus diffusus* and *Hydrocotyle rotundifolia* - mostly herbs.

Table 11.

THE DISTRIBUTION OF MALAYAN GENERA FROM THE ABORLAND FLORA.
(After Burkill, 1924).

Genus.	Nature.	Reach N. W. Himalaya from N.E. India.	Reach N. W. Himalaya from beyond N.E. India.	Endemic in N.W. Him.	Reach S. India from beyond N.E. India.	Reach S. India from beyond N.E. India.	Endemic in S. India.	Reach N. or S.E. China from N.E. India.	Reach N. or S.E. China from elsewhere.	Endemic in China.	Total Himalaya.	Endemic therein.
Dendrobium	epiphytes.	3	3	1	2	1	15	3	1	5	37	8
Eria.	epiphytes.	1	1	...	1	...	16	...	1	8	27	6
Litsea.	trees.	3	2	...	...	3	18	...	6	16	20	3
Aglaia.	trees.	...	...	...	...	2	1	...	1	...	...	...
Hoya.	epiphytes.	2	...	...	...	...	5	...	1	1	10	6
Coelogyne.	epiphytes.	3	2	...	...	...	5	1	...	2	20	4
Aeschynanthus.	epiphytes.	...	...	1	...	...	2	1	...	1	9	4
Sarcochilus.	epiphytes.	...	...	...	...	...	5	...	...	2	3	1
Globba.	shade herbs.	...	...	1	1	1	1	...	...	...	8	2
Fagraea.	trees, shrubs & some epiphytes.	...	...	...	...	1	1	...	...	...	1	...
Pinanga.	shade palms.	...	...	...	...	...	1	...	...	...	1	...
Artocarpus.	trees.	...	1	...	...	...	3	...	1	1	1	...
Dipterocarpus.	tall trees.	...	...	...	...	...	5	...	...	...	1	...
Rhapidophora.	epiphytes.	1	...	...	...	1	...	...	1	...	5	...
Sarcanthus.	epiphytes.	...	...	...	...	1	1	...	...	8	4	2
Helicia.	tall trees.	...	...	...	...	...	3	...	2	1	1	...
Ceratostylis.	epiphytes.	...	...	...	...	...	...	...	...	...	1	...
Xanthophyllum.	trees.	...	...	...	...	...	...	...	...	...	1	1
Vatica.	trees.	...	...	...	...	...	4	...	...	...	1	...
Dillenia.	trees.	...	...	...	...	2	2	...	...	...	3	...

Alocasia.	shade herbs.	...	1	...	...	3	...	...	2	1	3	...
Chisocheton.	trees & shrubs.	...	...	...	...	...	...	...	...	...	1	...
Neonauclea.	trees & shrubs.	...	...	...	...	...	3	...	...	...	1	...
Vanda.	epiphytes.	2	1	...	...	1	2	...	...	2	4	2
Amoora.	trees.	...	...	...	...	1	3	...	1	...	2	...
Phalaenopsis.	epiphytes.	...	...	...	...	...	...	...	1	...	1	...
Aglaonema.	shade herbs.	...	...	...	...	...	...	...	...	...	1	...
Conocephalus.	climbers.	...	...	...	...	...	...	...	...	...	1	...
Gomphandra.	trees.	...	...	...	1	...	1	...	...	...	1	...
Glycosmis.	shrubs.	...	1	...	...	1	1	...	1	...	3	1
Lepisanthes.	trees & shrubs.	...	...	...	...	...	...	...	...	...	1	...
Caryota.	forest palms.	...	...	...	...	1	...	...	1	1	2	1
Arenga.	forest palms.	...	...	...	...	...	1	...	1	1	1	...
Schima.	forest trees.	...	...	...	...	...	...	...	1	1	1	...
Sadiria.	shrubs.	...	...	...	...	...	...	...	...	...	2	2
Pyrenaria.	small trees.	...	...	...	...	...	...	...	...	...	1	...
Myrioneuron.	small shrubs.	...	...	...	...	...	...	...	...	...	1	...
Dinochloa.	big bamboos.	...	...	...	...	...	...	...	...	...	1	...
Stauranthera.	shade herbs.	...	...	...	...	...	...	...	...	...	1	...
Tinomiscium.	climbers.	...	...	...	...	...	...	...	...	...	1	...
Anadendrum.	epiphytes.	...	...	...	...	...	...	...	...	...	1	...
Dichroa.	shrubs.	...	...	...	...	...	...	...	1	...	1	...
Macropanax.	small trees.	...	...	...	...	...	...	...	...	...	2	...
Abroma.	trees & shrubs.	...	1	...	...	...	...	...	1	...	1	...
Hodgsonia.	climbers.	...	...	...	...	...	...	...	...	...	1	...
TOTAL		15	13	3	5	19	99	5	24	51	191	43
			31			123			80			
			Endemism 10 per cent.			Endemism 80 per cent			Endemism 64 per cent.			

The distribution of Malayan or rain forest genera from Abor land flora in different parts of India is given in table 11 on pp. 38—39.

Phyto-geographical patterns of some important Indian trees: The following main phyto-geographical types may be recognised in Indian forest trees:—

(1) Forest trees that are distributed more or less uniformly throughout India. This class is shown in figs. 3, 4, 5, 6, 7, 8 on pp. 42, 43—44.

Terminalia tomentosa and *Terminalia arjuna* are distributed in the southern region and various species of *Diospyros, Albizzia, Acacia, Gmelina arborea, Adina cordifolia, Eugenia jombolana,* etc. have this general pattern of distribution. In the geographical patterns given in these figures, the absence of the various species of this group from the desert areas is well marked.

(2) Forest trees that are distributed discontinuously over large parts of India. *Lannea grandis, Tectona grandis, Ougeinia dalbergioides, Bombax malabaricum, Careya arborea, Anogeissus latifolia,* and *Hymenodictyon excelsum* may be mentioned as belonging to this category of forest trees and their distribution is shown in figs. 9, 10, 11 & 12 on pp. 45—46.

(3) Forest trees that show discontinuous distribution in Western Ghats and Eastern Ghats and Assam and Burma. Of this type *Mesua ferrea, Xylia xylocarpa, Michelia champaca, Lagerstroemia flos-reginae* may be mentioned. Their distribution is shown in figs. 13, 14, 15, & 16 on pp. 47–48.

(4) Forest trees that have discontinuous distribution in the Deccan. *Hardwickia binata* and *H. pinnata, Hopea parviflora, H. wightiana* and *H. odorata* may be mentioned. Their distribution is in figs. 17 & 18 on pp. 49.

(5) Forest trees in the eastern parts of India with a discontinuous distribution. Of this category *Podocarpus nerifolia, Homalium tomentosum* may be mentioned figs. 19 & 20 on p. 50 *Terminalia bialata* and *T. manii* are distributed in the mainland and the Andamans and Nicobar Islands and their distribution is shown in fig. 21 on p. 51. *Terminalia paniculata* has a different distribution pattern than the other *Terminalias* (See fig. 22 on p. 51).

(6) Forest trees that show discontinuous distribution in Burma, Assam, Andamans, Eastern Ghats, Ceylon and Western Ghats. Species of *Chickrassia tabularis, Calophyllum, Artocarpus, Dipterocarpus,* etc. belong to this category. Their distribution is shown in figs. 23, 24, 25 & 26 on pp. 52–53.

(7) Forest trees that show discontinuous distribution in Western Ghats, Eastern Ghats, Ceylon, East India, Central India and parts of western Himalayas. To this category belong *Carallia integerrima,* and *Grewia tiliaefolia, Dillenia pentagyna, Cedrela toona,* and their distribution is shown in figs. 27–30 on pp. 54—55.

(8) Forest trees that are distributed mainly in the Himalayas and extend to the Eastern Himalayas with a continuous or some-what discontinuous distribution. Belonging to this category are *Betula alnoides and Ulmus Wallichiana. Acre campbellii, Acer oblongum, Bischofia javanica Engelhardtia spicata, Juglans regia,* is another species which may form a category of its own, distributed both in Assam, Burma, western Himalayas and the western Ghats. The distribution of these types is shown in figs. 31–34 on pp. 56—57.

(9) Forest trees that are distributed in the Western Himalayas, extending continuously or discontinuously to Eastern Himalayas. The various conifers and *Dalbergia sissoo* belong to this category of forest trees. Their distribution is shown in figs. 35–38 on pp. 58—59.

(10) There are another set of forest trees that are more widely distributed in the whole of the Country. Species of *Diospyros, Acacia, Bombax* and *Boswellia, Albizzia* are shown in figs. 39–42 on pp. 60—61. Excepting *Acacia* spp. they seem to avoid western desert regions.

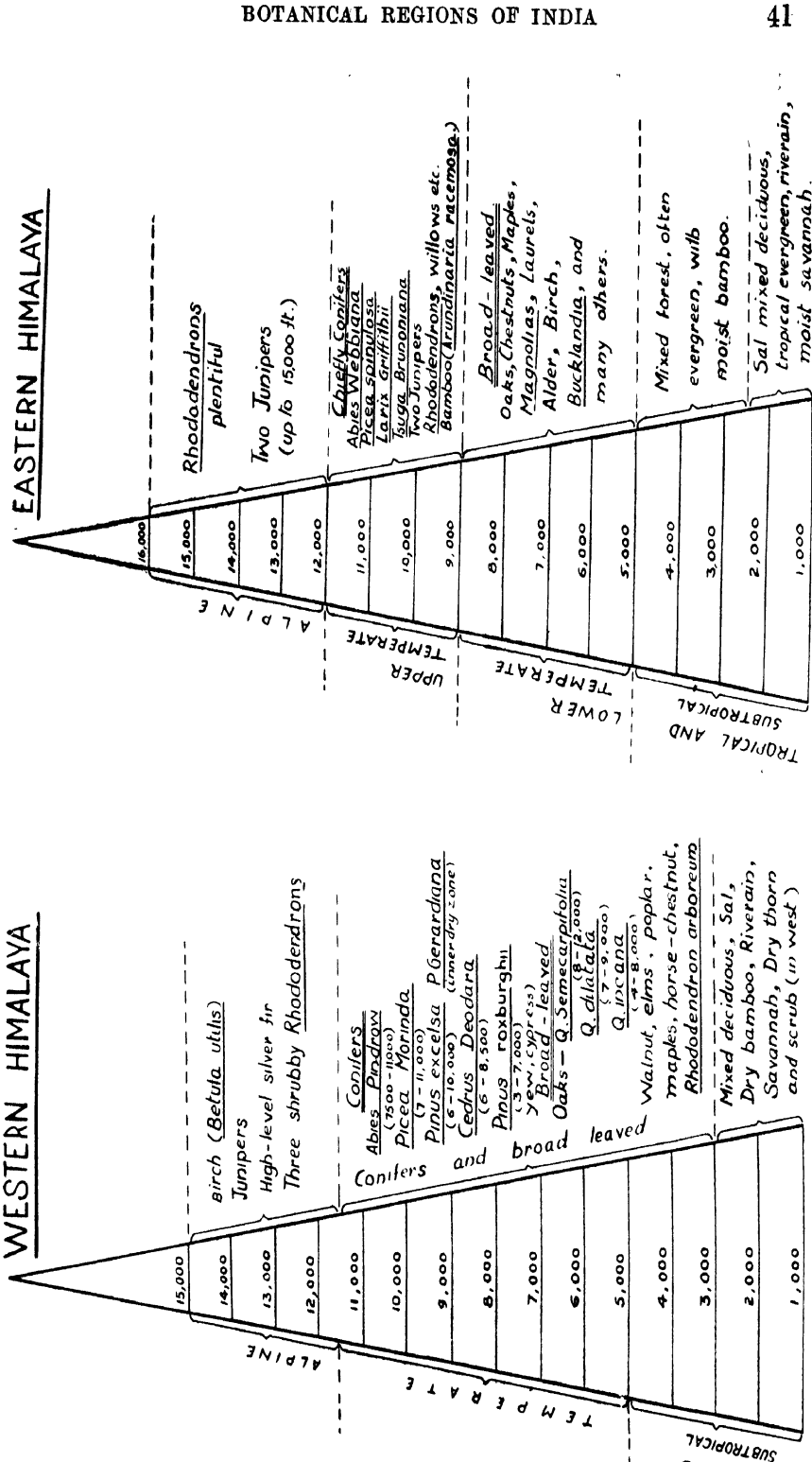


Fig. 2. Vegetation zones in the Western and Eastern Himalayas (diagrammatic)

MAP
SHOWING DISTRIBUTION
OF
TERMINALIA TOMENTOSA
(COLOURED RED)
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 4

MAP
SHOWING DISTRIBUTION
OF
TERMINALIA ARJUNA
(COLOURED RED)
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 3

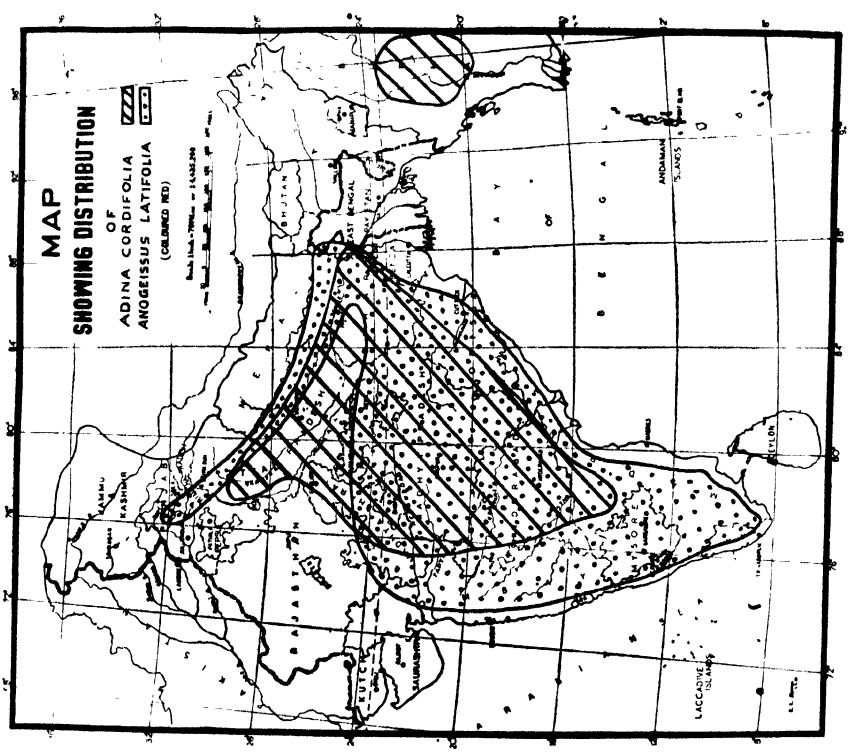

MAP
SHOWING DISTRIBUTION
OF
ADINA CORDIFOLIA
ANOGEISSUS LATIFOLIA
(COLOURED RED)
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 6

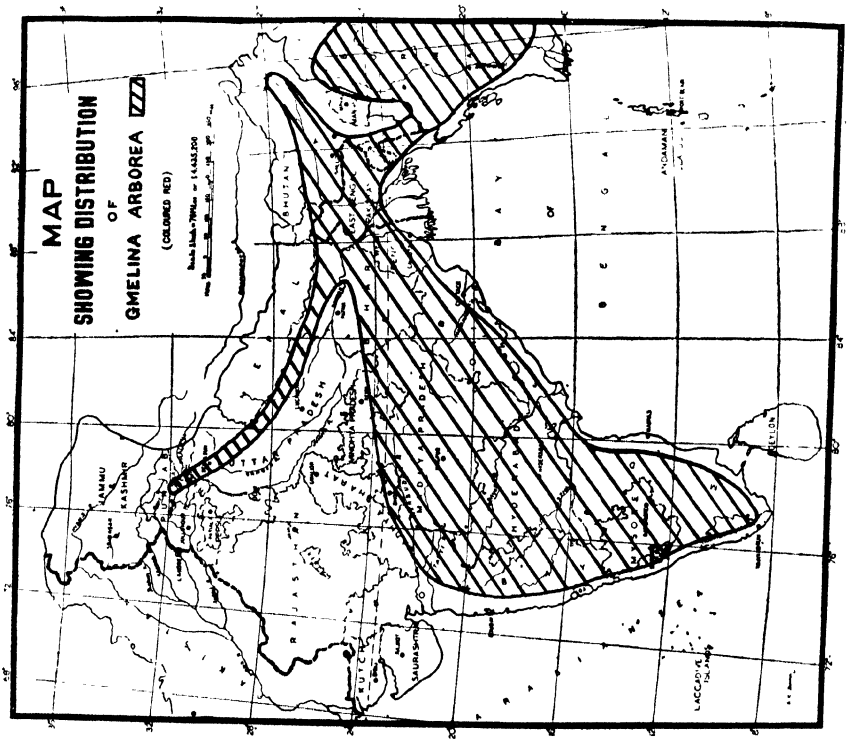

MAP
SHOWING DISTRIBUTION
OF
GMELINA ARBOREA
(COLOURED RED)
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 5

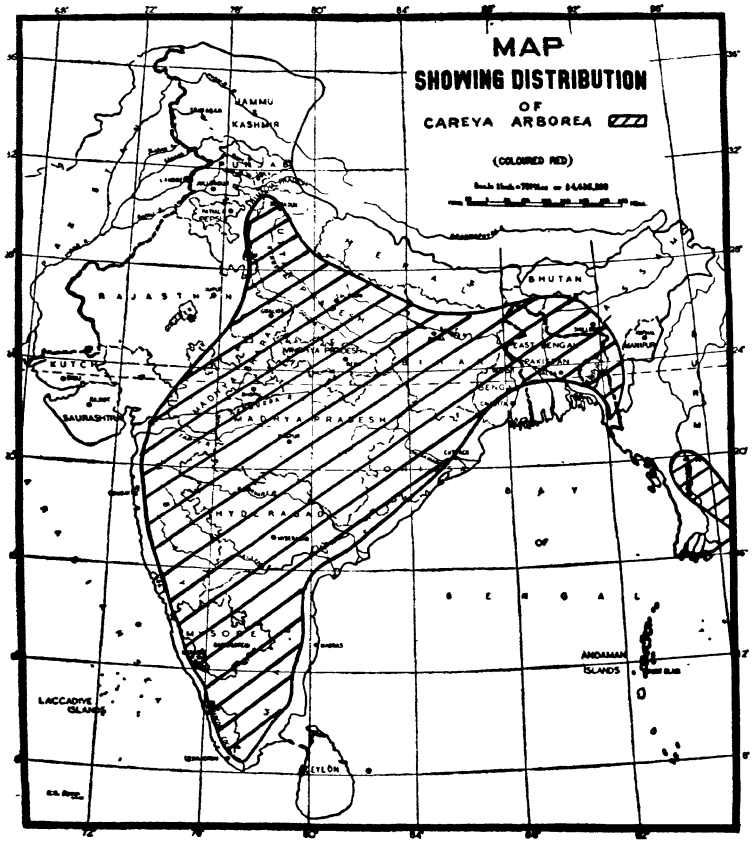

MAP
SHOWING DISTRIBUTION
OF
CAREYA ARBOREA
(COLOURED RED)
JAMMU & KASHMIR
BHUTAN
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
MYSORE
EAST BENGAL
BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 7

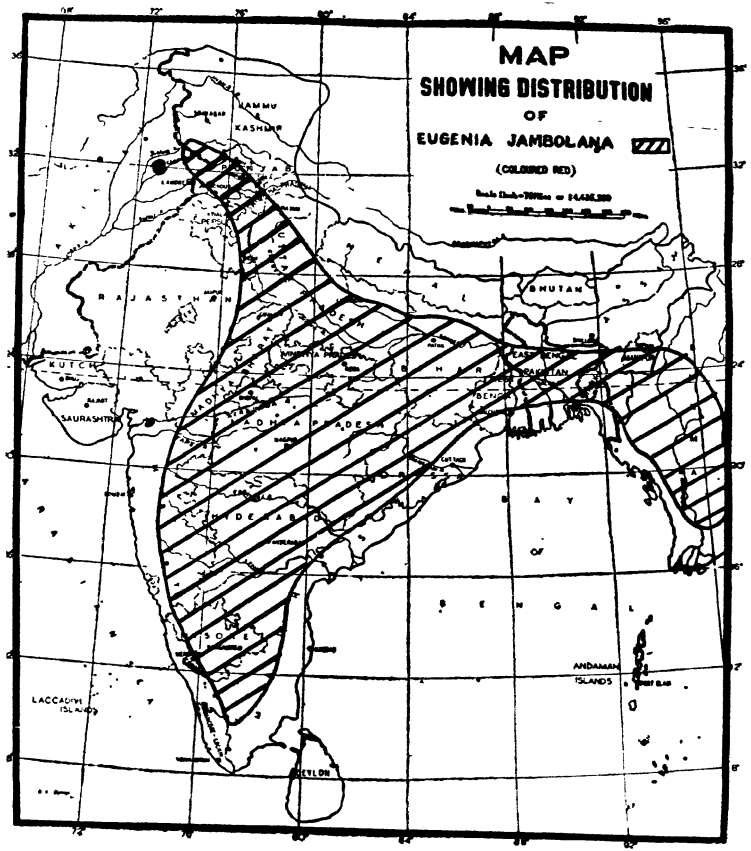

MAP
SHOWING DISTRIBUTION
OF
EUGENIA JAMBOLANA
(COLOURED RED)
JAMMU & KASHMIR
BHUTAN
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
MYSORE
EAST BENGAL
BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 8

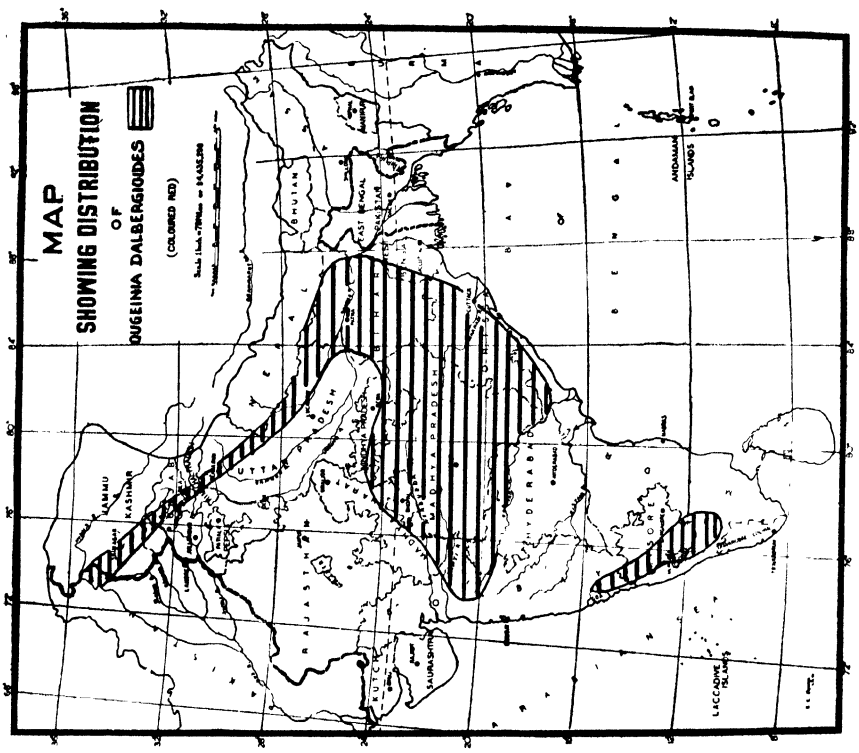

MAP
SHOWING DISTRIBUTION
OF
DUGEINIA DALBERGIOIDES
(COLOURED RED)
JAMMU
KASHMIR
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 10

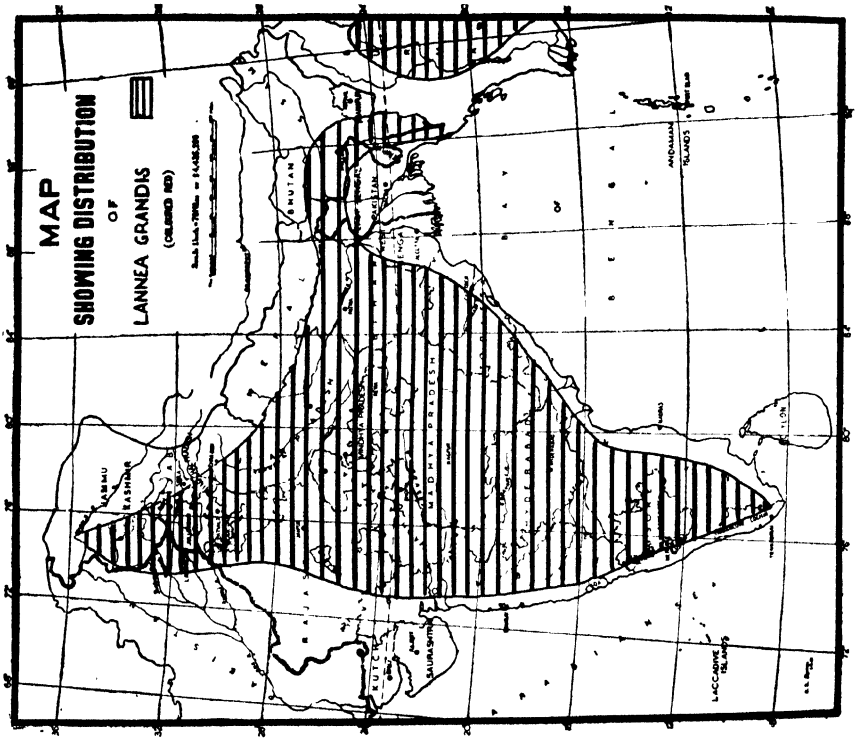

MAP
SHOWING DISTRIBUTION
OF
LANNEA GRANDIS
(COLORED RED)
JAMMU
KASHMIR
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 9

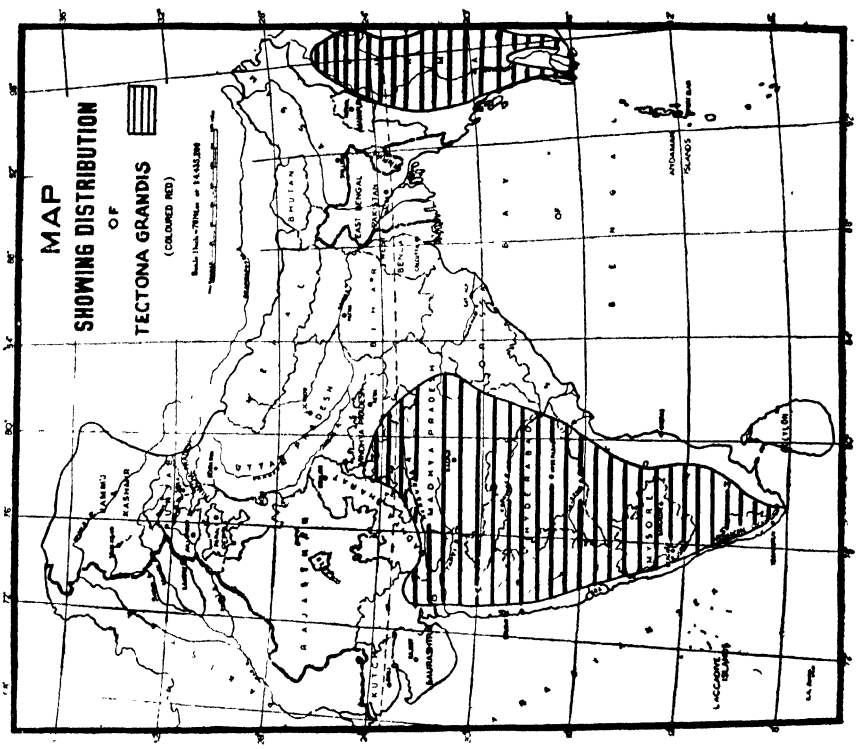

MAP
SHOWING DISTRIBUTION
OF
TECTONA GRANDIS
(COLOURED RED)
BHUTAN
EAST BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 12

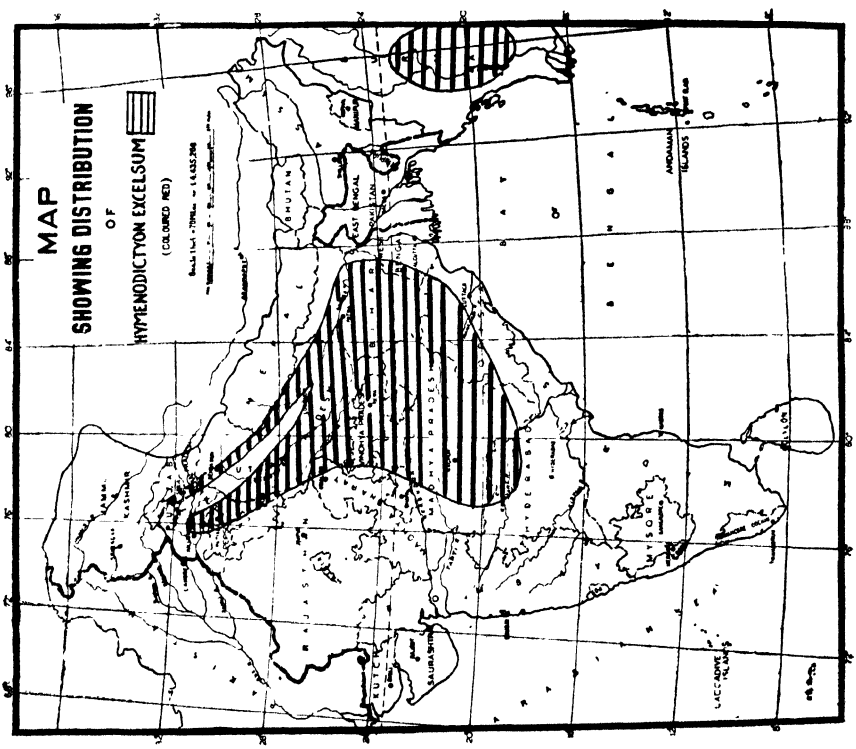

MAP
SHOWING DISTRIBUTION
OF
HYMENODICTYON EXCELSUM
(COLOURED RED)
BHUTAN
EAST BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 11

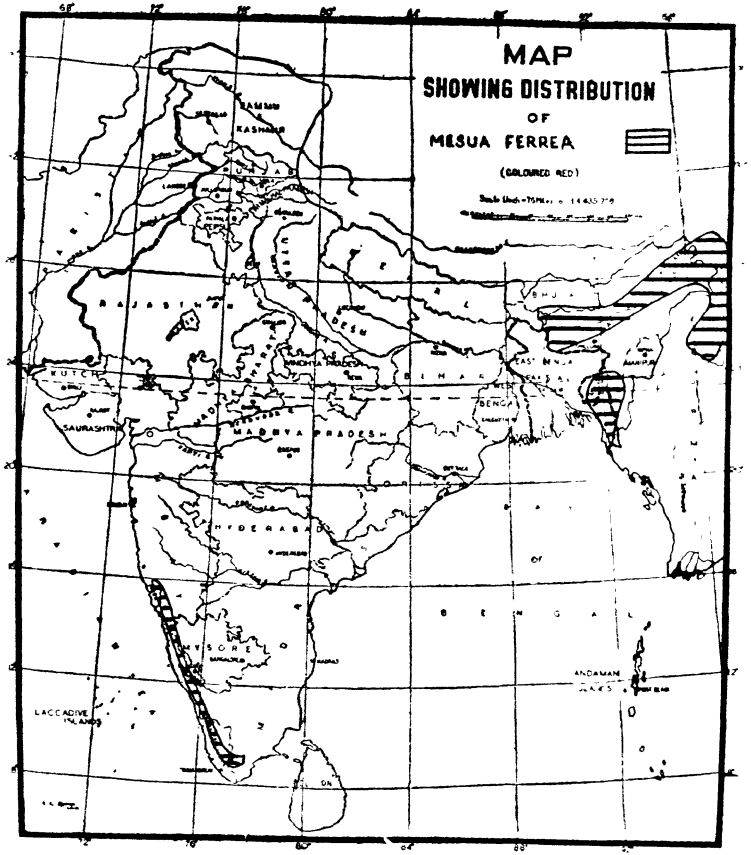

MAP
SHOWING DISTRIBUTION
OF
MESUA FERREA
(COLOURED RED)
KASHMIR
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
BIHAR
BENGAL
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 13

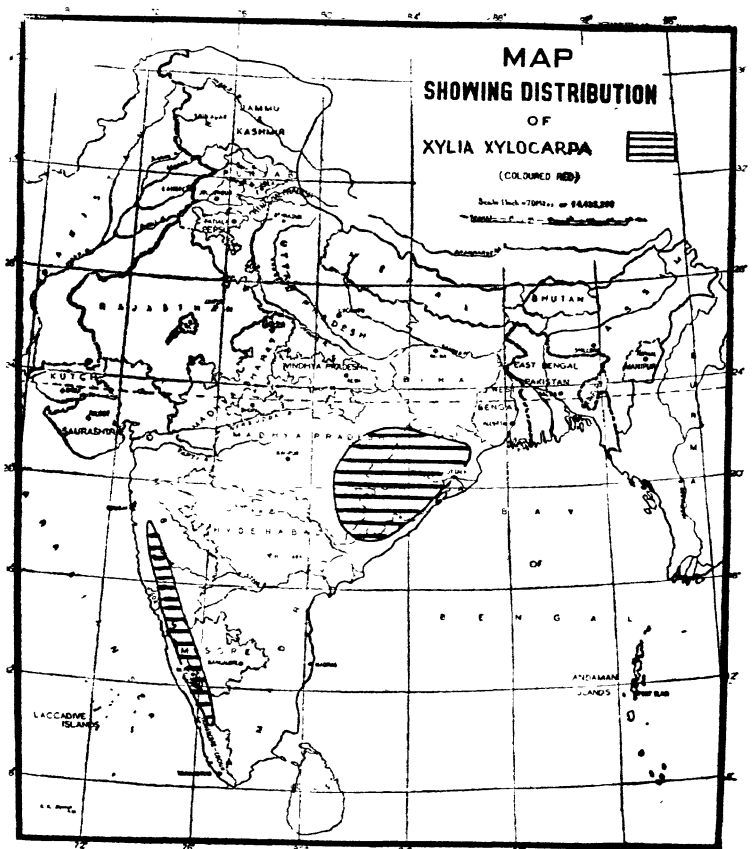

MAP
SHOWING DISTRIBUTION
OF
XYLIA XYLOCARPA
(COLOURED RED)
KASHMIR
BHUTAN
EAST BENGAL
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
BIHAR
BENGAL
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 14

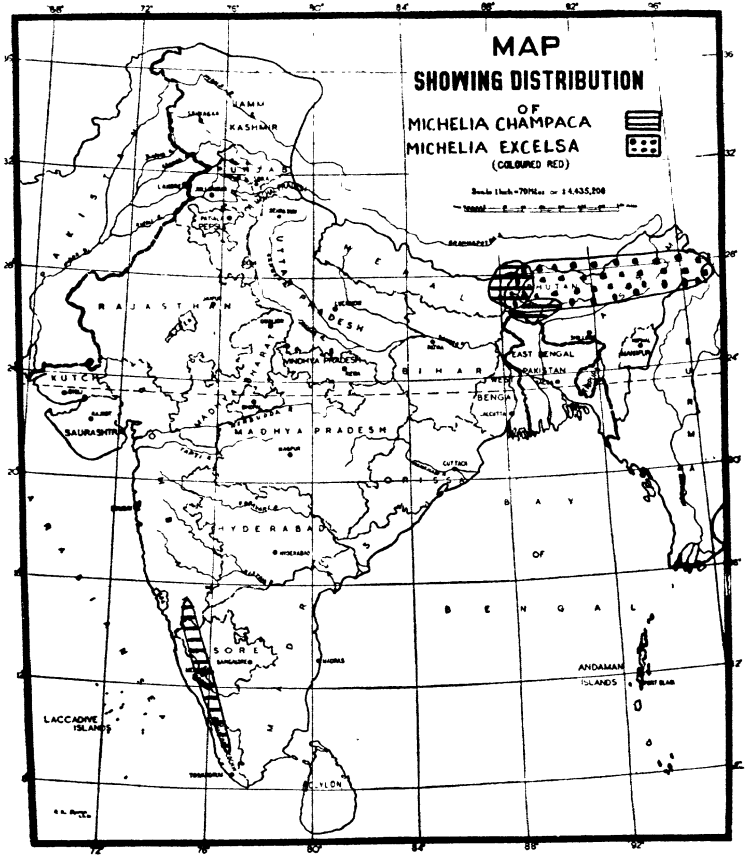

MAP
SHOWING DISTRIBUTION
OF
MICHELIA CHAMPACA
MICHELIA EXCELSA
(COLOURED RED)
JAMMU & KASHMIR
RAJASTHAN
UTTAR PRADESH
HIMACHAL PRADESH
PUNJAB
HARYANA
DELHI
NEPAL
BHUTAN
EAST BENGAL
PAKISTAN
BIHAR
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig 15

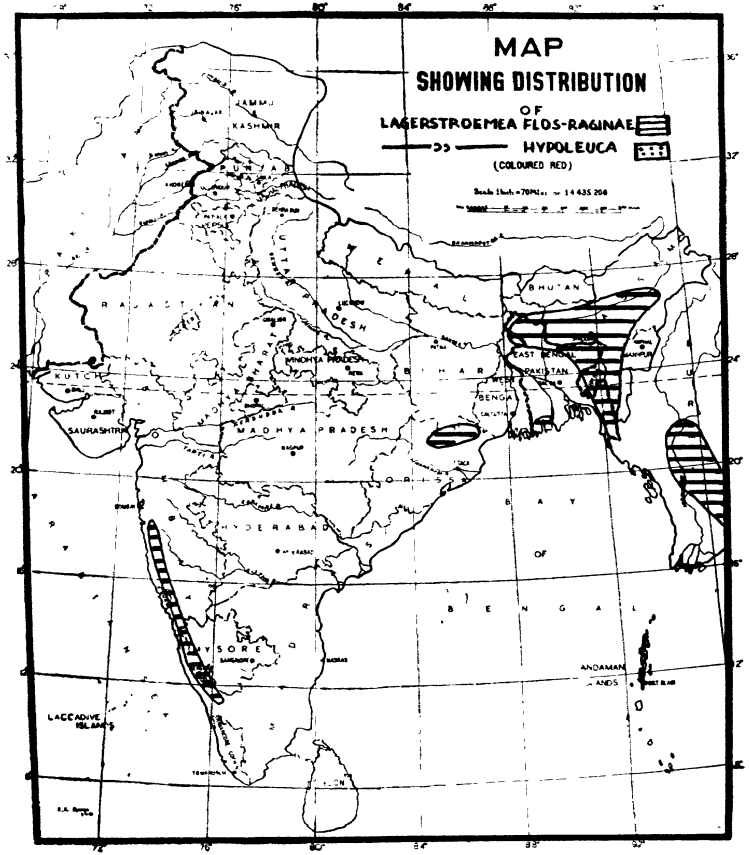

MAP
SHOWING DISTRIBUTION
OF
LAGERSTROEMEA FLOS-RAGINAE
HYPOLEUCA
(COLOURED RED)
JAMMU & KASHMIR
RAJASTHAN
UTTAR PRADESH
HIMACHAL PRADESH
PUNJAB
HARYANA
DELHI
NEPAL
BHUTAN
EAST BENGAL
PAKISTAN
BIHAR
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 16

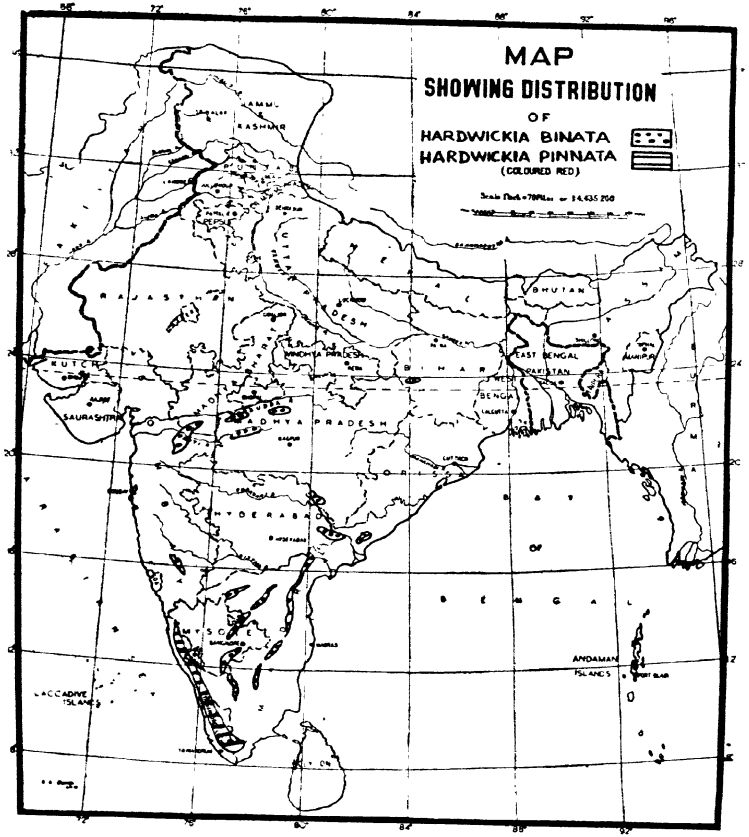

MAP
SHOWING DISTRIBUTION
OF
HARDWICKIA BINATA
HARDWICKIA PINNATA
(COLOURED RED)
KASHMIR
RAJASTHAN
BHUTAN
EAST BENGAL
PAKISTAN
MADHYA PRADESH
SAURASHTRA
KUTCH
MYSORE
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 17

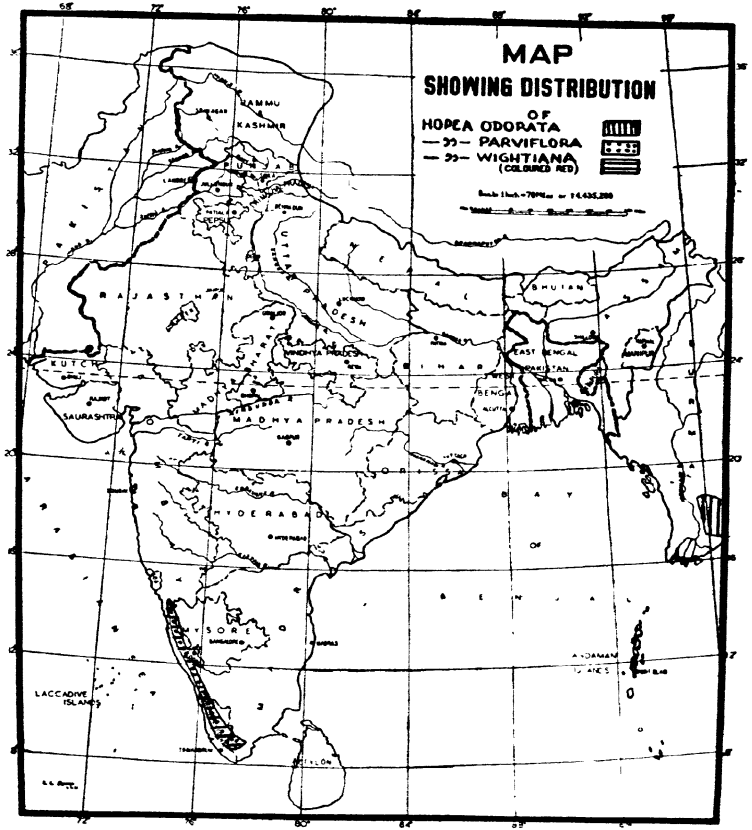

MAP
SHOWING DISTRIBUTION
OF
HOPEA ODORATA
— 〃 — PARVIFLORA
— 〃 — WIGHTIANA
(COLOURED RED)
KASHMIR
RAJASTHAN
BHUTAN
EAST BENGAL
PAKISTAN
MADHYA PRADESH
SAURASHTRA
KUTCH
MYSORE
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 18

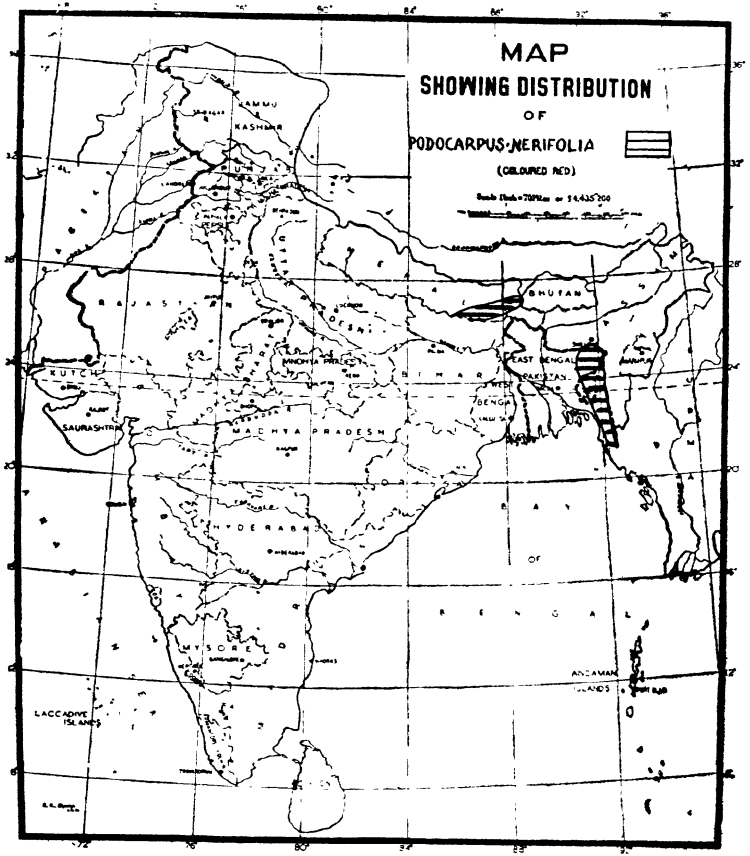

MAP
SHOWING DISTRIBUTION
OF
PODOCARPUS NERIFOLIA
(COLOURED RED)
JAMMU & KASHMIR
BHUTAN
EAST BENGAL
MADHYA PRADESH
SAURASHTRA
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 19

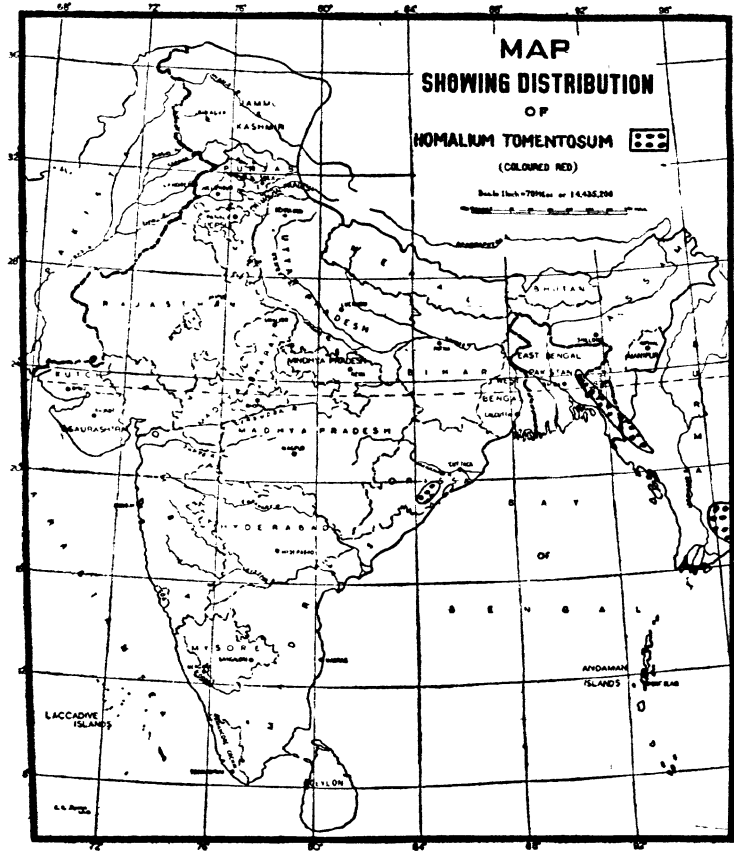

MAP
SHOWING DISTRIBUTION
OF
HOMALIUM TOMENTOSUM
(COLOURED RED)
JAMMU & KASHMIR
BHUTAN
EAST BENGAL
MADHYA PRADESH
SAURASHTRA
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 20

MAP
SHOWING DISTRIBUTION
OF
TERMINALIA BIALATA
TERMINALIA MANII
(COLOURED RED)
BAY OF BENGAL
ANDAMAN ISLANDS
BHUTAN
NEPAL
BIHAR
MADHYA PRADESH
RAJASTHAN
MYSORE
HYDERABAD
KUTCH
SAURASHTRA
LACCADIVE ISLANDS
CEYLON

Fig. 21

MAP
SHOWING DISTRIBUTION
OF
TERMINALIA PANICULATA
(COLOURED RED)
BAY OF BENGAL
ANDAMAN ISLANDS
BHUTAN
NEPAL
BIHAR
MADHYA PRADESH
RAJASTHAN
MYSORE
HYDERABAD
KUTCH
SAURASHTRA
LACCADIVE ISLANDS
CEYLON

Fig. 22


MAP
SHOWING DISTRIBUTION
OF
CHICKRASSIA TABULARIS
CHLOROXYLON SWIETENIA
(COLOURED RED)
KASHMIR
BHUTAN
RAJASTHAN
MADHYA PRADESH
BIHAR
EAST BENGAL
PAKISTAN
KUTCH
SAURASHTRA
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 23

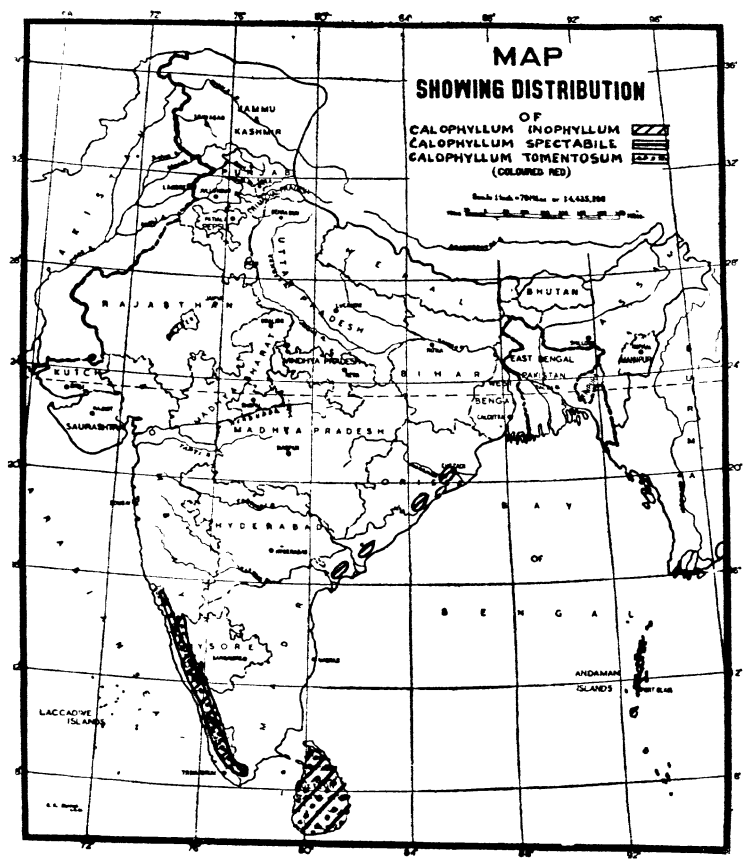

MAP
SHOWING DISTRIBUTION
OF
CALOPHYLLUM INOPHYLLUM
CALOPHYLLUM SPECTABILE
CALOPHYLLUM TOMENTOSUM
(COLOURED RED)
KASHMIR
BHUTAN
RAJASTHAN
MADHYA PRADESH
BIHAR
EAST BENGAL
PAKISTAN
KUTCH
SAURASHTRA
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 24

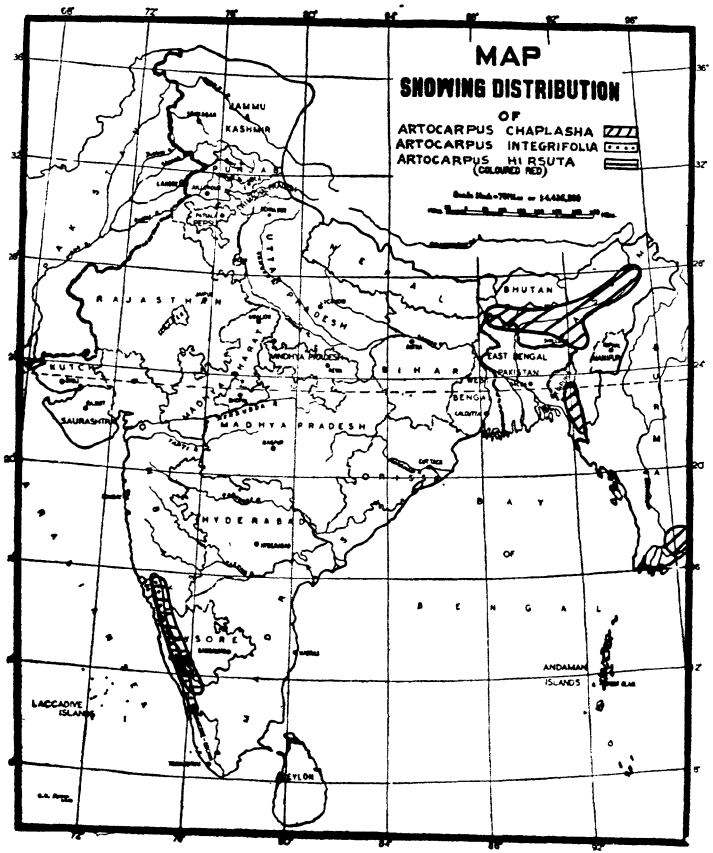

MAP
SHOWING DISTRIBUTION
OF
ARTOCARPUS CHAPLASHA
ARTOCARPUS INTEGRIFOLIA
ARTOCARPUS HIRSUTA
(COLOURED RED)
JAMMU & KASHMIR
PUNJAB
RAJASTHAN
UTTAR PRADESH
BHUTAN
EAST BENGAL
BIHAR
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 25

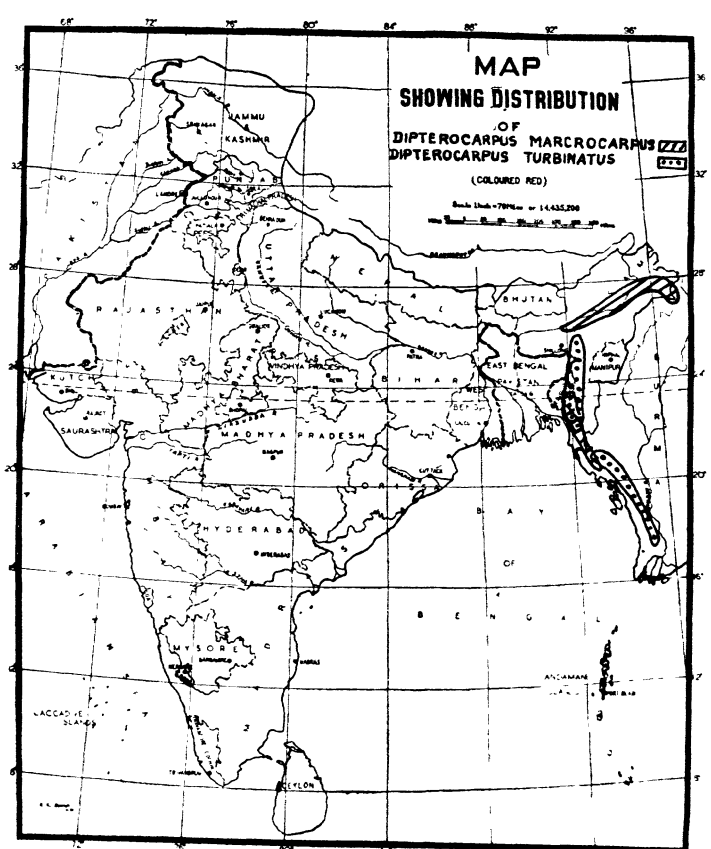

MAP
SHOWING DISTRIBUTION
OF
DIPTEROCARPUS MACROCARPUS
DIPTEROCARPUS TURBINATUS
(COLOURED RED)
JAMMU & KASHMIR
PUNJAB
RAJASTHAN
UTTAR PRADESH
BHUTAN
EAST BENGAL
BIHAR
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 26

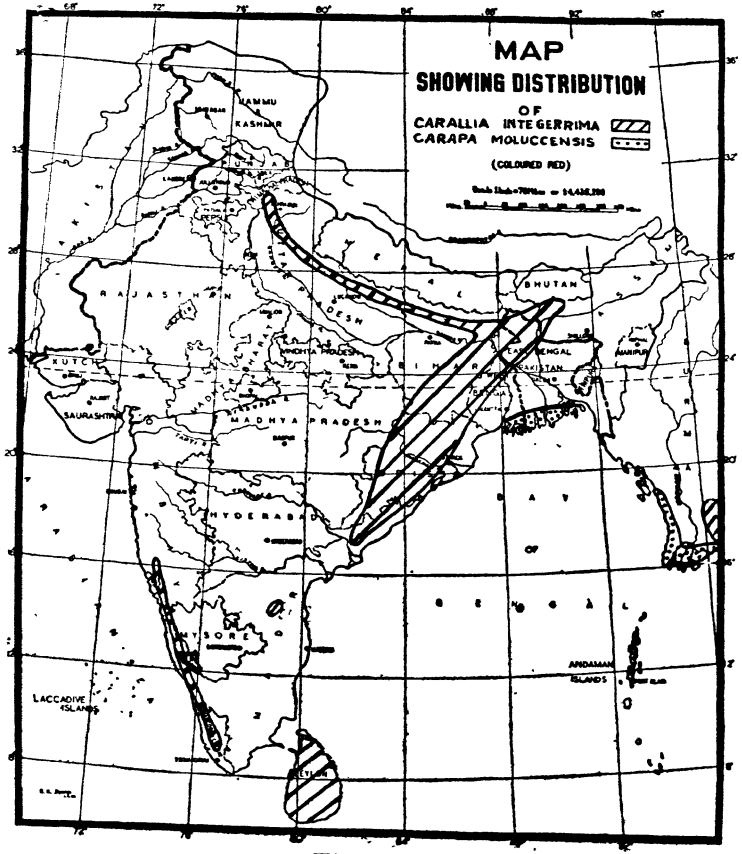

MAP
SHOWING DISTRIBUTION
OF
CARALLIA INTEGERRIMA
CARAPA MOLUCCENSIS
(COLOURED RED)
JAMMU
KASHMIR
RAJASTHAN
BHUTAN
EAST BENGAL
PAKISTAN
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
B A Y
O F
B E N G A L
ANDAMAN
ISLANDS
LACCADIVE
ISLANDS
CEYLON

Fig. 27

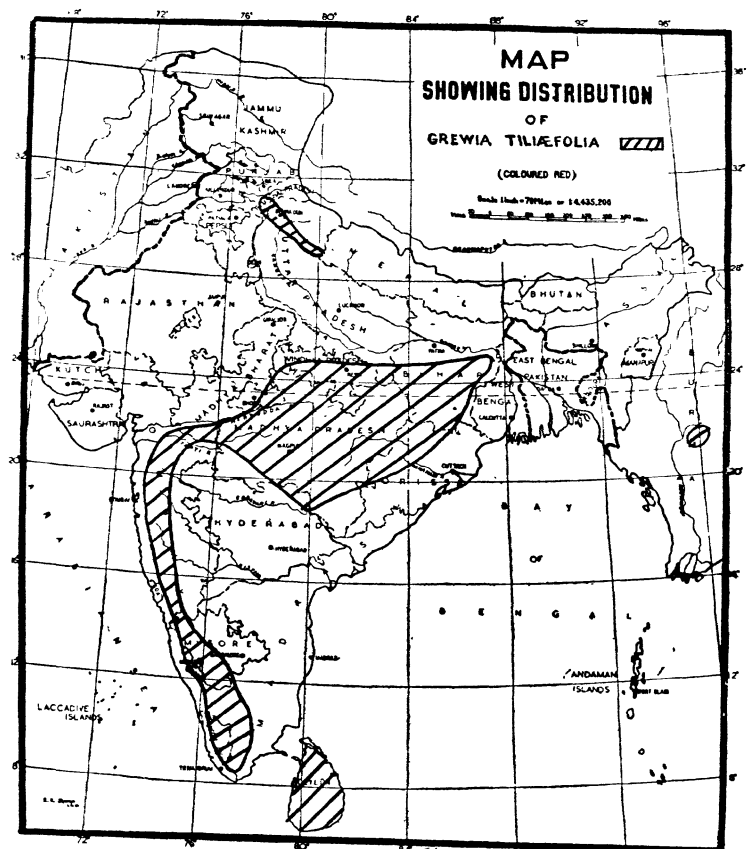

MAP
SHOWING DISTRIBUTION
OF
GREWIA TILIÆFOLIA
(COLOURED RED)
JAMMU
KASHMIR
RAJASTHAN
BHUTAN
EAST BENGAL
PAKISTAN
KUTCH
SAURASHTRA
MADHYA PRADESH
HYDERABAD
B A Y
O F
B E N G A L
ANDAMAN
ISLANDS
LACCADIVE
ISLANDS
CEYLON

Fig. 28

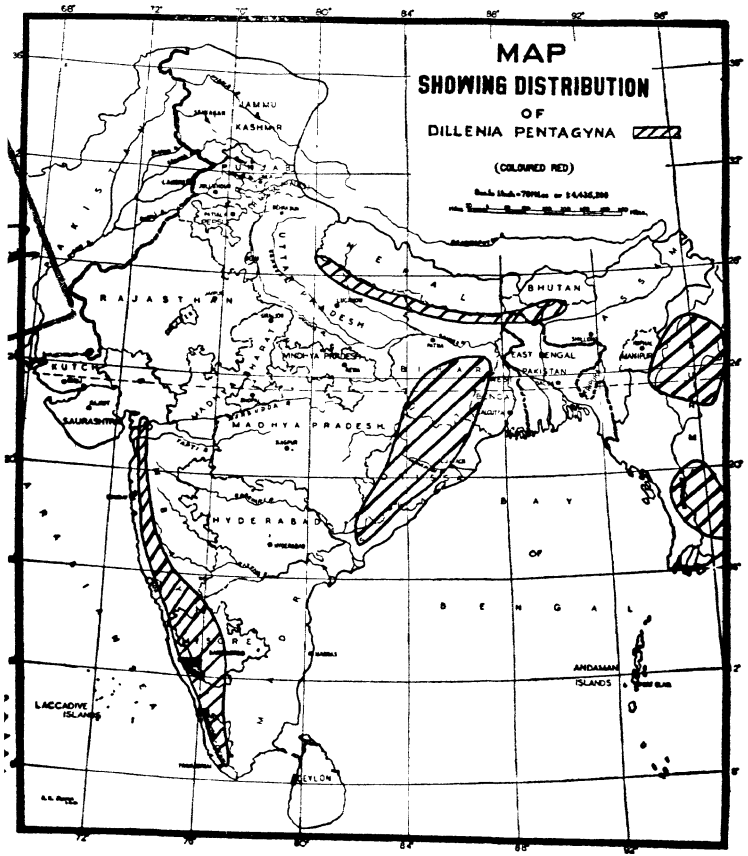
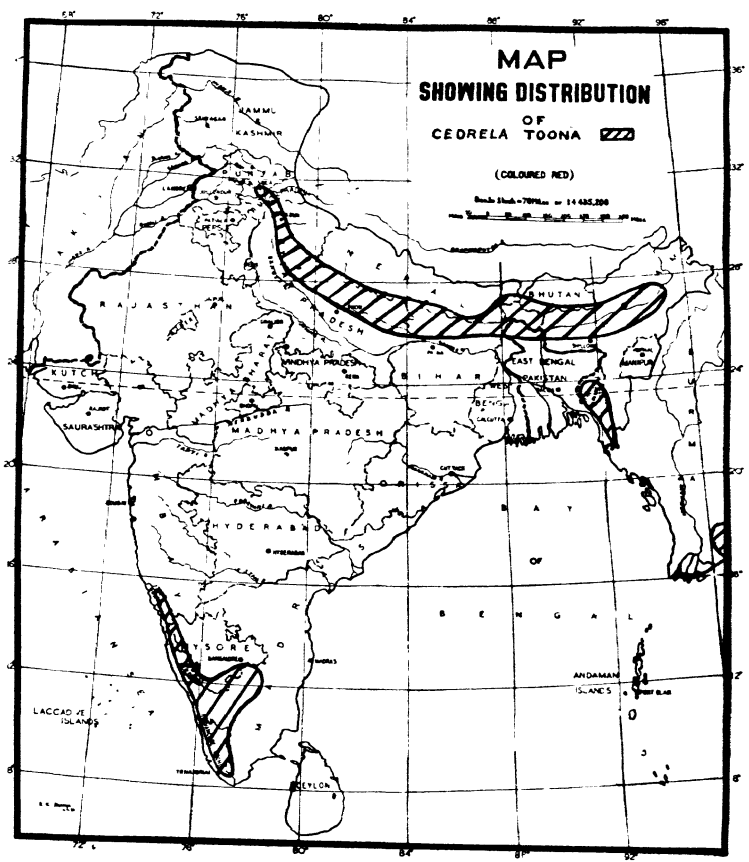

MAP
SHOWING DISTRIBUTION
OF
DILLENIA PENTAGYNA
(COLOURED RED)
JAMMU
KASHMIR
BHUTAN
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
EAST BENGAL
PAKISTAN
HYDERABAD
MYSORE
BAY
OF
BENGAL
ANDAMAN
ISLANDS
LACCADIVE
ISLANDS
CEYLON

Fig. 29


MAP
SHOWING DISTRIBUTION
OF
CEDRELA TOONA
(COLOURED RED)
JAMMU
KASHMIR
BHUTAN
RAJASTHAN
KUTCH
SAURASHTRA
MADHYA PRADESH
EAST BENGAL
PAKISTAN
HYDERABAD
MYSORE
BAY
OF
BENGAL
ANDAMAN
ISLANDS
LACCADIVE
ISLANDS
CEYLON

Fig, 30

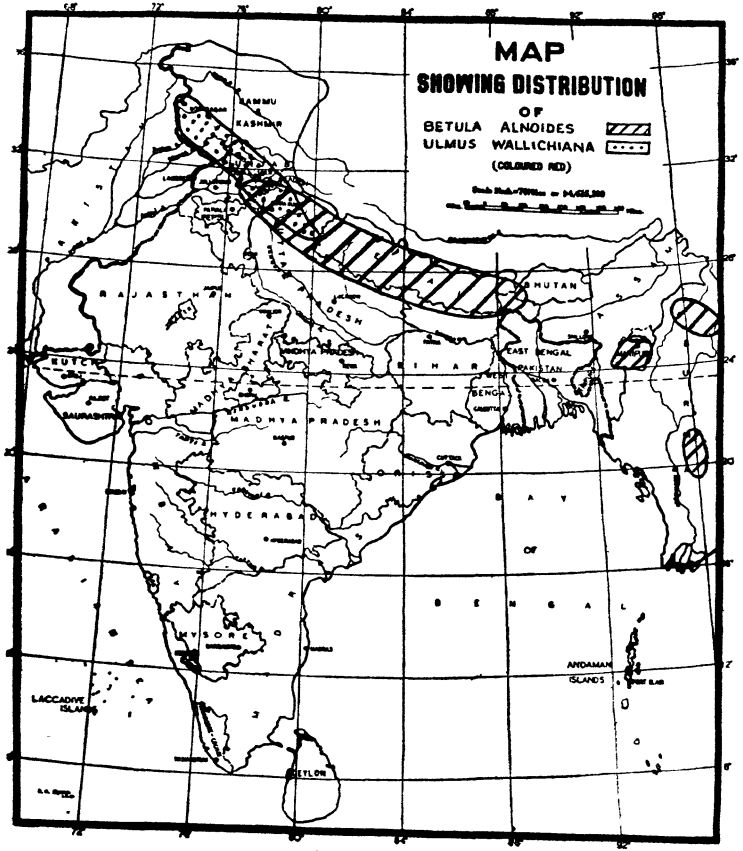

MAP
SHOWING DISTRIBUTION
OF
BETULA ALNOIDES
ULMUS WALLICHIANA
(COLOURED RED)
KASHMIR
BHUTAN
RAJASTHAN
MADHYA PRADESH
BIHAR
EAST BENGAL
PAKISTAN
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 31

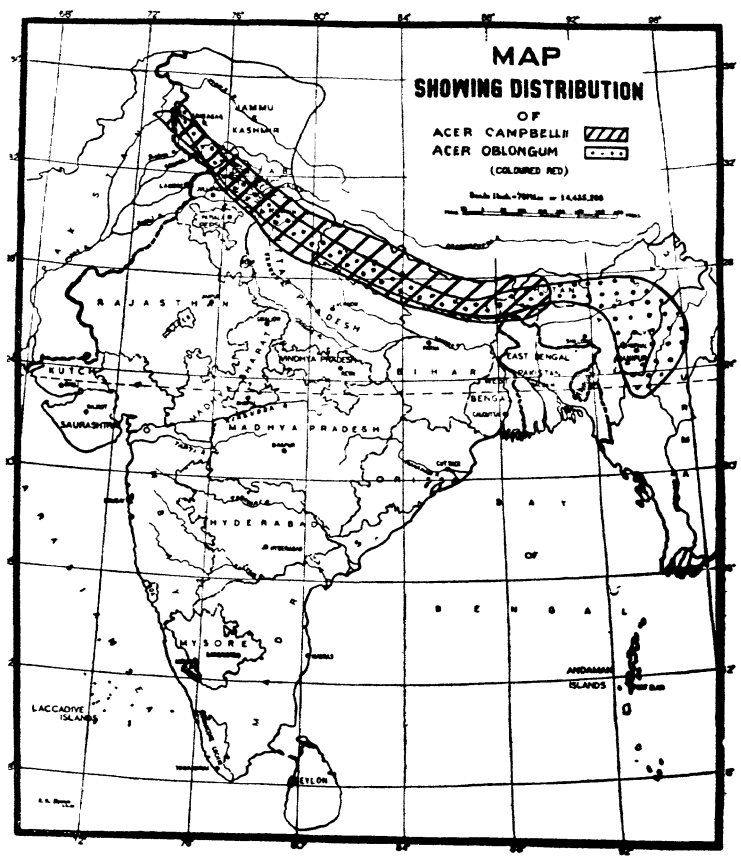

MAP
SHOWING DISTRIBUTION
OF
ACER CAMPBELLII
ACER OBLONGUM
(COLOURED RED)
KASHMIR
RAJASTHAN
MADHYA PRADESH
BIHAR
EAST BENGAL
PAKISTAN
HYDERABAD
MYSORE
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 32

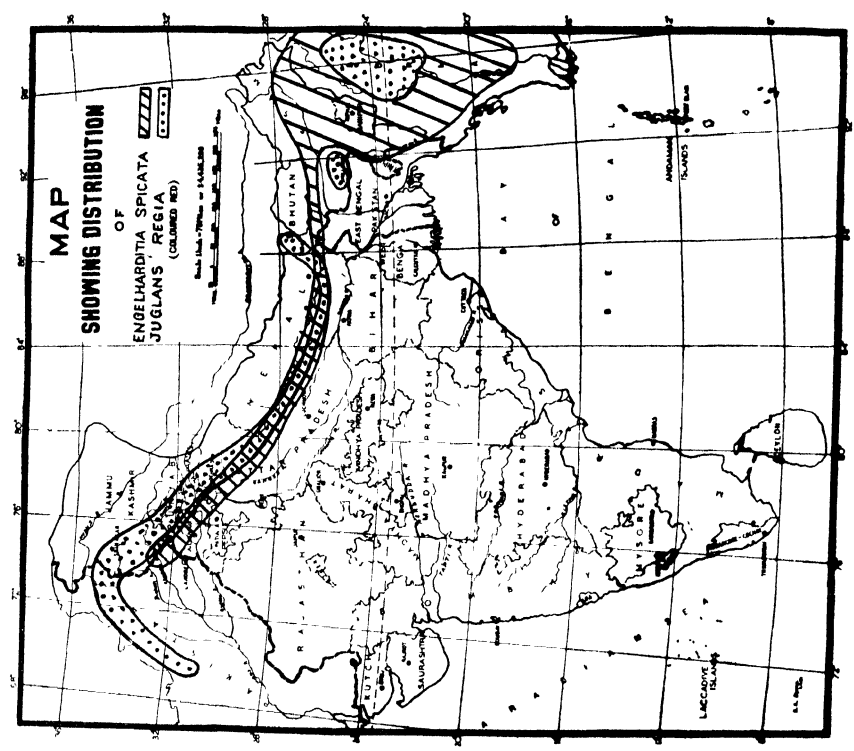

MAP
SHOWING DISTRIBUTION
OF
ENGELHARDTIA SPICATA
JUGLANS REGIA
(COLOURED RED)
BHUTAN
BIHAR
MADHYA PRADESH
MYSORE
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 34

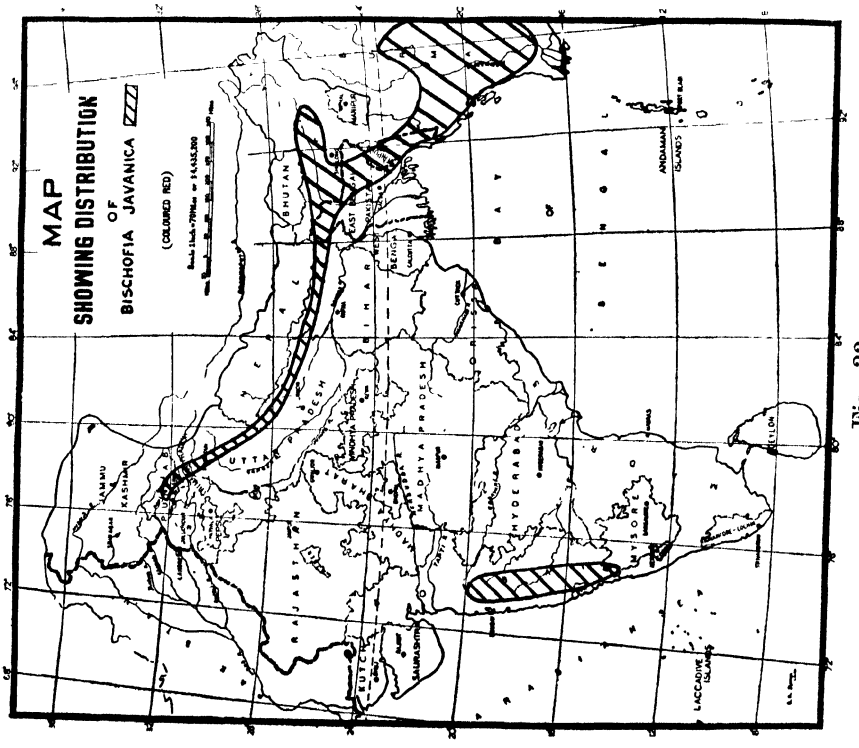

MAP
SHOWING DISTRIBUTION
OF
BISCHOFIA JAVANICA
(COLOURED RED)
BHUTAN
BIHAR
MADHYA PRADESH
MYSORE
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 33

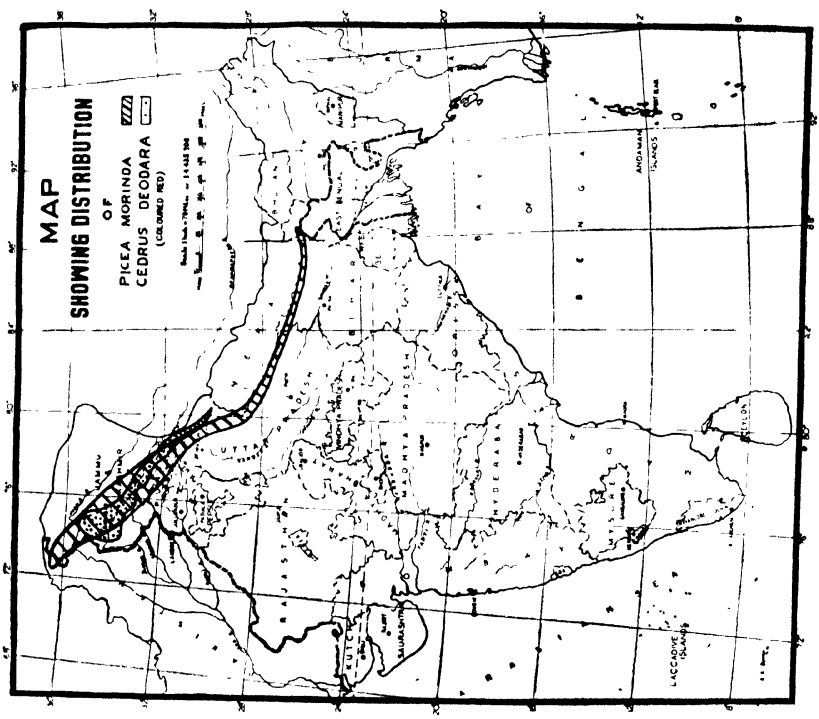

MAP
SHOWING DISTRIBUTION
OF
PICEA MORINDA
CEDRUS DEODARA
(COLOURED RED)

Fig. 36

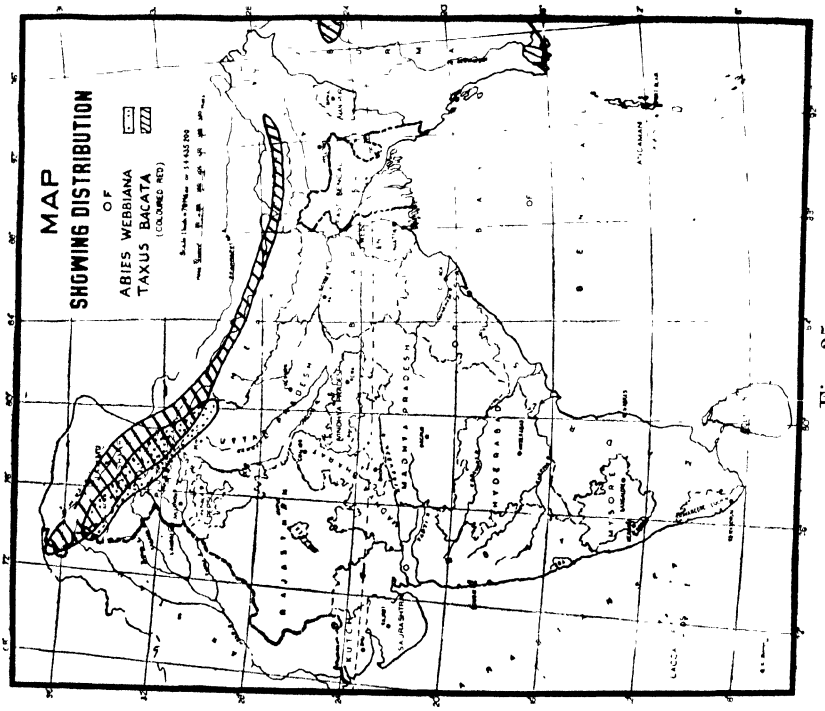

MAP
SHOWING DISTRIBUTION
OF
ABIES WEBBIANA
TAXUS BACATA
(COLOURED RED)

Fig. 35

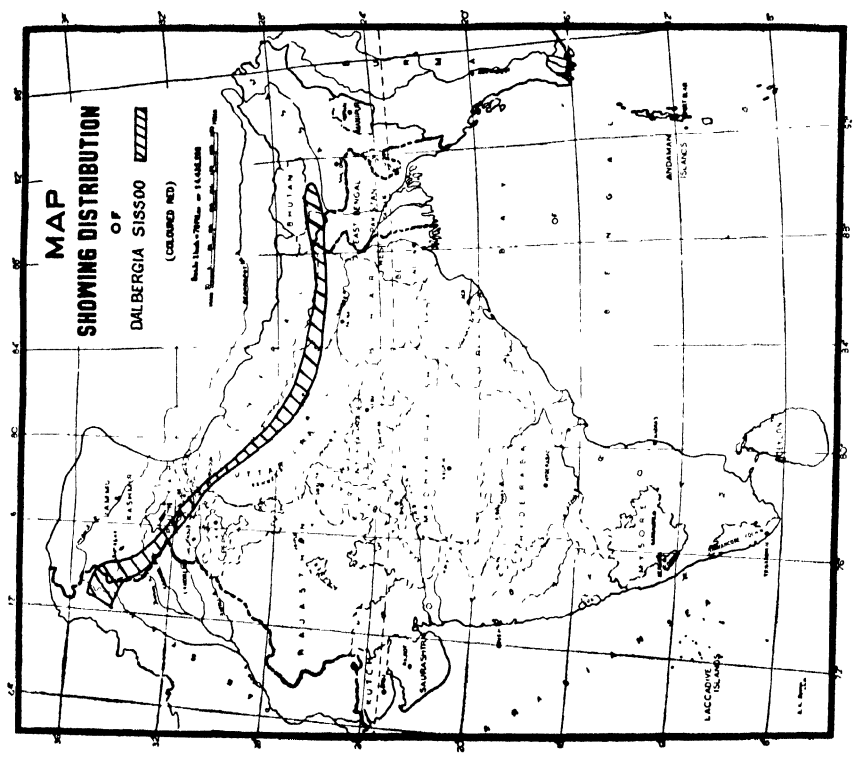

MAP
SHOWING DISTRIBUTION
OF
DALBERGIA SISSOO
(COLOURED RED)
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig 38.

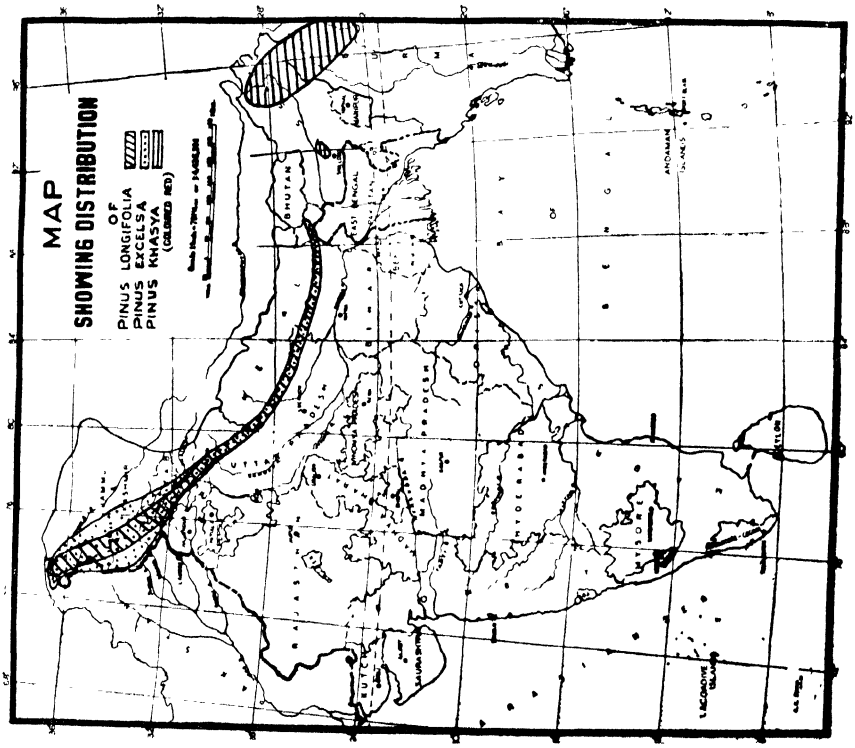

MAP
SHOWING DISTRIBUTION
OF
PINUS LONGIFOLIA
PINUS EXCELSA
PINUS KHASYA
(COLOURED RED)
BHUTAN
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 37

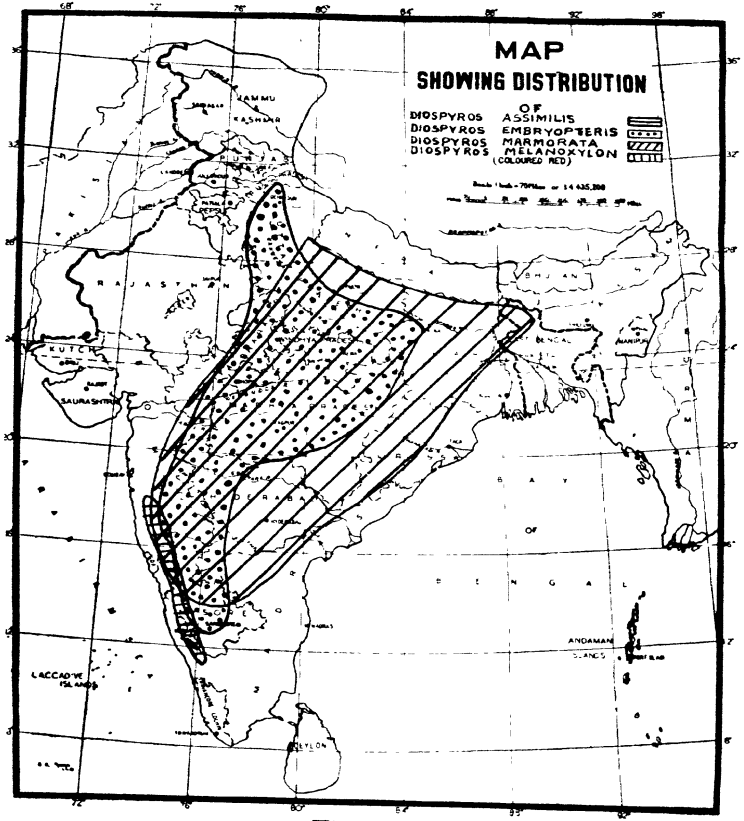

MAP
SHOWING DISTRIBUTION
OF
DIOSPYROS ASSIMILIS
DIOSPYROS EMBRYOPTERIS
DIOSPYROS MARMORATA
DIOSPYROS MELANOXYLON
(COLOURED RED)
KASHMIR
RAJASTHAN
BHUTAN
KUTCH
SAURASHTRA
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 39

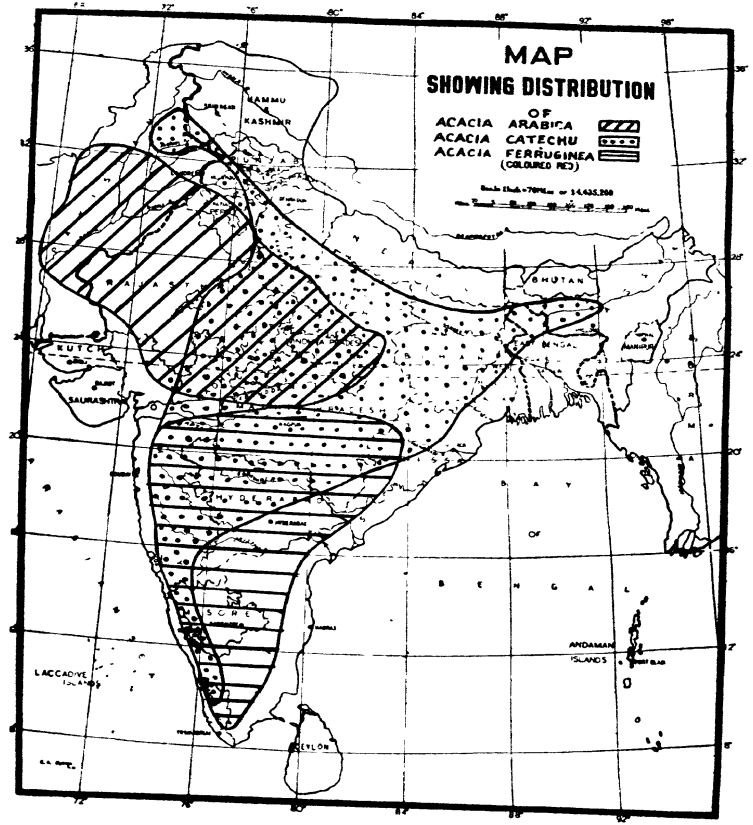

MAP
SHOWING DISTRIBUTION
OF
ACACIA ARABICA
ACACIA CATECHU
ACACIA FERRUGINEA
(COLOURED RED)
KASHMIR
BHUTAN
KUTCH
SAURASHTRA
BAY OF BENGAL
ANDAMAN ISLANDS
LACCADIVE ISLANDS
CEYLON

Fig. 40

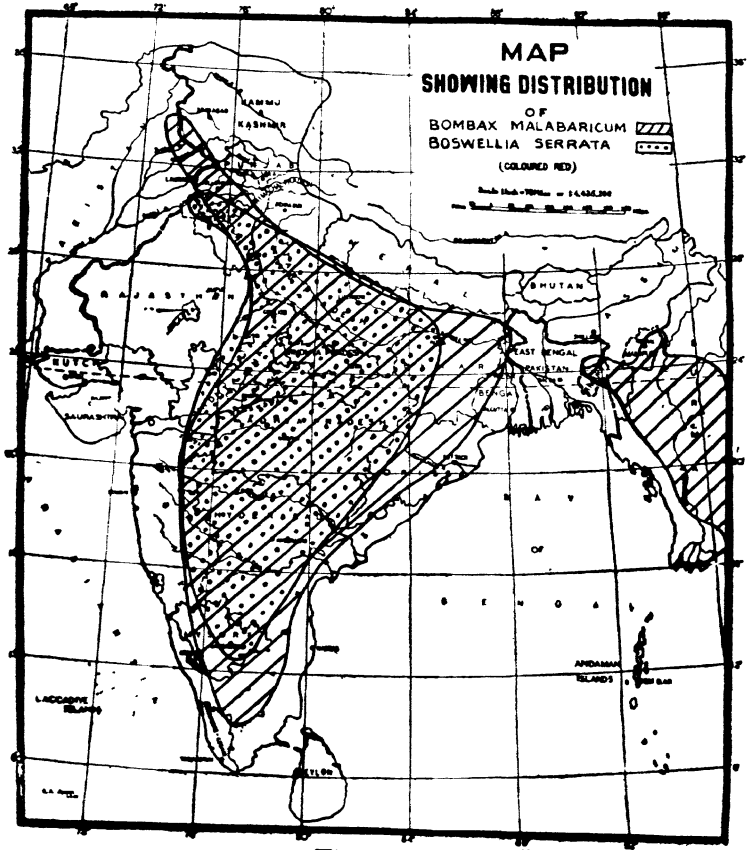

MAP
SHOWING DISTRIBUTION
OF
BOMBAX MALABARICUM
BOSWELLIA SERRATA
(COLOURED RED)
BHUTAN
EAST BENGAL
PAKISTAN
SAURASHTRA
ANDAMAN ISLANDS
LACCADIVE ISLANDS

Fig. 41

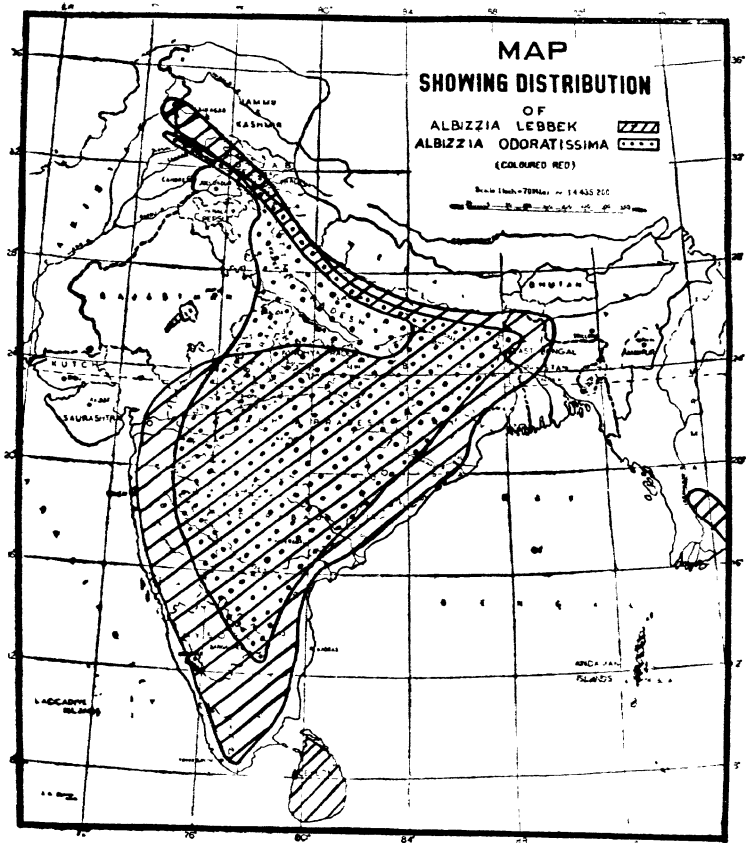

MAP
SHOWING DISTRIBUTION
OF
ALBIZZIA LEBBEK
ALBIZZIA ODORATISSIMA
(COLOURED RED)
BHUTAN
SAURASHTRA
LACCADIVE ISLANDS

Fig. 42

Theories to explain the discontinuous distribution of some Indian forest trees: Various attempts have been made in the past to explain the reason for the discontinuous distribution of the Indian forest tree species. There are in the main five theories to explain the above patterns of distribution of Indian Plants:

(1) **Himalayan glaciation theory:** During the Pleistocene the glaciation in the Himalayas lowered temperatures throughout the country. Medlicott and Blanford (1879) first suggested that "the occurrence of Himalayan plants and animals on the higher ranges of southern India may be due to the retreat of the species in the first place towards the equator, and subsequently, as the temperature increased, to the higher parts of the hills". Hora (1949) does not agree with the temperature factor and considers that high humidity during the glacial period was more potent in the distribution of animals, and aridity produced a discontinuous distribution. Sufficient work has not been done on this theory but it may appear that glaciation, by changing the ecological conditions of the environment, has certainly influenced what-ever factors may have been responsible for bringing about discontinuous distribution of Indian plants. As a result of the refrigeration of climate during the Ice Age, great quantity of limestone from the Himalayas was dissolved out and was washed to soils in plains, thus changing the fertility and mineral composition of soils, both in the hills and plains. It seems probable that plant species which have been growing on these limestone soils in the Himalayas were able to successfully migrate through the plains to south Indian hills, where the conditions of the climate and the soil were probably similar to that of the Himalayan region during the Pleistocene and the post glacial period. A good deal of work is needed to provide evidence for this conjecture, however.

(2) **Southern route across Indian Ocean theory:** This theory postulates the occurrence of a land connection between India, Australia, and India and New Zealand. Land connnections do not seem to have occurred over the Bay of Bengal but across the Assam hills through the Vindhya-Satpura trend of mountains to the western Ghats and then down south to Ceylon. It is conjectured that plant migration in the past has occurred along these land routes.

(3) **Deccan Traps theory:** The occurrence of similar genera of birds in south India and Malayan peninsula led to the postulation of the theory that the Deccan Traps were probably responsible for discontinuous distribution. But Hora (1949 a) showed that this could not be the reason since the migration occurred in waves during the Pleistocene period and not during the Tertiary.

(4) **Continuous Range theory:** According to this theory, the localities at which species are found at present, must have at one time, formed part of a continuous range of distribution of the species. This was postulated by Hora from the distribution of fishes and other animals and since then a lot of evidence has been brought forward in favour of this theory, resulting in the formation of Hora's Satpura Hypothesis.

(5) **Satpura Hypothesis**: This envisages that the Satpura-Vindhyan ranges had an altitude of 5,000 to 6,000 feet during the Pleistocene, forming a continuous range of mountains between the Himalayas and the Western Ghats. During that period the region had a rainfall of 150 inches, supporting thick tropical evergreen forests. This hypothesis is based on the following fundamental concepts of Hora (1949):

"(1) Continuity of the Vindhya-Satpura ranges with the Assam Himalayas in the east and the western Ghats in the west.

(2) Five to six thousand feet elevation of the Vindhya-Satpura ranges and of the northern section of the western Ghats.

(3) Continuity of an ecological belt of mountains with rainfall of about 100 inches or above and consequently, of the tropical evergreen forests between the Assam Himalayas and the mountains of Ceylon via the Vindhya-Satpura Trend and the Western Ghats.

(4) Dispersal of the fauna from east to west and the consequent changes in topography necessary therefore".

These concepts of Hora endeavour to explain the presence of Malayan flora and fauna in Peninsular India and Ceylon, conceiving the route of migration from Assam and eastern Himalaya to the plateau of Chota Nagpur, across the Garo Rajmahal gap. The migration from Chota Nagpur plateau was probably along Vindhya-Satpura-Western ghats route and Orissa hills-Eastern ghats-western ghats route. The modern distribution pattern of various species follow ecological conditions of the habitat of which temperature played relatively unimportant part than annual precipitation and relative humidity throughout the year. The migration had taken place during the Pleistocene.

The probability of the existence of the continuous Satpura ranges was discussed by Auden (1949) who feels that "the evidence is not in favour, therefore, of the conception of major Ur-Satpura range extending across India during the Tertiary period that has subsequently been worn down to the present elevations. It suggests rather the downfaulting along the Narbada and Tapti rifts at the close of the eruption of the traps, and the unequal elevation of the region since the Miocene. It is considered probable that a connnection did arise between the Shillong plateau and the Peninsula during the Miocene and that the final break causing the present Garo - Rajmahal gap took place during the Pleistocene along a N.W. - S.E. line of fracture extending from the Darjeeling Himalaya to Comilla and Chittagong. Consequently, it is necessary to suppose that while the central part of the Peninsula was undergoing mild uplift during the Pleistocene, the bordering areas of Cutch, Saurashtra, and northern Bengal were subjected to depression". He laid stress on the role of climatic changes caused by the Pleistocene glaciation for the migration of flora and fauna from the eastern Himalayas and the western Himalayas to the Peninsular India.

De Terra and Paterson (1939) have brought a considerable amount of evidence from their study of the Karewa deposits of the Kashmir Himalayas to showthat during the Pleistocene Period there have been five glacial and four inter-glacial periods and glaciers had extended down the valley to 4,000-5,000 feet above sea level. This had lowered temperatures in Peninsular India and probably brought about a mountain climate to areas which are plains to day. This would certainly have helped the migration of the mountain fauna and flora to the Peninsular India.

The existence of a continuous Satpura ranges of hills was also questioned by Dey (1949), who also favoured the theory of glaciation in plant and animal migration.

The question of the existence of the Satpura across the gap has therefore not been finally agreed and the explanation for the existence of the northern element in the flora of Peninsular India may have to be sought in the effect of glaciation during the Pleistocene.

Burkill's views regarding the discontinuous distribution of plants in India: Burkill (1924) discussed the importance of Pleistocene glaciation in the dispersal and migration of different floras in India. The poverty of rain forest endemic species in the Himalayas is explained

to be due to the climate having not yet become steady after the glacial period. He gives the following distribution of northern genera, which occur in the mountains of tropical Asia and Malaya.

Table 12.

DISTRIBUTION OF NORTHERN GENERA IN MOUNTAINS OF TROPICAL ASIA AND MALAYA.

(After Burkill, 1924)

	Himalaya	Indian Peninsula	Ceylon	Siam	Malay Peninsula.	Sumatra.	Java	Borneo	East Malaysis.
Anemone rivularis.	H	D	C	...	...	...	...	...	
A. sumatrana.	...	...	...	S	...	S	...	...	
Thalictrum javanicum.	H	D	C	...	...	S	J	...	
T. saniculaelaeforme.	...	D	...	...	...	...	...	...	
T. dalzellii.	...	D	...	...	...	...	...	...	
Ranunculus diffusus.	H	...	...	...	...	S	J	...	
R. reniformis.	...	D	...	...	...	...	...	...	
R. sagittifolius.	...	...	C	...	...	...	...	...	
R. subpinnatus.	...	D	...	...	...	...	...	...	
R. javanicus.	...	...	...	...	...	S	J	...	
R. wallichianus.	...	D	C	...	...	...	...	...	
R. lowii.	...	...	...	...	...	...	...	B	Celebes.
R. muricatus.	H	D	...	...	...	...	...	...	
R. pennsylvanicus.	H	...	...	...	...	...	J	...	
Viola patrinii.	H	D	C	S	...	S	J	...	
V. serpens.	H	D	...	S	...	S	J	B	
V. malvina.	...	...	...	...	...	S	...	...	
V. distans.	H	D	...	...	...	...	...	...	
V. arcuata.	H	...	...	...	...	...	J	...	
V. sumatrana.	...	...	...	...	...	S	...	...	
V. alata.	...	...	...	...	...	...	J	...	
Stellaria paniculata.	H	D	...	...	...	...	...	...	
S. drymarioides.	...	...	C	...	...	...	...	...	
S. saxatilis.	H	D	...	...	...	...	J	...	
S. media.	H	D	...	...	...	...	J	...	
S. pauciflora.	...	...	...	...	...	...	J	...	
S. uliginosa.	H	D	...	...	...	...	...	...	
Cerastium indicum.	...	D	C	...	...	...	J	...	
C. glomeratum.	H	D	...	...	...	...	J	...	
Arenaria neelgerrensis.	H	D	...	...	...	...	...	...	
Linum mysorense.	H	D	C	...	...	...	...	...	
Reinwardtia trigyna.	H	D	...	S	...	...	...	...	
R. tetragyna.	H	D	...	...	...	...	...	...	
Geranium nepalense.	H	D	C	...	...	...	J	...	
Alchemilla indica.	...	D	C	...	...	...	...	...	
A. villosa.	...	...	...	...	...	...	J	...	
Agrimonia zeylanica.	...	...	C	...	...	...	...	...	
A. eupatoria.	...	...	...	...	...	...	J	...	

Table 12. (Contd.)

	Himalaya	Indian Peninsula	Ceylon	Siam	Malaya Peninsula	Sumatra.	Java.	Borneo	East Malaysia.
Potentilla mooniana.	H	...	C	...	...	...	...	B	
P. leschenaultiana.	H	D	...	...	...	...	...	...	
P. kleiniana.	H	D	C	...	...	...	...	...	
P. supina.	H	D	...	...	...	...	...	...	
P. leuconota.	...	...	...	...	...	...	...	B	
P. parvula.	...	...	...	...	...	...	J	B	
Poterium indicum.	...	...	C	...	...	...	...	...	
Cotoneaster buxifolia.	H	D	...	...	...	...	...	...	
Parnassia wightiana.	H	D	...	...	...	...	...	...	
P. mysorensis.	...	D	...	...	...	...	...	...	
Tilaea pentandra.	H	D	...	...	...	...	...	...	
Circaea alpina.	H	D	...	...	...	...	...	...	
Sanicula europaea.	H	D	...	...	M	S	J	B	
Heracleum hookerianum.	...	D	...	...	...	...	...	...	
H. rigens.	...	D	C	...	...	...	...	...	
H. aquilegifolium.	...	D	...	...	...	...	...	...	
H. ceylanicum.	...	D	C	...	...	...	...	...	
H. candolleanum.	...	D	...	...	...	...	...	...	
H. sprengelianum.	...	D	...	...	...	...	...	...	
H. courtallense.	...	D	...	...	...	...	...	...	
H. concanense.	...	D	...	...	...	...	...	...	
H. pedatum.	...	D	...	...	...	...	...	...	
H. pinda.	...	D	...	...	...	...	...	...	
Aralia malabarica.	...	D	...	...	...	...	...	...	
A. filicifolia.	...	...	...	...	...	S	...	...	
A. montana.	...	...	...	...	...	...	J	...	
A. ferox.	...	...	...	...	M	...	J	B	
A. dasyphylla.	...	...	...	...	...	S	J	...	
A. javanica.	...	...	...	...	...	...	J	...	
Rubia cordifolia.	H	D	C	...	...	S	J	B	
R. siamensis.	...	...	...	S	...	...	...	...	
Galium javanicum.	H	D	...	...	...	...	J	...	
G. asperifolium.	H	D	C	...	...	...	...	...	
G. cuspidatum.	...	...	...	...	...	...	J	...	
G. junghuhnianum.	...	...	...	...	...	...	J	...	
Valeriana hardwickii.	H	...	...	...	M	S	J	...	
V. arnottiana.	...	D	...	...	...	...	...	...	
V. moonii.	...	...	C	...	...	...	...	...	
V. hookeriana.	...	D	...	...	...	...	...	...	
V. leschenaultii.	...	D	...	...	...	...	...	...	
V. beddomei.	...	D	...	...	...	...	...	...	
Dipsacus leschenaultii.	...	D	...	...	...	...	...	...	
D. walkeri.	...	...	C	...	...	...	...	...	
Anaphalis cinnamomea.	H	...	C	...	...	...	...	...	
A. fruticosa.	...	...	C	...	...	...	...	...	
A. beddomei.	...	D	...	...	...	...	...	...	
A. adnata.	H	...	...	S	...	...	...	...	

Table 12. (Contd.)

	Himalaya	Indian Peninsula	Ceylon	Siam	Malay Peninsula	Sumatra.	Java	Borneo	East Malaysis.
A. elliptica.	...	D	C	...	...	...	...	...	
A. margaritacea.	...	...	...	S	...	...	...	...	
A. thwaitesii.	...	...	C	...	...	...	...	...	
A. travancorica.	...	D	...	...	...	...	...	...	
A. notoniana.	...	D	...	...	...	...	...	...	
A. subdecurrens.	...	D	...	...	...	...	...	...	
A. leptophylla.	...	D	...	...	...	...	...	...	
A. lawii.	...	D	...	...	...	...	...	...	
A. aristata.	...	D	...	...	...	...	...	...	
A. meeboldii.	...	D	...	...	...	...	...	...	
A. wightiana.	...	D	...	...	...	...	...	...	
A. bournei.	...	D	...	...	...	...	...	...	
A. zeylanica.	...	...	C	...	...	...	...	...	
A. marcescens.	...	D	C	...	...	...	...	...	
A. brevifolia.	...	D	C	...	...	...	...	...	
A. neelgerriana.	...	D	...	...	...	...	...	...	
A. javanica.	...	...	...	...	...	S	J	...	
A. viscida.	...	...	...	...	...	...	J	...	
Artemisia parviflora.	...	D	...	...	...	...	...	...	
A. vulgaris.	H	D	C	...	M	S	J	...	
Carduus Wallichii.	H	D	...	...	...	...	...	...	
Ainsliaea pteropoda.	H	...	...	S	...	S	J	...	
Pratia montana.	H	...	...	...	...	S	J	...	
P. nummularia.	H	...	...	S	...	S	J	...	
P. borneensis.	...	...	...	...	...	...	...	B	
Campanula canescens.	H	D	C	...	...	...	...	...	
C. ramulosa.	...	D	...	...	...	...	...	...	
C. wightii.	...	D	...	...	...	...	...	...	
C. alphonsii.	...	D	...	...	...	...	...	...	
C. fulgens.	H	D	C	...	...	...	...	...	
Primula imperialis.	...	...	...	...	...	S	J	...	
Gentiana quadrifaria.	H	D	C	...	...	...	J	...	
G. hesseliana.	...	...	...	S	...	...	...	...	
G. sumatrana.	...	...	...	...	...	S	...	...	
G. lateriflora.	...	...	...	...	...	...	...	...	Celebes
G. laxicaulis.	...	...	...	...	...	...	J	...	
G. borneensis.	...	...	...	...	...	...	...	B	
G. malayana.	...	...	...	...	M	...	...	...	
Clementis lycopodioides.	...	...	...	...	...	...	...	B	
Pedicularis perrottetii.	...	D	...	...	...	...	...	...	
P. zeylanica.	...	D	C	...	...	...	...	...	
Brunella vulgaris.	H	D	...	...	...	...	...	...	
Elaeagnus latifolia.	H	D	C	...	...	S	J	...	
Agrostis canina.	H	D	...	...	...	...	...	B	
A. peninsularis.	...	D	...	...	...	...	...	...	
A. reinwardtii.	...	...	...	...	...	...	J	...	

Table 12. (Contd.)

	Himalaya	Indian Peninsula	Ceylon.	Siam.	Malay Peninsula	Sumatra.	Java.	Borneo.	East Malaysis.
A. rigidula.	...	...	...	...	...	...	J	...	
A. infirma.	...	...	...	...	...	S	J	B	
Calamagrostis pilosula.	H	D	C	...	...	...	...	...	
C. schmidii.	...	D	...	...	...	...	...	..	
C. javanica.	...	...	...	...	...	...	J	...	
C. deyeuxia.	...	...	...	...	...	...	J	...	
C. epileuca.	...	...	...	...	...	...	...	B	
Avena aspera.	H	D	C	...	...	...	...	...	
A. polyneura.	...	D	...	...	...	...	...	...	
A. junghuhnii.	H	...	...	...	...	S	J	...	
Bromus asper.	H	D	...	...	...	...	...	...	
B. insignis.	...	...	...	...	...	...	...	B	
Brachypodium sylvaticum.	H	D	C	...	...	...	J	...	
Festuca nubigena.	...	...	...	...	...	...	J	...	
F. gigantea.	H	...	...	...	...	...	J	...	
Species in common with the Himalaya	49	40	19	6	3	16	27	5	
Species which are not in the Himalaya....		47	17	4	2	9	20	10	
Total	...	87	36	10	5	25	47	15	
Percentage of Non-Himalayan species....		54	47	40	40	36	43	67	

Out of the 49 temperate species in the Himalayas which occur in tropical mountains, 40 are recorded from hills in Deccan, 27 from Java, 19 from Ceylon, more than 16 from Sumatra, 6 from Malaya, 5 from Borneo and 3 from Siam. Discussing the distribution of the various species, Burkill considers that "there is no reason for thinking that there has been any lateral migration between the mountains of the Deccan or Ceylon and the mountains of Sumatra or Java: but into Malaysia there may well have been two routes for these northern plants, one via Burma to Sumatra and on to Java; the other via Formosa and the Philippine Islands to Borneo, and it is possible that in Borneo the two routes have met; to Borneo, Bonthain peak in Celebes seems to owe the origin of some of its plants. New Guinea has very little in common with the Himalaya."

The proportion of species endemic along the three routes is:

First route, Deccan and Ceylon.....56 out of 107 or 52 percent.
Second route, Siam, Malaya Peninsula, Sumatra, Java..... 28 out of 58 or 48 percent.

Third route, Borneo, Celebes.....11 out of 16 or 69 percent.

The spread of the Malaysian rain forest genera took place before the glacial period by the Bay of Bengal route and the deterioration of the climatic conditions after the glacial period disrupted the continuity of vegetation in different areas. The Himalayan plants spread to other parts of India later than the rain forest element came to southern India through the Ceylon-Deccan route. The genera of plants that migrated to mountains of south India, Ceylon and Malaysia during the glacial period had their lower limit of distribution in the Himalayas as follows:-

Table 13.

THE LOWER LIMIT OF DISTRIBUTION IN THE HIMALAYAS OF THE GENERA THAT HAD MIGRATED TO S. INDIA, CEYLON AND MALAYASA DURING THE GLACIAL PERIOD.

(After Burkill, loc. cit.)

Anemone	4,000 ft.	*Rubia.*	Edge of Himalaya.
Thalictrum.	3,000 ft.	*Galium.*	Punjab plain.
Ranunculus.	Punjab Plain, etc. (R. sceleratus lower)	*Valeriana.*	4,000 ft.
		Dipsacus.	6,000 ft.
Viola.	Punjab plain.	*Anaphalis.*	4,000 ft.
Stellaria.	4,000 ft.	*Artemisia.*	Punjab plain.
Cerastium.	6,000 ft.	*Carduus.*	6,000 ft.
Arenaria.	Plains of upper India.	*Ainsliaea.*	5,000 ft.
Linum.	Edge of Himalaya	*Pratia.*	2,000 ft.
Reinwardtia.	Edge of Himalaya.	*Campanula.*	Edge of Himalaya.
Geranium.	Edge of Himalaya.	*Primula.*	4,000 ft.
Alchemilla.	8,000 ft.	*Gentiana.*	Edge of Himalaya.
Agrimonia.	3,000 ft.	*Pedicularis.*	5,000 ft.
Potentilla.	Edge of Himalaya.	*Brunella.*	4,000 ft.
Poterium.	5,000 ft.	*Elaeagnus.*	2,000 ft.
Cotoneaster.	1,500 ft.	*Luzula.*	9,000 ft.
Parnassia.	4,500 ft.	*Agrostis.*	Edge of Himalaya.
Tillaea.	Edge of Himalaya.	*Calamagrostis.*	5,500 ft.
Circaea.	7,000 ft.	*Avena.*	Edge of Himalaya.
Sanicula	4,000 ft.	*Bromus.*	5,000 ft.
Heracteum.	5,000 ft.	*Brachypodium.*	6,000 ft.
Aralia.	Edge of Himalaya.	*Festuca.*	5,000 ft.

These species would find it easy to migrate southwards by mere change in climatic conditions brought about by glaciation.

Burkill's views have thus cleared the phytogeographical problem of two different types of floras. The Malayan element in the hills of south India is much older and had migrated through the Bay of Bengal or Ceylon-Deccan route. The Himalayan element is glacial in age and its spread to south Indian hills was brought about by glaciation. This very phenomenon destroyed the rain forest Malayan element from the Himalayan ranges to the west and further checked its westward migration. The glacial theory of distribution of plants to south Indian hills thus gains further ground in the light of Burkill's studies.

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4

GEOLOGICAL HISTORY OF FOREST VEGETATION OF INDIA.

In a study of forest vegetation in relation to habitat factors it is usual to consider the climatic features, nature of the soil and human influences only. These factors, however, do not always afford ecological data of sufficient importance in evaluating the exact relationship of vegetation in time. It is, therefore, necessary that the time factor in terms of geological history of the vegetation be carefully studied, since this approach has helped in practical ecology, when historical reasons for the absence of deodar and oaks from the Kashmir Valley were given (Puri, 1949).

Traces of forest plants in pre-Tertiary-vegetation of India: The forest vegetation in India dates back mainly to the Tertiary Period. The pre-Tertiary fossils discovered from India have little or no angiospermic affinities, and except for some homoxylous woods from the Jurassics of the Rajmahal hills, described by Sahni (1931) under the name of *Homoxylon rajmahalense*, no other plant fossil, even with remote angiospermic affinities has been discovered from pre-Tertiary rocks. *Homoxylon rajmahalense* has affinities with the Magnoliaceae in which homoxylous woods are present. It could not be decided whether this fossil has clearly angiospermic affinities or it belonged to the *Cycadeoidea*, the Cycad-like-plants found in these very beds.

A number of fossil woods described under Pentoxyleae from the Jurassic beds have some affinities with Coniferales, Bennettitales and Cycadales.

Under specific names *Desmiophyllum indicum, Araucarites cutchensis* some fossil leaves and cone scales of Coniferales were described from the Gondwana rocks. A number of similar genera indicating the presence of Podocarpaceae, Araucarineae, Taxodineae and Abietineae in pre-Mesozoic rocks of India have been described from a number of localities.

The geological distribution and affinities of some of the Indian fossil conifers are given in table 14 on p. 71.

The conifers were at their height during the Jurassic period and they suffered greatly during the Cretaceous Period in India.

In other countries angiosperms formed the most prominant feature of the vegetation of the Cretaceous period but no angiospermic fossils have been discovered from India so far.

Tertiary vegetation: During the Tertiary period in India conifers were extremely few, there being only one species, which is allied to the modern *Podocarpus latifolia*, occuring in the Peninsular India. Both, in the Himalayas and in the Deccan, a number of angiospermic plant fossils have been discovered, the most important of which are woods of palms, described under the form genus *Palmoxylon*. These woods have affinities with *Borassus, Cocos, Bactris, Nipa fruticans* and several other genera, not fully worked out. These were discovered from the Inter-trappean beds of the Deccan. Another type of fossil wood, described under the name

Table 14.

DISTRIBUTION OF FOSSIL GYMNOSPERMS IN INDIA.

(AFTER SAHNI, 1931).

	TAXINEAE.	PODOCARPINEAE.	ARAUCARINEAE	TAXODINEAE	CUPRESSINEAE.	ABIETINEAE.	CONIFERAE INCERTAE SEDIS.	
Modern	*Taxus* (1) *Cephalotaxus* (2)	*Podocarpus* (3) *Dacrydium* (1)	...	...	*Cupressus*(1) *Juniperus*(4) *Libocedrus* 1)	*Pinus*(5) *Abies*(1) *Cedrus*(1)*Larix*(1) *Picea*(1) *Tsuga*(1)	...	
Post-Gondwana.			*Dadoxylon*(2)		*Cupressinoxylon* (1)	*Pityostrobus* 1)	*Indostrobus* (1) *Takliostrobus*(1)	
Tertiary.	...	*Mesembrioxylon* (1)	...	...	...			
Upper cretaceous		...	...	...	...			
Upper Gondwana. Lower Cretaceous.	...	...	*Araucarites*(1) *Dadoxylon*(1)	...	...	...	*Elatocladus*(1) *Retinosporites* (1) *Brachyphyllum*(1) *Desmiophyllum*(1)	*Pagiophyllum*(1) *Conites* (1) *Conif. wood*(1) *Conites* 7) *Strobilities* (2)
Jurassic (Incl. Rhaetic).	*Toreyites* (1 or 2)	*Mesembrioxylon* (4)	*Araucarties* (3) *Dadoxylon* (2 or 3).	*Athrotaxites* (1)	*Cupressinoclados* (2) *Cupressinoxylon* (2)	...	*Elatocladus*(5 or 6) *Retinosporites*(1) *Brachyphyllum* 5) *Pagiophyllum*(2 or 3).	*Masculostrobus* (1) *Conif. wood*(2 or 3) *Coniferocaulon* (1)
Lower-Gondwana. Triassic.	...	...	...	...	...	...	...	
Permian & Upper Carboniferous.	...	...	...	...	...	...	*Moranocladus* (horiz. uncertain(I) *Buriadia*(I) *Volizia* (I)	*Coniferous* nature. uncertain.

(The number of recorded species is given in brackets after each genus)

Cyclanthodendron, has affinities with the South American family Cyclanthaceae. Fruits and flowers of Lythraceae have been described from the Inter-trappean beds under names of *Enigmocarpon* (Sahni, 1943) and *Sahnianthus* (Shukla, 1944), respectively. The Deccan Inter - trappean flora has a number of plants which resemble Eocene London Clay Flora. This latter flora has a number of tropical plants of Indo-Malayan origin.

A number of fossil leaves have been recently described from the Deccan Inter-trappean Series which again shows the presence of a rich angiospermic flora during the Tertiary period.

From the Tertiaries of Assam, Seward (1912) described some fossil leaves under the form genus *Phyllites*. Edwards (1923) identified fossil leaves from south-east Burma under the names of *Ficophyllum burmense* and *Dipterocarpophyllum gregoryi*.

Chowdhury (1952) has described a number of fossil woods under the following names:—

(1) **Glutaxylon** from Cachar hills, Iravadi system in Burma and Raniganj coal field, thus showing that the genus *Gluta* was "growing in the Miocene period in an area starting from the east of Raniganj coal field, on the west, up to Indo-China, that is throughout the present provinces of west and east Bengal, Assam, Burma, Siam and Indo-China. The present distribution of the species of *Gluta* in India shows that *Gluta travancorica* is confined to the west coast of Travancore and *Gluta elegans* and *Gluta tavoyana* occur in Burma. Thus, there has been a tendency in these genera for an east-ward migration, since the Tertiary period."

(2) **Dipterocarpoxylon garoense** has been described by Chowdhury from the upper Miocene rocks of the Garo hills in Assam. Another fossil wood showing resemblances to this species was discovered from the Raniganj coal field, the age of which is put to be Miocene to Pleistocene.

(3) **Cynometroxylon:** Under this form genus fossil woods from the Miocene of north Cachar hills have been described. One of the modern species, *Cynometra polyandra* grows very near the fossil locality. Of the other modern Indian species *C. polyandra* and *C. ramiflora* occur in Bengal, *C. ramiflora* and *C. cauliflora* occur in Burma, *C. travancorica*, *C. beddomei* and *C. bourdillonii* are found in Madras, *C. ramiflora* also occurs in South Bombay and Ceylon. *Kayeoxylon assamicum* another fossil wood species is described from Sibsagar, Assam. The genus *Kayea* has two species, *K. assamica* and *K. floribunda*. The former occurs in a small area in the northern bank of the Brahmputra at the foot of the Himalayas, while *K. floribunda* grows within a distance of a hundred miles from the locality of fossil occurrence. *K. nervosa* and *K. floribunda* occur in Burma, *K. manii* in Andamans and *K. stylosa* in Ceylon.

Lakhanpal and Bose (1951) have described fossil leaves from Tertiary beds in Rajasthan which have affinities with *Mesua*, *Garcinia*, and *Calophyllum* of the Guttiferae. This discovery extends the occurrence of tropical evergreen forests during the Tertiary to as far west as Rajasthan area where a poor type of scrub forests and desert conditions are found today.

From the Tertiary rocks of the Kasauli range in the western Himalayas a number of fossil leaves were discovered, which were identified as follows in table 15 on page 73:

Most of these plant species are Tropical and Sub-tropical in present day distribution, but do not give much information on the nature of vegetation in India during the period of its occurrence.

Table 15

PLANT FOSSILS FROM THE KASAULI BEDS IN THE HIMALAYAS.

(Extracted from Mohan, 1933).

Natural family.	Genus.	Present habitat.
Sapindaceae.	Nearest approach to *Sapindus dubius* (Unger).	Essentially tropical, India and tropical parts of South America.
Ericaceae.	Close resemblance to *Andromeda vaccinifolia* (Flora Tertiaria Helvetiae.)	No characteristic habitat. Both within and without the Tropics. In the former on high lands. Rather rare in India.
Lauraceae.	Referrible to genus *Tersia;* species *branuni* and genus *Larus.*	Cool places of the Tropics of either hemisphere. Northern India and lower zone of Himalayas.
Moraceae.	Various specimens of genus *Ficus* and one identical with *Ficus religiosa.*	Tropical and sub-tropical.
Cycadaceae.	Genus not identifiable.	Tropical.
Coniferae.	Several acerose midribbed leaves and fragments of cone scales but too badly marked to admit of generic identification.	Sub-tropical and Temperate.
Palmaceae.	Closely allied to *Flabellaria rapitisfolia* (Sternburg).	Tropical.
Cyperaceae.	Cyperites, some allied to *Deucatinois,* species *Tennis tritis,* Fragment of *Carices.*	Evidently Tropical but met within marshes, ditches, meadows, heaths, groves, forests, running streams, blowing sands of sea shore and tops of mountains from Arctic to Antarctic.
Gramineae.	Referrible to *Poacites* .	Various.

A number of Tertiary fossil leaves from the Garo hills, Assam, were identified by Lakhanpal (1948) with *Eriodendron, Neolitsea* and *Celtis.*

From the Saline series of the Salt Range in the Punjab, the following microfossils were discovered by Trivedi (1946):—

From the Assam Tertiaries, Sahni, Sitholey and Puri (1948) examined a large number of microfossils, some of which show resemblances to angiosperms and gymnosperms. There are also some specimens of cuticles of leaves, spores and fungal mycelia. A few leaf specimens examined from this area have resemblance with *Quercus* and genera of the Lauraceae.

Table 16.

MICROFOSSILS FROM THE SALINE SERIES IN THE PUNJAB.

(from Trivedi, 1946).

Micro fossils.	Rock salt "Kallar" (19 samples).	Dolomites (21 samples including S.R.E. 40).	Oil shales (6 samples including 2 samples each of S.R.E. 19 & 38).	Total.
Angiospermous carbonised woods.	3	3	4	10
Angiospermous Non-carbonised woods.	26	11	4	41
Gymnospermous Non-carbonised woods.	7	3	1	11
Grass type cuticles.	7	3	—	10
Other types cuticles.	1	—	—	1

The modern distribution of the Tertiary vegetation and its significance in Phyto-geography of India:—

(1) **Inter-trappean Flora of the Deccan.** From the study of this flora, most of the elements of which are distributed, at the present time, in this very region, Sahni (1946) considered that estuarine conditions in which *Nipa fruticans* and Lythraceae occurred, existed during the Tertiary Period in the Deccan.

The *Enigmocarpon* and *Sahnianthus* show resemblances with the genera described from the London Clay beds, showing affinities of this flora with Europe. The migration of these and a number of other Indo-Malayan genera recorded from the London Clay flora was probably by way of the Tethys Sea.

(2) **Rajasthan Flora.** The fossil leaves belonging to the Guttiferae from this flora have affinities with *Mesua, Garcinia* and *Calophyllum.* The Guttiferae, at the present time, are common in the tropics of Asia and America but scarce in Africa. These trees mostly belong to tropical evergreen forests of India.

Mesua ferrea grows in the mountains of Eastern Bengal, the Eastern Himalaya, upper Burma, Tenasserim, the western coast of the Peninsula and the Andaman Islands. It is common in east India in almost all evergreen forests, western Duars, upper Assam, Khasi Hills and Chittagong Hill tracts. In south India, it is found only in evergreen forests of the western Ghats, south of North Kanara in Coorg, south Coimbatore, Ootacamund, south Kanara, south Malabar and Tinnevelly.

Garcinia cowa is found in S. Pegu, Mergui, Insein and Tavoy districts of Burma; Garo Hills, Khasi Hills, Darang and Kamrup in Assam; Chittagong Hill tracts of Bengal; Southern parts of Andaman Islands and Eastern Peninsula. *G. lanceaefolia* is common in evergreen forests of Lakhimpur, Sibsagar, Cachar, Nowgong, Khasi Hills, Garo Hills and Naga Hills in eastern Bengal and Assam.

Since the area comprising of eastern Bengal and upper Burma is the most suitable for a natural growth of *Mesua ferrea, Garcinia* and some others Guttiferae at the present time, it may seem probable that conditions similar to these existed in Rajasthan during the Eocene times when *Mesua ferrea* and other Guttiferae flourished in that area.

(3) **Kasauli Flora in the Himalayas**:- Most of the Kasauli plants have been assigned to Tropical and Subtropical families. There are some remains which have affinities with the Coniferae and the Lauraceae that are north Temperate in distribution. On the whole, the climatic conditions of the Kasauli flora indicate a Tropical climate, modified at places, by mountainous nature of the country and higher latitude.

(4) **Eastern Indian Flora**. The East Indian genera *Gluta, Melanorrhoea, Anisoptera, Cynometra* and *Kayea* are all distributed at the present time in the eastern region of Malaya, Philippines and Java. Of these, *Cynometra* is scattered in the tropics of both north and south hemispheres. Chowdhury (1952) compared the geological distribution of these genera with the present day occurrences and suggested that the "middle Tertiary flora of eastern India so far shows only a tropical range". The Tertiary flora of the Malayan region is also tropical. The persistence of the tropical conditions in this part of the world since the Miocene times is extremely interesting as climate in Rajasthan, Kasauli Range, and the Deccan, etc. has considerably changed since the early Tertiary times.

Bancroft (1933) has given an interesting geological and geographical distribution of the Dipterocarpaceae. With 350 species this family occurs in tropical Asia, India, Burma, Ceylon, Malayasia, Philippines, Moluccas, Celebes and New Guiana. One species is found in Seychelles and two occur in Africa. There are no Dipterocarpaceae in tropical Australia or tropical America, also there is no *Dipterocarpus* in Madagascar. The region of Burma and Malayasia seems to be the home of Dipterocarpaceae since gregarious forests occur here at low altitudes.

Dipterocarpus itself is the most widely spread genus. Its centre of origin was Malayasia in early Tertiary or late Mesozoic times. Then migration of the *Dipterocarpus* genus took place eastward to Philippines and northward to Burma, thence to India and into Africa.

In Ceylon there are more species and genera of Dipterocarpaceae than in India. So in the past India must have had a greater distribution of this family than now, as in Africa.

The brief review of the Tertiary vegetation given here shows that there were only few conifers in India during this period even in the Himalayan region. The vegetation of most of the country was mainly tropical or sub-tropical in nature. The recession from these areas of tropical vegetation was probably due to the Pleistocene glaciation and uplift of the Himalayas.

PLEISTOCENE VEGETATION OF INDIA.

The best known Pleistocene flora of India was described by Puri (1945, 1946, 1947, 1948) from the Kashmir valley. This flora is largely composed of modern species, some of which have become extinct from the valley proper, though they are still found in the neighbouring regions. This flora comprises of at least 128 modern species distributed over 69 genera and 34 families of flowering plants. Ecologically, the flora comprises of three distinct types:—

(1) **The Liddarmarg Flora**: so named after its locality - is principally composed of oaks, pine, cedar, and lauraceous plants. However, a low level simple leaved maple, box, fig, *Mallotus, Pittosporum, Berchemia, Leea, Myrsine* and silver firs (*Abies*) are also found. The angiospermic species of this flora which are discovered at an elevation of 10,600 ft., no longer form a part of the forest vegetation of the valley, but instead they thrive under tropical or subtropical conditions in Sub-Himalayan rainy forests and occupy an altitudinal zone between 3,000 and 6,000 ft.

(2) **The Laredura Flora:** which derives its name from its principal locality includes its own species, and all the plants that are discovered at Dangarpur, Nagbal, and Gogajipathri. In this flora, although we find a mingling of tropical and temperate forms, the former are much more strongly represented and dominate over the latter. The temperate species are *Aesculus indica, Acer caesium, Ulmus, Alnus,* pine, cedar, spruce, and silver firs. Thus, the general indications of this flora, which is mainly composed of three species of oak and many typically subtropical forms, e.g., *Mallotus, Woodfordia, Myrsine, Engelhardtia, Olea,* etc., unrepresented in the modern vegetation of the Kashmir Valley, tend to confirm the conclusion that this flora also like the Liddarmarg species developed under tropical conditions. This view, though it disagrees with Wodehouse's theory (Wodehouse, 1935), which postulates the existence during the Pleistocene at Liddarmarg and Laredura of a temperate climate, essentially similar to what we find today in the valley near the Manasbal Lake, satisfactorily explains the migration from the valley of tropical plants, which in response to a change in the valley climate brought about by a rise in the altitude of the Pir Panjal Range, began to inhabit the more congenial rainy parts of the outer Himalayan ranges.

(3) **The Ningal Nullah Flora:** deriving its name from its locality is composed of exclusively temperate forms like willows, poplars cherries, walnuts, maples, elms, alders and an abundance of spruce, silver firs, pine and cedar. Its modern representatives still exist in the Kashmir Valley and occupy an altitudinal zone between 7,000 and 10,000 ft. on the northern slopes of the Pir Panjal. The indications are that this part of the valley had, at least at one time during the Pleistocene, enjoyed a temperate climate essentially similar to what we find today in this region.

Modern distribution of the Pleistocene Flora and its phytogeographical importance.

Except the Coniferales, the Liddarmarg flora, which is mainly composed of oaks, lauraceous plants, figs, box, alder, maple, *Mallotus, Pittosporum, Berchemia,* etc., is unrepresented in the modern vegetation of the Kashmir Valley and the adjoining mountain slopes. The only dicotyledonous species that still survive in the valley are *Parrotia Jacquemontiana, Skimmia laureola* and *Pyrus communis,* but the altitudinal range of these species, as we shall see presently, has greatly changed since the Pleistocene. This fossil flora is characteristic of the present day subtropical and tropical rain forests of the outer Himalayan ranges. Modern representatives of the fossil species do not usually ascend to altitudes higher than 7,000 ft.; and though a few forms may be found at an elevation of 8,000 ft., their best development is seen between 6,000 and 6,500 ft.

Quercus glauca, a handome evergreen oak of the Outer Himalayan ranges, is met with in moist localities, usually along streams or ravines in valleys. It seldom ascends to an altitude of 6,000 ft. The other species (*Quercus incana*), which is also an evergreen tree of a moderately large size, occurs in the Western Himalayas between the altitudes of 4,000 and 8,000 ft., though it is gregarious in its development only between the elevations of 6,000 and 7,000 ft. It usually forms pure forests but also grows in association with such broad leaved species as *Cornus capitata, Acer oblongum, Alnus nepalensis, Machilus duthiei, M. odoratissima, Phoebe lanceolata, Litsaea umbrosa, Ulmus Wallichiana, Rhododendron arboreum, Pieris ovalifolia, Ficus nemoralis, Morus serrata, Pyrus pashia,* etc., etc. Towards the lower limit of the altitudinal zone of this oak *Quercus glauca* forms a fairly good crop. The most common shrubs, which are usually met with in oak forests are *Berberis nepalensis, B. lycium, B. aristata,*

Myrsine semiserrata, M. africana, Desmodium tiliaefolium, Loniciera quinquelocularis, Viburnum cotonifolium, Viburnum stellulatum, etc.

The commonest associates of *Quercus glauca,* which often forms pure patches along streams in the Western Himalayas, are *Quercus incana, Machilus duthiei, M. odoratissima, Phoebe lanceolata, Litsaea elongata, Rhododendron arboreum, Pieris ovalifolia, Pinus roxburghii,* etc.

Of the most abundant plants next to *Quercus* is a species of *Machilus,* which though difficult to be assigned to any one modern species with certainty, shows more resemblances with *Machilus odoratissima,* a moderate-sized evergreen tree, distributed in the outer Himalayas at altitudes of 2,000 to 7,000 ft. It usually occupies low valleys and sloping ridges of hills at higher altitudes, but at lower elevations it occurs in moist localities. In the Punjab Himalayas, it does not ascend higher than 6,000 ft. The second species of *Machilus* also found in a fossil state is *M. duthiei.* It is a shady evergreen tree larger than *M. odoratissima* and occurs in the Western Himalayas, usually in ravines and shady localities. The altitudinal zone of this species ranges between 4,000 and 8,000 ft. In the neighbourhood of Mussoorie, *M. duthiei* occurs in association with *M. odoratissima, Phoebe lanceolata, Litsaea elongata, Acer oblongum* and other evergreen trees in a mixed forest of *Quercus incana* and *Pinus excelsa.* Another small to moderate sized evergreen tree of the Lauraceae found fossilized at an elevation of 10,600 ft. at Liddarmarg, is *Phoebe lanceolata.* At the present time, this species ascends to an altitude of 6,500 ft. in the outer Himalayas, and occurs plentifully in low valleys and sub-Himalayan tracts under tropical conditions. *Litsaea lanuginosa,* another evergreen tree of the Lauraceae, is definitely tropical in its modern distribution and occurs in the outer Himalayas (fairly scattered from Kashmir to Sikkim) up to an altitude of 6,000 ft.

One of the commonest trees flourishing at the foot hills up to an altitude of 5,000 ft. is *Mallotus philippinensis,* fossil leaves of which have been found in the Karewas at two different localities, namely, Liddarmarg and Laredura. In the Himalayan subtropical pine forest of the Kangra Valley in the Punjab, it occurs (at altitudes of 3,000 to 3,500 ft) in association with *Quercus incana, Woodfordia fruticosa, Rhamnus triquetra, Pyrus pashia, Pieris ovalifolia, Albizzia stipulata, Pinus longifolia,* etc., etc. The species, also like many others, is unrepresented in the modern vegetation of the valley, though it is commonly found on the Punjab slopes of the Pir Panjal Range.

Ficus cunia, a moderate-sized ever-green tree of the Urticaceae, is found in the fossil state at an elevation of 10,600 ft. It grows in the Sub-Himalayan region from the Chenab eastwards, ascending to 4,000 ft., and spreads into Bengal and Orissa. It is fairly common in the Siwaliks, especially near Saharanpur, where it is usually associated with other subtropical plants. This species is quite common in the Bengal subtropical hill forest and according to Champion it occurs in the *Castanopsis-Schima* forest, Kalimpong division in association with *Castanopsis tribuloides, C. indica, Schima wallichii, Terminalia belerica, Eugenia spp., Albizzia procera, Grewia vestita, Litsaea polyantha, Eurya* spp., etc., etc.

In the moist temperate deciduous forests the three Western Himalayan species of *Acer* occur gregariously in association with broad leaved genera, e.g., in Dwali, Western Almora Division (Kumaon in the Uttar Pradesh). *Acer caesium* and *Acer pictum* are found in association with *Aesculus indica, Carpinus viminea, Ulmus wallichiana, Betula alnoides, Juglans regia, Fraxinus micrantha, Quercus semecarpifolia, Corylus colurna, Cornus macrophylla, Rhus punjabensis, Taxus baccata, Spiraeae.*

In the western oak fir forests of Garhwal Himalayas *Acer caesium* occurs with *Abies pindrow, Picea morinda* and several broad leaved species, namely, *Quercus semecarpifolia, Q. dilatata, Ulmus wallichiana, Aesculus indica, Corylus colurna, Rosa macrophylla, Rubus sp., Syringa emodi*, etc.

In the western mixed conifer forests of Grahan Nal, Parbatti Valley (Punjab) *Acer spp.* occurs with *Abies, Picea, Cedrus, Juglans regia, Corylus colurna, Celtis australis, Ulmus wallichiana* and here the oaks are not associated with maples. Similarly, in the broad-leaved forests of the Kashmir Valley, where the species of *Acer* are fairly abundant, we do not have a trace of oaks but the former are associated with *Populus ciliata, Juglans regia, Aesculus indica, Salix wallichiana, Ulmus wallichiana*, etc. etc.

Populus ciliata grows at the present time in Temperate Himalayan regions, from Kashmir to Bhutan at altitudes ranging from 4,000 to 10,000 ft., though it is best represented above 7,000 ft. In the Western Himalayas, according to Gamble, it is fairly abundant in mixed forests of *Quercus ilex, Quercus dilatata, Cedrus deodara* and *Pinus excelsa*, but its conifer associate in the Kagan Valley, as reported by Parker, is *Abies webbiana*. In the Kashmir Valley, it is best represented to-day at an elevation of about 7,000 ft. above the level of sea and grows in association with *Salix wallichiana*, the latter occupying moister places and *Morus serrata, Morus alba, Celtis alpina, Fraxinus excelsior, Ulmus wallichiana, Platanus orientalis, Parrotia jacquemontiana, Populus nigra, Cedrus deodara, Pinus excelsa*, etc., in sheltered places or under mesophytic conditions.

Populus ciliata is fairly gregarious outside Kashmir too, and its occurrence as taken from authentic sheets in the herbaria may be mentioned eastwards from Kashmir in Monali and Nagni in the Kulú Valley, Kalatop at Dalhousie, Matiyana and Nagkanda in the Simla Hills, Bashahr, Mussoorie and Dharmsala; and also in gregarious patches on the China slope at an altitude of 7,000 ft. in Naini Tal.

In order to appreciate properly the significance of fossil vegetation it is necessary to give here a short account of the present day vegetation of the Kashmir Valley.

Kashmir Valley Flora: In the present vegetation of the Kashmir Valley there are no oaks, laurels and several other species. The vegetation of the valley and the neighbouring mountains have the following four zones:—

1. The *Alpine* Zone. This zone begins well above the upper limit of conifer forest and ranges between the altitudes of 12,000 and 13,500 ft. The climate is extremely cold and supports a thick vegetation of stunted trees of *Juniperus communis* and *J. squamata* which hold their sway on rocky slopes. A dwarf willow, species of *Lonicera*, and *Rhododendron anthopogon* are a few of the woody plants which manage to survive here inspite of a strong wind.

2. The *White birch* Zone. This zone lies just above the coniferous forest zone between the altitudes of 10,500 and 12,000 ft. Pure community of *Betula utilis* forms a dominant feature of the scenery, though *Rhododendron campanulatum, Pyrus foliolosum, Salix denticulata, Syringa emodi* and *Lonicera spp.*, are also associated with it at these altitudes.

3. The *Coniferous Forest* Zone. In this zone the dominant tree above 7,000 ft. is *Abies pindrow*, which covers rocky slopes and clayey deposits of the older Karewas up to an elevation of 10,500 ft. The next commonest tree in this region is the blue pine, though *Picea smithiana* and *Taxus baccata*, which form almost pure communities at some places, are usually associated with it. The chief broad leaved trees and shrubs

in these conifer forests are *Prunus cornuta, Aesculus indica, Acer caesium, Juglans regia, Crataegus oxyacantha, Viburnum nervosum, Rosa macrophylla, Ribes sp., Berberis spp.*, and *Lonicera spp.*, which demand a temperate climate, with very little summer rain and a heavy snowfall during winter months. This zone receives a local rainfall during the months of January and February.

4. The *Kashmir Valley* Zone. The altitudinal range of this zone lies between 5,000 and 7,000 ft., which supports a mixed vegetation of broad leaved trees and conifer species (*Pinus excelsa* and *Cedrus deodara*), that may often form pure belts. The commonest broad leaved trees and shrubs which usually occur in gregarious patches in moist ravines, or along streams in this region, may be enumerated as follows: *Juglans regia, Populus ciliata, P. nigra var. fastigiata, P. alba, Salix wallichiana, Ulmus wallichiana, Platanus orientalis, Celtis alpina, Acer sp., Rhus sp., Morus serrata, M. alba, Fraxinus excelsior, Parrotia Jacquemontiana* and *Rhamnus purpurea.* The climatic conditions in this zone are essentially temperate, though a few tropical species may find their way in exposed places or in low situations in the valley.

Changes of climate and vegetation in the Kashmir Valley since the Pleistocene: The Kashmir slopes of the Pir Panjal which support an overwhelmingly mesophytic vegetation usually receive very little rain during summer months, whereas the Punjab slopes which lie in the direction of the prevailing monsoon winds receive a heavy rainfall during this period and consequently allow the growth of a flora which is altogether different in species from what flourishes in the Kashmir Valley. The dominant dicotyledonous trees on the Punjab slopes are oaks, laurels, figs, box, alder, *Mallotus, Woodfordia, Acer oblongum,* etc., which either form broad leaved forests or grow in gregarious patches in forests of *Pinus roxburghii* and *Pinus excelsa.* This type of vegetation grows at Murree, in the Simla Hills, Mussoorie and other places in the outer Himalayas, which receive a heavy monsoonic rainfall. The amount of moisture diminishes gradually as winds go from east to west along the Himalayas. The occurrence in the valley of a tropical rain forest would lead one to conclude that this region during the Pleistocene received a heavy monsoon rainfall. The present dry conditions in these parts are brought about by the lofty ranges of the Pir Panjal (height about 15,000 ft.) that rise on the southern side of the Kashmir Valley in the form of a formidable barrier to the monsoon winds, which are, therefore, not able to precipitate their moisture on its northern slopes; the only rain which this region receives in summer months is brought about by the winds that escape into the valley through the Jhelum gorge, near Baramulla. Thus, it seems clear that the present topography of the south eastern part of the Kashmir Valley, which directly influences the amount of rainfall, is responsible for creating in this region a temperate climate under which a mesophytic flora, altogether different in species from the vegetation of the Punjab slopes, is able to exist.

Himalayan uplift during the Pleistocene: Such a striking contrast in the composition and distribution of the past and present floras of the Liddarmarg locality is both interesting and significant. The northern slopes of the Pir Panjal Range, which supported a subtropical flora characteristic of foothill regions during the Pleistocene, now allow the growth of a temperate vegetation. This would show that the climate of the Kashmir Valley has materially changed since the early Pleistocene. Everything else remaining constant, the climate of a region usually depends upon topography and the direction of the prevailing winds. If the testimony of palaeobotany is accepted, a comparison of the past and present floras of Kashmir leads one irresistibly to the conclusion that the topographical

features of the Kashmir Valley at the time when the oaks, laurels, figs, etc., flourished in this region were very different from what they are now. The only topographical difference, which could materially change the climate of this region would amount to lowering of the southern barrier; and the evidence of fossil plants strongly favours the view that the Pir Panjal which now forms a formidable barrier to the prevailing winds was sufficiently low during the early Pleistocene, and thus allowed the southern winds to precipitate their moisture in the valley for the growth of a tropical flora. On the low ridge of those times the fossil species would have lived at much lower altitudes than those at which they are found fossilised today, and their present occurrence in elevated regions is a direct proof to show that these strata have been uplifted since the date of their deposition in the valley.

POST-GLACIAL VEGETATION OF INDIA.

There are very few available complete records of the Post-glacial vegetation of India, though some leaves and remains of other parts of plants found embedded in calcareous tuffa abundantly occur in the outer Himalayas. The study of these has, however, not been undertaken so far.

The records of the post-glacial climatic changes recognised in the Kashmir Valley and other parts of northern India tend to show, however, that vegetation must have been greatly affected by these. The present dry physiography of the country was stabilised only during the post-glacial period.

It was during this period that final phase of uplift of the Himalayan mountain belt witnessed the folding and dragging up of the youngest Karewa beds on the Pir Panjal by at least 6,000 ft., and the tilting of the late Pleistocene lake terraces round Srinagar. The effects of this upheaval were felt in the Potwar and even as far west as the Salt Range, which shows post-Pleistocene deformation. After various observations it is thought that the tilting movement must have taken place after the arrival of man in this part of the world (Sahni, 1936-37).

Wadia (1937) agrees with this view and states that during early Pleistocene times the drainage of the present Ganges valley ran northwestwards and was discharged into the Indus by a great prehistoric river. Of this river, variously called the Siwalik River, or the Indobrahm, the lower part is believed to have flowed along a northwest prolongation of the present Jumna river, and then through the broad, but now almost deserted, channel of the Soan River in the Potwar to join the Indus near Makhad, with the differential earth movements which converted the old Potwar basin into a plateau. The Punjab section of the Siwalik River was severed from the upper part of the channel, in which the flow of water became reversed and which became the modern Ganges.

De Terra and Hutchinson (1936-37) give the following sequence of Post-Glacial climatic changes in N.W. India:—

Wet.	5th terminal moraine in Kashmir, epiglacial.
—	Assumed dry interval, so far unrecorded.
Wet.	6th terminal moraine in Kashmir, epiglacial.
Dry.	Possibly dry pre-Neolithic patination of Indus boulder at Attock and Campbellpore?
Wet. Ca. 4,000-2,500 B.C.	Megalithic settlements in Kashmir, rainfall in excess of present precipitation in Baluchistan and upper Sind.

Dry. ?2,000-300 B.C.	Post-megalithic loessic soil in Kashmir. Desiccation in Baluchistan and North-West India antedating Alexander's campaign. Pre-Tibetan Man period upward extension of agriculture in the first millenium A.D.
?Wet 8th Century A.D.	Period of floods in Central Tibet.
Dry. 11th-12th Century A.D.	Submerged Hindu temples in Kashmir.
?Wet Middle.	In western Tibet (Tang-tse) drawing of stag.
Wet.18th Century-early	High lake levels on Lake Mansarovar in Tibet.
19th Century.	High lake levels in western Tibet.
Dry. Middle of 19th century.	Low lake levels in western Tibet.

Wet. Early 20th century. Almost all lakes rising in western Tibet.

As a result of the refrigeration of climatic conditions in the Post-glacial period over a large part of north India, a number of Himalayan species must have migrated to south Indian hills. An account of these plant migrations has already been given in the last chapter. Unless the wealth of plant fossils embedded in calcareous tuffa has been examined, it would not be possible to say anything more on the post-glacial vegetational changes in India.

Historical records of climate and vegetation in India: There are no direct data available from any part of the country to give changes in climate and vegetation in historic times but some indirect records of probable conditions in the historical times have recently come from Mohanjodaro. Chowdhury and Ghosh (1951) have described from remains of a coffin from Harappa woods of *Cedrus deodara, Ulmus sp., Dalbergia latifolia* and *Zizyphus spp. Deodar,* rose wood and elm have most probably been transported to Mohanjodaro and the only timber of local origin seems to have been *Zizyphus.* From this it has been inferred that scrub vegetation with tall grass and pockets of marshy lands occurred near Harappa during the historical times. Large tracts of the Aravallis, near Baran and Kotah in Rajasthan have a tree vegetation in which trees of *Zizyphus* are found. These trees are tall with a clear bole of 15-20 ft. and a spreading crown resembling *Prosopis spicigera* trees.

The civilization of the Indus Valley, between 3,000 B.C. to 2,500 B.C. appears to have been quite as advanced, in some respects even more advanced, than in contemporaneous Egypt, El-Irak and Elam. Though this civilisation is pre-Vedic and pre-Aryan, even then many of the present beliefs and cults of India can be traced in it. This civilisation has been found to have extended nearly to the foothills of the Himalayas in the north and Gujrat in the south, also to some cities of Rajputana in the west.

The occurrence of some seals found in Mohanjodaro shows the links that were probably established by trading intercourse between the Indus Valley people and their neighbours from Sumer and Elam. There are also indications of communications with Baluchistan. The period of the Indus civilisation is contemporaneous approximately with the sixth dynasty of Egypt, which came into power after the great pyramid builders had passed away.

The disappearance of vegetation in which tigers and rhinos had roamed in the Indus Valley may also be due to the export of the wood to Egypt and other countries, or by use locally in the development of the civilisation, such as burning bricks for building, etc.

Panini's work written in about 500 B. C. makes a mention of a number of forest tree species (Aggarwala, 1952) occurring in northern India.

The following trees are mentioned in the Sutras:—

Sanskrit name.	Botanical name.
1. Asvattha.	*Ficus religiosa.*
2. Nyagrodha.	*Ficus bengalensis.*
3. Plaksha.	*Ficus infectoria.*
4. Amra.	*Mangifera indica.*
5. Palasa.	*Butea frondosa.*
6. Bilva.	*Aegle marmelos.*
7. Khadira.	*Acacia catechu.*
8. Simsapa.	*Dalbergia sissoo.*
9. Varana.	*Crataeva religiosa.*
10. Sami.	*Prosopis spicigera.*
11. Pilu.	*Salvadora indica.*
12. Karshya.	*Shroea robusta.*
13. Tala.	*Borassus flabellifer.*
14. Jambu.	*Eugenia jambolana.*
15. Haritaki.	*Terminalia chebula.*

The names of trees that occur in the Ganas are:—

1. Karkandhu Badara, kuvala.	*Zizyphus jujuba.*
2. Kutaja.	*Holarrhena antidysenterica.*
3. Patali.	*Stereospermum suaveolens.*
4. Vikankata.	*Flacourtia sapida.*
5. Injudi.	*Ximenia aegyptiaca.*
6. Salmali.	*Bombax malabaricum.*
7. Udumbara.	*Ficus glomerata.*
8. Nipa.	*Nauclea kadamba.*
9. Rohitaka.	*Andersonia rohitaka.*
10. Vibhitaka.	*Terminalia belerica.*
11. Sirisha.	*Mimosa sirisa* (*Albizzia lebbek*).
12. Kantakara.	*Solanum jaguini.*
13. Karira.	*Capparis aphylla.*

This shows that a good tree vegetation with evergreen species had existed in parts of the country as early as 500 B.C., however, the plants like *Holarrhena, Capparis,* etc. give an indication of degradation of vegetation.

Randhawa (1945) has brought some interesting evidence to show that dessication in northern India has set in about 2,000 to 3,000 years ago. He pointed out that about 2,000 years ago, the Brij districts which today have a vegetation of plants that are now found in the deserts were covered with a wet tropical forest containing evergreen trees of Indo-Malayan affinities. The presence of animals of the swamps, like elephants and rhinoceros, in Sind and the western Punjab is proved from the seals recovered from Mohenjodaro and Harappa which date from Ca. 3,250 B.C. to Ca. 2,750 B.C. Sind and Western Punjab are practically deserts now. Babar and his party are said to have shot rhions near Peshawar as late as 1526 A.D.

By a close examination of the sculptures found in the excavations in Mathura, four plants were identified which were depicted in these sculptures. These are *Saraca indica, Anthocephalus indicus, Michelia champaca* and *Mesua ferrea.*

These trees are at present found in the evergreen forests of India, Burma, Ceylon, Malaya, and Sumatra, with a rainfall of over 80 inches.

Saraca indica is the most moisture loving of all the four trees, hardly surviving where rainfall is 40″.

From the present natural distributon of these four trees, Randhawa assumed that about 2,000 years ago, Mathura district, which has now almost become a desert with an average rainfall of about 24 inches, had a much higher rainfall in the past. Use of aquatic animals like fish, alligator in decoration of pillars, etc., and figures of women bathing under water falls, all suggest that there was wet climate all over Mathura.

While the more moisture loving *Saraca indica* has disappeared on account of increasing desiccation, the comparatively more drought resistant *Anthocephalus indicus* has survived in some swampy pockets. Where there were forests of Kadamba, now there are only xerophytic shrubs and herbs.

This 'Brij' country, which was once covered with luxuriant evergreen tropical forests about 2,000 years ago, has now got vegetation of the following species:—

Capparis aphylla, Salvadora oleoides, Acacia arabica, Prosopis spicigera, Balanites aegyptiaca, Diospyros cordifolia, Ficus cordifolia and several species of *Tamarix*. The wastelands between villages are more or less bare, with occasional patches of *Zizyphus rotundifolia, Salvadora persica, Butea frondosa*, etc. Rocky areas are covered with *Anogeissus parviflora. Leptadenia spartium, Alhagi camelorum, Arnebia hispidissima, Capparis bulbosa* and *Ceropegia bulbosa* are other species which are found. Mathura has got now an average annual rainfall of only 23.61 inches.

Although, there is no direct evidence available at present it appears that vegetation in most parts of the country in the past had been a forest. This has been destroyed both by the biotic interference and by the resulting desiccation of the area as a result of disforestation. Much of the Rajputana desert is man-made and it is believed that aridity and desert conditions are now being created locally over the fertile Gangetic valley and other parts of India by ruthless cutting of forests. Arid conditions are also developing in the heart of the peninsula due to disforestation. The presence of scrubby and desert vegetation is in itself an indication that it has been degraded from a high forest and that conditions are continually made more difficult for the survival of good vegetation.

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5

CLASSIFICATION OF INDIAN VEGETATION.

The best known, and in fact the only complete classification of Indian vegetation (fig. 43) available at present is that of Champion (1938). This classification is based on mainly the known climatic features of the vegetation and is admittedly preliminary. A relationship of the vegetation types with rainfall is given in fig. 44 after Chatterjee (loc.cit). The examination of the rainfall and temperature data of the various vegetation types shows that, although, main types seem to be related to temperature and rainfall, detailed classification on these factors alone is not feasible. This has already been shown by Misra and Puri (1954), and Shanbhag (1956) and Subrahmanayam (1956) have tried recently to give rational classification of Indian climate. These studies need further elaboration, however, the necessity for the revision of this classification has been felt and in this work broad lines on which it needs revision have been indicated.

The basis of classification of Indian vegetation: The vegetation of the sub-continent of India is governed by the complex of the environmental features including climate, geology, soil, forest biota and forest history. While climate paints the general picture, details are related to other factors of the habitat. In the case of an ancient country like India where much of the climax vegetation has long been destroyed, biota and edaphic features are considered more responsible for the present structure, composition and status of various vegetation types than the climate. Moreover, for management of forest vegetation in small areas soil, geology and biota are the important factors that can be manipulated for desired results. The basis for classification, therefore, must include these important factors for applied ecology.

(i) **Climate.** a. **Temperature.** The main elements of climate used by Champion in classifying vegetation types, are temperature and rainfall, though humidity, wind, etc., have also been considered in some cases, where data were available. Following Schimper and Warming, Champion divided the vegetation of the country into the following four main zones on temperature, although he was himself not quite satisfied with this zoning:—

Table 17.

TENTATIVE TEMPERATURE-VEGETATION ZONES OF INDIA.
(According to Champion).

Temperature vegetation zone.	Mean annual temperature.	Mean January temperature.	The nature of winter.
I. Tropical.	Over 75°F.	Over 65°F.	No winter and no frost.
II. Sub-tropical.	62° – 75°	50° – 65°	Winter definite, but not severe, frost rare.
III. Temperate.	45° – 62°	30° – 50°	Winter pronounced, with frost and some snow.
IV. Alpine.	Under 45°F.	Under 30°F.	Winter severe, with much snow.

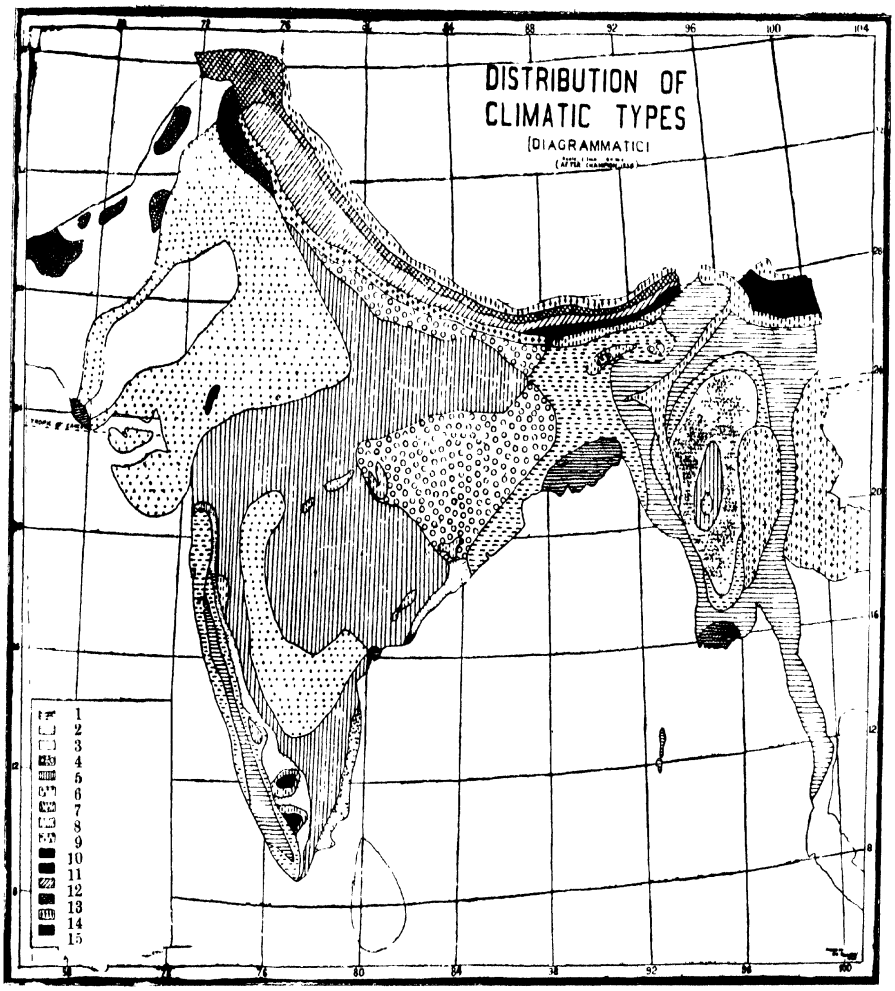


Fig 43

VEGETATION TYPES OF INDIA, ACCORDING TO H. G. CHAMPION.

1. Tropical Wet Evergreen
2. Tropical Semi Evergreen
3. Tropical Moist Deciduous
4. Tropical Moist Deciduous (*Sal*)
5. Tropical Dry Deciduous
6. Tropical Thorn Forest.
7. Tropical Dry Evergreen
8. Sub-tropical Wet Forest.
9. Sub-tropical Pine.
10. Sub-tropical Dry
11. Wet Temperate
12. Moist Temperzte
13. Dry Temperate
14. Alpine
15. Tidal

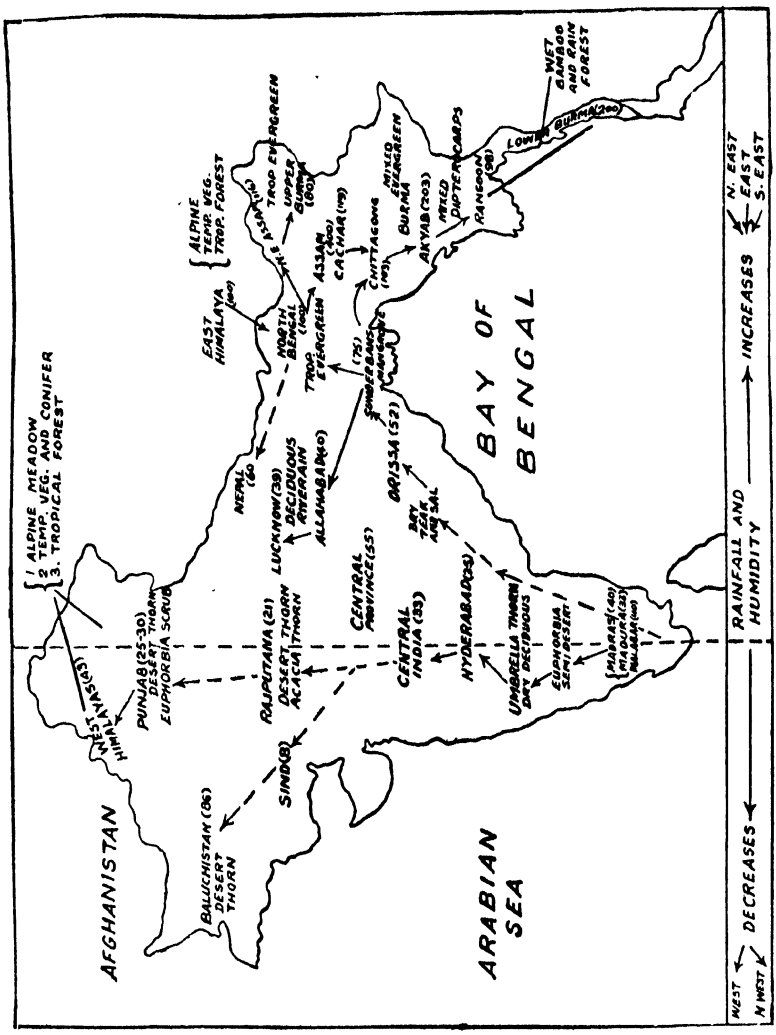


Fig. 44 MAP SHOWING
VEGETATIONAL TYPES OF INDIA AND THEIR VARIATIONS WITH RAINFALL AND ALTITUDE.
(After Chatterjee, loc. cit.)

Champion realised that on this classification the same locality falls in one zone on mean January temperature and into another on mean annual temperature. This is due, in part, to topographical differences on the altitudinal lines, some interesting examples of which may be given in Table 18.

Table 18.

TEMPERATURE DATA FOR THREE PARTS OF INDIA.

Mean Annual temperature. 62°F	In Nilgiris at 6,000 ft.	In West Himalayas at 5,500 ft.	In Assam at 5,000 ft.
January temperature of 50°F	at 7,000 ft.	at 5,200 ft.	at 5,000 ft.

The range in monthly means of temperature increases from south to north as well as from east to west on account of monsoon type of rainfall. The classification of Indian vegetation into altitudinal zones is, therefore, not correct. The rate of fall in temperature with altitude varies on the east and west sides, also with south and north. For example, on the west side of the Nilgiris there is a fall of 1° F for a rise of 330 feet; but on its eastern side, the same amount of fall in temperature occurs with a rise of 400 feet. In northern India the rate of fall during summer months is much more rapid than in winter. Temperature alone is, therefore, not a proper guide for classification of vegetation.

b. **Rainfall.** The other factor that has been considered for vegetation classification is rainfall. The main temperature zones are subdivided on the basis of available moisture content, chiefly during the growing season. Moisture content varies with rainfall and soil conditions, but on account of the absence of sufficient data, Champion considered rainfall differences as the sole criterion in vegetation classification. The examination of his types with rainfall figures shows a great over-lapping in rainfall conditions of succeeding types.

c. **Temperature and rainfall.** Thornthwaite's classification provides probably the nearest approximation for relating vegetation with temperature and rainfall. This was worked out by Misra and Puri (1954) and a tentative classification was given. Since then Subrahmanyam (1955) has made detailed studies. While these details will be given in the chapter on climate, it may be stated that according to Thornthwaite's system the climate of the south-west parts of India is not humid, since there is a deficiency of water during winter. The moisture adequacy throughout the year is found only in north-eastern section of India. Some high peaks of the Nilgiris, Western Ghats and the Palghat have no moisture deficiency in any season during the year. Champion regretted the absence of adequate knowledge of climate and it now seems that the climatic classification given by him will need some modification.

Types of Indian vegetation. Following Schimper, Köppen and Thornthwaite, Champion divided the tropical forests into a series of successively drier types as evergreen forest, deciduous forest, savanna, thorn forest and steppe. The fallacy of this system becomes at once apparent when we know that there are no climatic grasslands and steppes known from India. Of the other types, savanna and thorn forests are largely biotic or bio-edaphic communities. The deciduous forests in some parts of the country are also not truly climatic. There are some differences in the composition of forests on the north and south of the Tropic of Cancer.

These differences are only partly climatic, having been exaggerated by biotic features and geological structure of the hills, etc., and it would be difficult at present to state definitely whether the division of these types into northern and southern sub-types be permissible, especially when the climatic zones run from east to west. Champion's classification has, therefore, been followed in this book only with slight modification. The need for further detailed studies on this topic are indicated.

Tropical climax types. The tropical forests of Champion are subdivided in table 19.

Table 19.

CLASSIFICATION OF TROPICAL FORESTS OF INDIA ACCORDING TO SUCCESSIVE DRYNESS OF THE HABITAT.

(Modified from Champion.)

Type of forest.	Brief characters of vegetation.
1. Wet evergreen or rain forest.	Dense tall forest, entirely evergreen or nearly so.
2. Semi-evergreen forest.	Dominants include deciduous species, but evergreens predominate.
3. Moist deciduous forest.	Dominants mainly deciduous but sub-dominants and lower storey species largely evergreen. Top canopy rarely dense even, but over 80′ high.
4. Dry deciduous forest.	Entirely deciduous, or nearly so. Top canopy rather light and rarely over 80′ high.

Of these the dry deciduous forests cannot be called truly climatic, but appear to be degraded forms of the moist deciduous type, due to biotic interference.

The thorn forest and dry evergreen types, given by Champion under tropical climax types, are not confined only to tropical regions but also occur as degraded forms of normal forests in sub-tropical and temperate regions, occupying areas that had been very greatly disturbed by the human factor. These two types are, therefore, taken away and are described under biotic types.

The differences in the north and south forms of the above sub-types of tropical forests, are largely in their floristic composition and as already noted this may not be due to climate but to biotic and edaphic features. It would, therefore, be advisable to drop the distinction and treat the types in their entire zone of distribution, treating differences as different communities.

Tropical-edaphic types. In his classification Champion has recognised the role of soil in the development and classification of Indian vegetation. But in the absence of detailed knowledge of Indian forest soils he had been forced to take only the criterion of maturity or otherwise of the soil in the classification of vegetation. Thus, the vegetation types occurring on mature soils in a particular climate have been called climatic climax, while types on immature or newly formed soils have been designated as edaphic variations of climatic climaxes. These types are truly seral in character, but in some cases when the evidence for rapid succession of these types to climatic climaxes are lacking, they have been called edaphic climaxes - a term which has been disfavoured by Clements (1936). Champion

used the terms sub-climax and pre-climax for some such types and post-climax for types that have been influenced largely by historical factors and biotic influences.

In addition to the climax types of tropical forests given in table 19, the following four edaphic pre-climaxes have also been recognised (table 20):—

Table 20.

EDAPHIC PRE-CLIMAXES IN TROPICAL FORESTS OF INDIA.

(Modified from Champion.)

(i)	Beach forest.	On coastal sand, usually seral to wet evergreen or semi-evergreen and somewhat resembling the latter in physiognomy.
(ii)	Tidal forest.	On estuarine mud, seral to any of the climax types and nearest in form to the dry evergreen type.
(iii)	Fresh water swamp forest.	On wet alluvium seral to wet evergreen, semi-evergreen, moist or dry deciduous and resembling in physiognomy the semi-evergreen climax.
(iv)	Riverain forests.	On new alluvium often, periodically inundated, seral to wet evergreen, semi-evergreen, moist and dry deciduous, and resembling dry deciduous or the thorn forest in physiognomy.

Although, these types have been called pre-climaxes in nature they do not progress to the climax stage to which they pertain. They remain fixed in their particular types in this condition.

Biotic types. There had been a variety of human malpractices in the past in the country which have greatly modified the normal course of development and successional relationships of the Indian forest vegetation. The chief of these is the shifting cultivation; fire, grazing and the forest management have also affected the forest succession, either by checking the progression of vegetation to the higher successional stage or by bringing about a retrogression. Champion has not separated this category of vegetation types. The types now classified under biotic were placed by him as seral under different climatic types.

The following biotic types which are secondary in origin are, therefore, recognised as distinct from climatic or edaphic:—

Table 21.

BIOTIC VEGETATION TYPES.

Vegetation type.	Brief characters of vegetation.
1. Dry evergreen.	Hard leaved evergreen trees predominate, often dense, but usually under 60′ high, preserved mainly by biotic factors.
2. Thorn forest.	Deciduous low thorny trees with xerophytic features, canopy always broken.
3. Savanna.	Deciduous trees scattered in grassy flats.
4. Grasslands.	Grassy areas preserved by fire, grazing, etc.
5. Desert scrub.	Xerophytic thorny, mealy or aphyllous bushes, heavily browsed.

Sub-tropical Forest. The sub-tropical and temperate forests of India are really montane sub-tropical and montane temperate. On account of the monsoonic pattern of rainfall all types of vegetation should as a matter of fact be called monsoonic. The differences in sub-tropical and temperate types of vegetation are due to the physiography, topography, and altitude, which bring about differences in rainfall and temperature conditions. Thus, montane sub-tropical forests are distinguished from the tropical and the montane temperate types on altitude rather than latitude. The sub-tropical zone forms more or less a transition from the tropical to the temperate and some times it is difficult to distinguish it from either of the two on the form or composition of vegetation. In the western and central Himalayas, the types occupy distinct areas, but in south Indian hills there is no sharp distinction between tropical and temperate vegetation. With a slight change in the amount of moisture the subtropical form may extend into the altitudinal zone of the temperate, or vice versa. Here geology and soil differences associated with differences in altitudes also play important part in differentiating the zonation of the two types. The types of montane sub-tropical forests recognised by Champion are given in table 22.

Table 22.

SUB-TROPICAL TYPES OF INDIAN VEGETATION.

(After Champion.)

	Type of forest.	Brief characters of vegetation.
(i)	Sub-tropical wet hill forest.	Composed of broad leaved, largely evergreen high forest trees.
(ii)	Subtropical moist hill (pine) forest.	Pine is the predominant tree.
(iii)	Sub-tropical dry evergreen forest.	Low xerophytic forest and scrub, which may be partly biotic.

Champion divides the first type into northern and southern forms, but there does not seem to be much justification for this subdivision and the type is considered as a whole. The second type of Champion really seems to be an edaphic association, since in its stable stage pine community is confined to quartzite formation in the Himalayas. The third type may also be not truly climatic. These deviations from Champion have thus to be recognised here.

Temperate forests. Montane temperate forests were also divided by Champion into south and north Indian types, of which there are slight differences in rainfall patterns. These are given in table 23.

Table 23.

MONTANE TEMPERATE TYPES OF INDIAN VEGETATION.

(After Champion.)

	Type of forest.	Brief characters of vegetation.
(i)	Wet temperate forest.	Evergreen forest without conifers.
(ii)	Himalayan moist temperate forest.	Evergreen forest, mainly sclerophyllous - oaks and conifers.
(iii)	Himalayan dry temperate forest.	Open coniferous forest with sparse xerophytic under growth.

The south and north types of the wet temperate forests are very different but the moist and dry temperate forests are confined to the Himalayas. Geological and soil features, remarkably influence the type of vegetation that grows in these zones. The second type is greatly disturbed. Conifers owe their existence in Oak climax to biota or natural disturbance in the geological and soil complexes. The third type is due also to biotic interference.

Alpine forests. Alpine forests are found only in the Himalayas above the forest limit, although some stunted deciduous or evergreen trees with or without conifers and scrub and park-lands are also classified under this. Three main types are recognized as follows:—

Table 24.

ALPINE TYPES OF INDIAN VEGETATION.

(After Champion.)

	Type of forests.	Brief character of vegetation.
(i)	Alpine forest.	Stunted deciduous or evergreen forest, usually in close formation with or without conifers.
(ii)	Moist Alpine scrub.	Low, but often dense scrub.
(iii)	Dry Alpine scrub.	Xerophytic shrubs in open formation.

The first type is influenced by geological conditions and the other two are partly edaphic, being influenced by sheep grazing in high altitudes. The concept of these also needs modification when more data are available.

Objection to the climatic classification of Indian vegetation. The critical examination of Champion's classification in the light of additional data on the environmental factors that have been collected since 1938, seems to indicate the necessity of changes, some of which have been indicated. The well known phenomenon of latitudinal differences in vegetation witnessed in Europe is not visible in India. As indicated in the preceding pages some of the types considered by Champion as climatic are really edaphic or biotic or both. Another important change is in the nomenclature of the temperate type. The rainfall pattern and its effect on soil development in the Himalayas gives the impression that climate of the wet and moist temperate forests is not humid and these may, therefore, be properly classed with the tropical types. The dry temperate type only may probably be truly temperate in character, but that too seems to have mediterranean resemblances than the north temperate.

The typical tropical forests types developed in India also seem to be somewhat different from those in other countries.

The rainfall patterns and climographs for the Indian vegetation according to Champion's classification given by Misra and Puri (1954) exhibit a strong monsoonic pattern, therefore, the designation of some of the Himalayan and Nilgiri types as montane temperate has been rightly objected by Burtt Davy (1938), whose classification of tropical vegetation is discussed in the next few pages.

Another noticeable feature that needs pointing out in Champion's classification is the successional terminology used by him. The use of edaphic climax, although Burtt Davy agrees with Champion in its adoption, will not be acceptable to Clementsian school, which has been followed in most other cases. This can be avoided by calling the edaphic climaxes as fixed seral communities ,or pre-climaxes or sub-climaxes.

Much of the Indian vegetation has been greatly influenced in historical times by biotic influences. A great many types are biotic - controlled, others owe their existence and persistence to shifting cultivation, fire, etc. Recognising this there is little scope for using the word climatic climax or edaphic climax for most of the vegetation types.

Another feature that is absent from other tropical regions is the effect of glaciation during the Pleistocene period. This has, most probably, brought in a great deal of disturbance in the original vegetation of the country. There is a strong body of evidence to show that the presence of the Mediterranean, north European, and alpine elements in the Himalayan mountains is the direct result of glaciation. In the Himalayas, such elements are very little developed in unglaciated areas.

The existence of the Satpura range of hills right through the Bengal-Garo hill gap to Assam hills in geological times, as envisaged by Hora (1950), is another feature which has to be examined while discussing the position and distribution of some of the tropical types in different parts of India.

The rainfall in India is largely monsoonic and the climatic zones, such as humid, sub-humid, semi-arid, and arid follow from south-east to north-west. These are differentiated by the movement and direction of the Bay of Bengal branch of the monsoon. In south India, the Arabian sea-branch of monsoon affects the zonation of vegetation types on the western coast. Thus, it seems that the latitudinal zonation of vegetation, as is found in Europe and America, does not follow in India. Here the zonation is governed by monsoon and follows other S. E. Asian countries like South East China, Indonesia, and Japan. In the revision of Champion's classification of Indian vegetation these facts have to be considered, particularly.

Classification of Indian vegetation. The classification of Indian vegetation according to Champion, as modified according to the above concepts is given below. It may be stressed that the modifications suggested at present are by no means complete and indicate only lines of future work.

CLASSIFICATION OF INDIAN VEGETATION.

(Modified and re-arranged from Champion.)

MOIST TROPICAL FORESTS.

(A) Climatic.

Tropical wet evergreen forests.

Group 1 *a. Southern tropical wet evergreen forests.*

1. Evergreen *Dipterocarp.*
2. Eastern tropical evergreen.
3. Western tropical evergreen.
4. Low tropical evergreen.

Group 1 *b. Northern tropical wet evergreen forests.*

1. U. Assam tropical evergreen.
2. Cachar tropical evergreen.
3. N. Bengal tropical evergreen.

Tropical semi-evergreen forests.

Group 2 *a. Southern tropical semi-evergreen forests.*

1. West coast semi-evergreen.

Group 2 *b. Northern tropical semi-evergreen forests.*

1. U. Assam semi-evergreen.
2. Cachar semi-evergreen.
3. Sub-Himalayan semi-evergreen.
4. Orissa semi-evergreen.

Tropical moist deciduous forests.
Group 3 a. Southern tropical moist deciduous forests.
1. S. Indian moist deciduous forests.
Group 3 b. Northern tropical moist deciduous forests.
1. Moist *sal.*
2. Wet hill *sal.*

(B) (i) **Primary Edaphic.**
1. *Beach.*
2. *Tidal.*
   (a) Low mangrove.
   (b) Tree mangrove.
   (c) Salt water *Heritiera.*
   (d) Fresh water *Heritiera.*
3. *Delta fresh water swamp.*
4. *Tropical valley fresh water swamp.*
5. *Moist riparian fringing.*
6. Khair-sissoo
7. *Riverain moist deciduous.*
   (a) Southern moist deciduous riverain.
   (b) Gangetic moist deciduous riverain.
   (c) U. Assam moist deciduous riverain.
8. *Riverain semi-evergreen.*
   (a) Southern riverain semi-evergreen.
   (b) Northern riverain semi-evergreen (*Terminalia-Phoebe*).

(B) (ii) **Subsidiary Edaphic.**
1. *Eastern laterite semi-evergreen.*
2. *Western laterite* (*Xylia*) *semi-evergreen.*
3. *Andamans moist deciduous.*
4. *N. Indian moist deciduous.*
5. *N. India Terminalia.*
6. *E. Himalayan moist deciduous.*
7. *Cane brake.*
8. *Southern wet bamboo brake.*
9. (*a*) *Southern moist bamboo brake.*
9. (*b*) *Northern moist bamboo brake.*

(B) (iii) **Secondary edaphic.**
1. *Secondary evergreen Dipterocarp.*
2. *Secondary semi-evergreen.*
   (a) Southern secondary semi-evergreen.
   (b) Northern secondary semi-evergreen.
3. *East sub-Himalayan wet mixed.*
4. *Wet sal.*
   (a) Wet plains *sal.*
   (b) Coastal *sal.*
5. *Secondary moist deciduous.*
   (a) Southern secondary moist deciduous.
   (b) Northern secondary moist deciduous.
6. *Secondary bamboo brake.*

(C) **Biotic.**
1. *Moist savannah.*
   (a) Lower alluvial savannah.
   (b) Upper alluvial savannah.

DRY TROPICAL FORESTS.

(A) **Climatic.**
Tropical dry deciduous forests

Group 4 *a. Southern tropical dry deciduous forests.*
1. Dry teak.
2. South Indian dry mixed deciduous.
3. Red sanders.

Group 4 *b. Northern tropical dry deciduous forests.*
1. Northern dry mixed deciduous.
2. Dry *sal.*

Tropical dry evergreen forests.

Group 5. *Tropical dry evergreen forests.*

(B) **(i) Primary edaphic.**
1. *Southern dry tropical riverain.*
2. Khair-sissoo.
3. *Tamarix-poplar.*
4. Inundation babul.

(B) **(ii) Subsidiary edaphic.**
1. *Hardwickia.*
2. *Boswellia.*
3. *Butea.*
4. *Anogeissus pendula.*
5. *Aegle.*
6. *Babul.*
7. *Laterite thorn.*
8. *Inland dune.*
9. *Gangetic saline scrub.*
10. *Dry bamboo brake.*

(C) **Biotic.**

Tropical thorn forests.

Group 1 *a. Southern tropical thorn forests.*
1. Southern Cutch thorn forest.
2. Carnatic umbrella thorn forest.
3. Southern *Euphorbia* semi-desert scrub.

Group 1 *b. Northern tropical thorn forests.*
1. Northern desert thorn forest.
2. Northern *Acacia* scrub.
3. Northern *Euphorbia* scrub.
4. Secondary dry deciduous.
5. Dry deciduous scrub.
6. Dry savannah.

MONTANE SUBTROPICAL FORESTS.

(A) **Climatic.**

Group 6 *a. Southern subtropical wet hill forests.*
1. Nilgiri subtropical evergreen.
2. Coorg subtropical evergreen.
3. Bombay subtropical evergreen.
4. C. Indian subtropical evergreen.

Group 6 *b. Northern subtropical wet hill forests.*
1. Bengal subtropical hill forest.
(a) *Castanopsis-Schima.*
(b) *Schima-Castanopsis-Phoebe.*
(c) *Engelhardtia-Castanopsis-Schima-Betula.*
(d) *Ostodes.*
2. Assam subtropical hill forest.

Group 7. *Subtropical pine forests.*
1. Himalayan subtropical pine.
2. Assam - Burma pine.

Group 8. *Subtropical dry evergreen forests.*
1. Olive.

(C) **Biotic.**
1. *Nilgiri subtropical hill savannah.*

MONTANE TEMPERATE FORESTS

(A) **Climatic.**

Group 9 *a. Southern wet temperate forests.*
1. Southern wet temperate.

Group 9 *b. Northern wet temperate forests.*
1. E. Himalayan wet temperate.
   (a) *Laurel* (*Machilus--Michelia*).
   (b) *Buk Oak* (*Quercus lamellosa*).
   (c) *High level oak* (*Quercus pachyphylla*).
2. Assam wet temperate.

Group 10. *Himalayan moist temperate forests.*
1. Lower oak-Coniferous.
   (a) *Ban oak* (*Quercus incana*).
   (b) *Deodar* (*Cedrus*).
   (c) *Eastern oak - hemlock* (*Tsuga*).
2. Middle oak-coniferous.
   (a) *Moru oak* (*Quercus dilatata*).
   (b) *Western mixed coniferous.*
   (c) *Eastern mixed conferous.*
3. Upper oak coniferous.
   (a) *Kharshu oak* (*Quercus semecarpifolia*).

Group 11. *Himalayan dry temperate forests.*
1. Dry temperate mixed evergreen.
2. Dry temperate coniferous.

(B) **Subsidiary-Edaphic.**
1. *Cypress.*
2. (a) *Temperate moist deciduous.*
   (b) *Temperate dry deciduous.*
3. *Alder.*
4. *Temperate* Hippophae *scrub.*

(C) **Biotic.**
1. *Lower blue pine.*
2. *Oak scrub.*
3. *Secondary temperate scrub.*
4. *Thach parkland.*
5. *Temperate grass-land.*
6. *Western oak-fir.*
7. *Eastern oak-fir.*

ALPINE FORESTS.

(A) **Climatic.**

Group 12. *Alpine forest).*
1. Birch-fir (*Abies*).
2. Birch-*Rhododendron.*

(B) **Subsidiary Edaphic.**
1. *High level blue pine.*
2. *Larch.*

(C) **Biotic.**
Alpine scrub.

Group 14. Moist alpine scrub.
Group 15. Dry alpine scrub.

Classification of tropical vegetation. The classification of tropical vegetation has been attempted outside India by Schimper, Warming, Tansley and Chipp, mainly on rainfall, temperature and humidity conditions. These classifications for small regions, were recently critically examined by Burtt Davy (1938) who put forth a synthetic classification for application to the whole of the tropical region. This classification is no doubt a commendable effort but there are obvious difficulties in applying it to India. The chief of these is that, although geographically India is a part of the tropical region, its vegetation has resemblances with temperate forests of northern latitudes. The Indian region has a strong monsoonic climate and thus it differs from other tropical regions. Indian vegetation has Chinese, Japanese and Indo-Malayan elements, which makes it difficult to apply Burtt Davy's classification however, it is given here for its interest.

Burtt Davy's classification for tropical vegetation. In this classification, Burtt Davy combines Champion's classification for India and Burma with those of Chipp and his own for Africa, and of Warming and Schimper of other countries in the tropics. His main units of vegetation are formation types, as defined by Schimper, to be made up of a number of associations. A formation is a group of plants, such as a forest meadow, that has a fixed physiognomic character and is considered to be stable in terms of historic times. Formations are of two kinds (a) climatic formations controlled by climate over large areas and may or may not be climax, (b) Edaphic formations as controlled by some feature of the soil in small areas, in discontinuous patches. Edaphic formations are subordinate to climatic climaxes and since they remain more or less stable, as long as the particular edaphic environment remains, they are necessarily seral to the climatic climax. These are designated edaphic climaxes as they do not show a proof of rapid change.

Champion, although considers these edaphic climaxes as seral stages, calls them climaxes. The three main formations of Schimper, called by Burtt Davy formation types, have been named after the dominant life forms which are determined by available moisture content in the habitat, whether atmospheric or telluric. These are:—

1. **Woodland.** Including all such formations which have trees and shrubs as dominant plants, either with, or without, a herbaceous undergrowth of ferns, mosses, grasses, etc. This formation type is represented in India by a number of well defined forms.

2. **Grassland** is applied to grassy vegetation, mostly devoid of trees and shrubs, which only occur here and there. Besides grasses, other herbaceous plants are also present. The climate is characterised by a rainfall of 10-20 inches per annum, falling mainly in summer or spring. This formation is typically absent from India as Indian grasslands are all seral, being biotic or bioedaphic communities.

3. **Desert** is a vegetation type of stunted trees or shrubs with annual and perennial herbs. This type is also not found in India as climatic climax. But most Indian deserts are bio-edaphic or biotic in origin and nature.

4. **Tropical Woodlands.** (a) Moist woodlands in the tropics occur in areas of abundant moisture. Trees are buttresed and less branched, growing straight. Of these 7 types are climatic climax and 5 edaphic climax.

(b) Dry woodlands are the areas that have smaller amounts of water and they rank intermediate between moist evergreen woodlands and grass steppe or desert. Burtt Davy's scheme is given in table 25.

Table 25.

CLASSIFICATION OF TROPICAL VEGETATION.

(compiled from Burtt Davy.)

Burtt Davy's classification for the tropical vegetation.	Champion's classification for India.	Schimper's, Chipp's and other classifications of tropical vegetation.	Brief description of the type.
A. Woodland formation in the tropics.			
(a) Moist woodlands in the tropics			
(i) Moist climatic formations.			
(1) Tropical lowland evergreen rain-forest.	Wet evergreen forest (rain-forest).	Rain-forest; Tropical rain-forest; Lowland rain-forest; Equatorial rain-forest; Wet evergreen-forest.	This is a closed, tall evergreen forest with at least 100ft. tall trees, may reach 200 ft.. buttressed with woody lianes, woody epiphytes, large leaves.
Subformation. Tropical lower-montane ever-green rain-forest.	Montane subtropical forest.	Subtropical rain forest; Montane subtropical forest.	It does not appear to differ sufficiently from the last named formation.
(2) Tropical semi-evergreen rain-forest.	Tropical semi-evergreen forest.	Tropical semi-evergreen forest; Semi-evergreen forest; Evergreen forest; Transition forest; Mixed deciduous forest in part; Wet mixed forest; Low level evergreen-forest.	Dominants include deciduous species, but evergreens predominate.
(3) Tropical moist deciduous forest.	Tropical moist deciduous forest includes the important teak bearing forests, *Terminalia* forests of Bombay. and the Padauk forests of the Andamans.	Monsoon forest; Tropical moist deciduous forest; Moist deciduous forest; Moist mixed deciduous forest; Mixed deciduous forest in part.	Deciduous are the dominants and evergreens largely form the sub-dominant and lower storeys. Top canopy rarely dense but over 80 ft. high. In Africa this is, perhaps only a subformation of Tropical semi-evergreen rain-forest.

(4) Tropical upper-montane rain-forest.	Montane wet temperate forest. Broad leaved evergreen forests without conifers.	Temperate Rain-forest in the tropics; Temperate Rain-forest; Warm-temperate Rain forest, Mountain-forest; Montane Rain-forest; Montane wet temperate forest; Warm-temperate montane broad leaved Rain-forest: Hill forest; High-forest, Cloud forest; Subtropical evergreen forest.	Trees evergreen, broad leaved, without buttresses; Lianes fewer and thinner in stem; Epiphytes much smaller; usually herbaceous, and represented far more by Cryptogams than by Phanerogams, with an extraordinarily luxuriant development of epiphytic lichens, or mosses.
(5) Tropical high-montane conifer-orest.	Montane temperate coniferous forest.	Montane temperate coniferous forest: Warm temperate evergreen conifer-forest.	The coniferous genera *Widdringtonia* in Nyasaland and *Juniperus* in Kenya, form an evergreen forest zone at 7,000 to 9,000 ft.
(6) Tropical montane bamboo forest.	Temperate bamboo brakes (Not accepted as climax).	Temperate Bamboo-brakes.	It occurs between 7,500 and 11,000 ft. on the equatorial mountains of East Africa. *Arudinaria alpina* dominant growing to 40 to 65 ft. height.
(7) Tropical alpine elfin-woodland.	Alpine forests of the Himalayas.	Alpine forest; Elfin-wood; Krummholz; Subalpine evergreen scrub forest.	It is the belt of alpine woodlands above the Tropical high montane conifer forest and the tropical montane Bamboo forest.
(ii) Moist edaphic formations.			
(8) Tropical riparian woodland.	Riparian forest; Riverian forest.	Fringing forest; Riverain forest; Moist Riparian fringing forest; Gallerie-wald (German); Gallerie-forest (French); Riparian fringing forest; Hydrophilous fringing bush.	An edaphic formation of river banks, dependent on a constant supply of telluric moisture.
(9) Tropical fresh swamp forest.	Tropical fresh water Swamp forest.	Swamp vegetation.	On water-logged alluvial soil, consists of several tiers, tall trees 60 to 70 ft. high, small trees, shrubs and plants clothing the ground. Usually contains palms.
(10) Tropical palm-swamp.	Not found in India.	Tropical palm-grove.	Palm-groves devoid of grassy ground cover frequently occur on soils which become swampy during the rainy season.

Table 25. (Contd.)

Burtt Davy's classification for the tropical vegetation.	Champion's classification for India.	Schimper's, Chipp's and other classifications of tropical vegetation.	Brief description of the type.
(11) Tropical mangrove woodland.	Tidal forest.	Mangrove, Mangrove swamp; Tidal forest.	Below high tide mark: sometimes forest like, sometimes more shrub like or bush like.
(12) Tropical littoral woodland.	Beach forest, Dune forest.	Strand vegetation; Beach forest; Dune forest.	On sandy and gravelly sea shores; not subject to immersion but under constant maritime influence; often sclerophyllous.
b. Dry wood-land in the tropics.			
(13) Tropical dry evergreen forest.	Tropical dry evergreen forest.	Dry evergreen forest, Dry zone forest.	Hard-leaved evergreen trees predominate under 60 ft. high; stocking often dense.
(14) Tropical savanna woodland.		Tree savannah; Bush savannah; Parkland; Dry forest; Tree veld; Savanna forest; Trockenwald (German).	Xerophilous trees, deciduous, small leaved, top canopy light, scattered shrubs, much tufted grass. Rainfall mostly below 50 inches with a rainless cool season of 7-8 months.
Sub-formations.			
(i) Tropical savanna forest.	Tropical dry deciduous forest.	Bush forest; Campos serrados, Tropical dry deciduous forest; Dry forest; Dry deciduous forest.	The climatic climax, deciduous savanna trees rarely over 80 ft. high, closely spaced; with closed canopy; a grassy ground cover, annual rainfall 40-50 inches.
(ii) Tropical open woodland.	Not found in India.	...	No closed canopy, trees in groups, herbaceous ground-cover, rainfall below 40 inches.
(iii) Tropical orchard country.	Not found in India.	Orchard-steppe; *Acacia*-Tall grass savanna.	Orchard like appearance with trees and palms occurring singly, generally scattered throughout the grass, dry season longer.

(iv) Tropical high grass low tree savanna.	Not found in India.	...	Low trees occurring in groups or singly, with short gnarled and generally blackened stem; grass 5-12 ft. high.
(v) Tropical dry palm stands.	Not found in India.	...	Palm stands with grassy ground cover. Pure group or belts of palms in tall grass.
(vi) Tropical bamboo-brake.	Not found in India.	...	Patches of bamboo, occur occasionally in Savanna-Woodland.
(15) Tropical thornland.	...	Thorn country; Thorn veld; Thorn Bush steppe; Orchard Steppe (in part); *Acacia*-Desert grass savanna.	Vegetation dominated by thorny trees or bushes. Dry season prolonged; Range of temperature great.
Sub-formations.			
(i) Thorn forest.	Thorn forest.	...	Dense thorny bushes, thin-stemmed climbers; general absence of grass.
(ii) Savanna-thornland.	Not found in India.	...	Thorny shrubs and trees predominate; Ground cover of grass and other herbs.
(iii) Thorn scrub.	Not found in India.	...	Grass absent, succulents abundant; Thorny trees sparse, passing into desert.
B. Grass-land formations. in the tropics.			
(16) Tropical grassland.	Not found in India.	Grass veld; Savanna; Savana; Savana; Grass steppe; Meadows; Marsh grassland; Mountain grassland.	Herbaceous vegetation, trees or shrubs scattered, Grasses or sedges predominate. Rainfall 10-20 inches or more, fairly evenly distributed. Hygrophilous or xerophilous.
C. Desert formations in the tropics.			
(17) Desert vegetation.	Not given by Champion, but found in India.	...	Sparse community, stunted trees and shrubs, annual or perennial herbs, Plants xeromorphic and succulent. Two morphological types (1) depend on direct precipitation (2) depend on telluric moisture.
Sub-formation.			
(i) Tropical semi-desert vegetation.	Not given by Champion but found in India.	...	Vegetation xerophytic, less sparse than that of true desert.

As already noted, Burtt Davy emphasises the absence of temperate vegetation from the Tropics, objecting to Champion's terminology of Montane temperate forests. As Champion (1936) himself admits this may justified. The term tropical or monsoon may be used for moist and wet emperate types of Champion.

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SECTION B

In this section an illustrated account of all types of Indian vegetation, climatic, edaphic and biotic, is given in detail. Forests, grasslands, deserts and aquatic habitats are classified ecologically. Successional status of each type and successional relationship of various communities are given.

6

ALPINE VEGETATION OF INDIA

The Alpine vegetation of India consists of alpine deserts, scrubs, meadows and forests, occuring throughout the Himalayan mountains above an altitude of 10,000 feet. While other types are believed to be climatic climax, the status of alpine meadow is doubtful and it may have been partly shaped by biotic features. The alpine vegetation of India is believed to contain a number of plants that are common with alpine regions of Europe. There are also central Asian, Tibetan and Japanese plants in the alpine belt of the Himalayas. No systematic study of alpine vegetation has so far been done and the following account of different types may be inadequate.

Himalayan alpine habitats are characterised by glaciers and glacial deposits, such as moraines, outwash, etc. (Photo 1).

(a) **Alpine Stony Deserts:** Stony deserts are found in the Himalayas a little below the zone of perpetual snow, above an altitude of 12,000 - 14,000 feet. The habitat is characterised by the presence of screes and bits of rocks, heavily encrusted with lichens, among which plants of *Sedum* and *Androsace* predominate. Sahni and Raizada (1955) have given a description of a stony desert above 13,000' in the Panch Chulhi area. *Sedum crassipes* and *Primula minutissima* have been recorded on glacial moraines and rocky slopes, respectively. They state that "here every little outcrop becomes a miniature rock garden. The most striking plant amongst rocks near the region of perpetual snow is *Saxifraga imbricata* Royle, a pretty cushion-like herb with creamish white flowers on high mountain tops which grows on precipitous rocks adapted against high winds and snow. This was seen on the upper basin of Panch Chulhi at 19,000 ft. *Sedum crenulatum* Hk. f and Th., a fleshy herb with succulent leaves in a rosette, was seen growing on sunny precipitous rocks at 19,000-20,000 ft." Photo 2 shows a rocky substratum at 11,500 ft. at Choor Peak with *Saxifraga stracheyi*.

The maximum altitude in the Himalayas from where flowering plants have been discovered is 20,000 ft. One of the Mount Everest parties collected *Leontopodium* and *Arenaria* at an altitude of 20,000 ft. There is no other record of the flowering plant above 20,000 ft., although one plant was found at over 21,000 ft. which however, is reported to have been lost.

(b) **Alpine Scrub:** Alpine scrub vegetation occurs throughout the Himalayas above the altitude of 10,000 - 12,000 ft. merging with the northern Tibetan plateau. In the western Himalayas in Kashmir, Lahaul, Garhwal, Kumaon, etc., tree limit often extends to about 12,000 ft. In the eastern Himalayas, however, it goes up to 12,500 to 13,000 ft. as in the Chhumbi valley, or even higher. Above this altitude the tree vegetation is replaced by shrubs, cushion plants and herbs. In the western Himalayas, dwarf willows and *Junipers* (Photo 3) predominate, whereas *Rhododendrons* (Photo 4) are the most common features in the eastern Himalayas. Typically alpine plants are carpet-like with a very short stem, buried in the soil. Above the soil the woody branches are prostrate and closely

packed together, spreading over a considerable area bearing numerous tufts of leaves. The whole structure is woven over the soil in the form of a carpet. In higher parts of Sikkim, above 12,000 ft., *Rhododendron anthopogon* (less than a foot in height) and *Salix sclerophylla* (3–4 inches in height) form typical carpets.

Smith and Cave (1913) have given an interesting account of the vegetation of Zemu and Llonakh valleys in the Sikkim Himalayas. Zemu glacier is situated above 13,000 feet. Up the glaciers on flats which were kept cool and moist by melting snow *Primula capitata, Picrorhiza kurrooa, Gentiana phyllocalyx, Salix, Diapensia, Diplarche* were recorded.

The Zemu vegetation is divided into three zones as follows:—

(1) From 8,000 - 11,000 feet *Picea, Larix, Tsuga, Abies, Juniperus* and numerous species belonging to the following genera are met with:— *Berberis, Ilex, Euonymus, Acer, Rubus, Neillia, Rosa, Spiraea, Pyrus, Ribes, Pentapanax, Viburnum, Lonicera, Gaultheria, Rhododendron, Enkianthus, Litsaea, Daphniphyllum, Elaeagnus, Corylus, Betula, Alnus.*

(2) From 11,000 - 14,000 feet the characteristic vegetation consists of :— *Berberis, Pyrus, Cotoneaster, Ribes, Lonicera, Rhododendron, Salix, Meconopsis, Cardamine, Corydalis, Lychnis, Astragalus, Potentilla, Sedum, Epilobium, Heracleum, Angelica, Saussurea, Primula, Pedicularis, Salvia, Polygonum, Rheum, Polygonatum, etc.*

(3) From 14,000 - 18,000 feet about the limit of vegetation the prevailing genera are *Anemone, Corydalis, Draba, Potentilla, Saxifraga, Sedum, Cortia, Nardostachys, Cremanthodium, Saussurea, Leontopodium, Anaphalis, Rhododendron, Cassiope, Diplarche, Diapensia, Primula, Androsace, Gentiana, Swertia, Picrorhiza, Lagotis, Pedicularis, Polygonum, Rheum, Salix, Juncus, Carex* and *Poa.*

The Llonakh flora is divided into the following three habitat types:—

(1) **Open flats.** The characteristic flora of this habitat comprises of *Rhododendron lepidotum, R. anthopogon, Berberis, Spiraea, Potentilla fruticosa, Lonicera, Hippophae, Salix* Other plants are *Ranunculus, Caltha, Poterium filiforme, Saxifraga pallida, Primula sikkimensis, P. tibetica, Pedicularis,* etc. On the drier flats were *Delphinium, Hypecoum, Lepidium, Arabis glandulosa, Viola kunawarensis, Stellaria decumbens, Stracheya, Guldenstaedtia, Astragalus, Oxytropis, Saxifraga flagellaris, Ant nnaria muscoides,* etc.

(2) **On Moraines and Screes.** Species of *Anemone, Callianthemum, Draba, Saxifraga, Sedum, Trigonotis, Onosma, Swertia multicaulis, Picrorhiza, Eriophyton, Polygonum tortuosum, Allium,* etc. are met with.

(3) On the higher cliffs the prevalent plants are *Meconopsis horridula, Draba, Braya, Thlaspi, Cochlearia, Potentilla microphylla,* and *P. fruticosa, Saxifraga imbricata, S. saginoides, Cortia, Allardia, Saussurea, Primula muscoides, Androsace selago, Myosotis hookeri, Veronica lanuginosa, Polygonum nummularifolium, P. hookeri, Rheum nobile, R. spiciforme,* etc.

The following species of west Himalayan and Tibetan plants were found in this area:-

Thalictrum tsangense, Ranunculus aquatilis, Isopyrum microphyllum, Corydalis hendersonii, C. hookerii, C. mucronifera, Braya tibetica, Diplophia salsa, Capsella thomsonii, Viola kunawarensis, Arenaria littledalei, Arenaria densissima, Oxytropis tatarica, Oxytropis sulphurea, Spiraea ulicina, Coluria longifolia, Hippuris vulgaris, Callitriche verna, Lonicera rupicola, Lonicera spinosa, Saussurea stella, Primula tibetica, Androsace

chamaejasme var. coronata, Glaux maritima, Microula benthami, Pedicularis oederi, Pedicularis rhinanthoides, Pedicularis alaschanica, Dracocephalum heterophyllum, Plantago tibetica, Polygonum tortuosum, Rheum spiciforme, Hippophae rhamnoides, Urtica hyperborea, Urtica dioica, Stipa purpurea.

Jain and Bhardwaja (1949) found the following genera on morainic deposits at Swagni Maidan in Kulu:- *Indigofera, Salvia, Viola, Angelica, Dipsacus, Trillium, Caltha, Fragaria, Podophyllum, etc.*

Puri (1950) studied the relationship of vegetation with geological and soil features in the Kulu Himalayas. In Chapter 22 are shown the plant cummunities at altitudes of 8,000 ft. and above in the Parbatti Valley. On moraines above 11,000 ft. *Bergia stracheyi, Cassiopes fastigiata, Corydalis cachemiriana, Gentiana carinata,* are found in grassy meadows. *Iris nepalensis* forms dense patches of vegetation in moist places, where the two orchids - *Orchis latifolia* and *Cephalanthera ensifolia* are also found. Photo 5 shows a view of a glacial moraine above 9,000 ft. in the Kulu valley covered with some of the plants given above.

Osmaston (1922) has given habitat features of two Communities of the alpine zone in the Garhwal Himalayas as under:- .

Caragana-Lonicera-Artemisia community found within the Tibetan zone between 9,000' and 15,000' elevation grows on soil that is extremely dry from about the beginning of June to the middle of September. Air is also dry and temperature of the soil and the adjacent air strata is high during the day. A strong south wind prevails throughout the day. The annual precipitation does not exceed 10", which mainly falls in the form of snow during the vegetative rest. Here the vegetation is strongly xerophytic. *Salix myricaria* association is mesophytic.

Betula-Rhododendron community extends over the whole of the moist, dry and arid zones between about 9,000 feet and 13,500 feet elevation. Here rainfall is sufficient, during the period of vegetative activity from about June to September. The annual precipitation is from 10" to 80" and 25 to 75 % of this falls as snow during the vegetative rest. Here again the vegetation is xerophytic.

Champion gives the following classification of the alpine scrub vegetation:-

Table 26.

CLASSIFICATION OF ALPINE SCRUB.

(according to Champion).

GROUP 14 MOIST ALPINE SCRUB.

Sub-type and distribution.	1	2	3
The whole length of the outer and middle Himalayas at elevation of above about 11,000', occasionally extending to lower levels also.	*Rhododendron anthopogon, Lonicera parvifolia, Berberis kumaonansis, etc.*	*Juniperus recurva, J. communis.*	*Cotoneaster* spp., *Polygonum vacciniifolium, Salix fruticulosa, Anemone, Fritillaria, Corydalis,* etc.

GROUP 15 DRY ALPINE SCRUB.

Sub-type and distribution.	1	2	3
Wide spread in the inner ranges in N. Garhwal and Punjab portions of inner Himalayas.	*Eurotia ceratoides*, *Juniperus Communis*, *Caragana* spp.	*Juniperus pseudosabina*, *Lonicera* spp, etc.	*Artemisia maritima*, *A. sacrorum*, *Potentilla*.

The moist type occurs mainly in the outer and middle ranges of the Himalayas and is represented by *Rhododendron* and *Junipers* with *Berberis*. *Junipers* occupy drier and limestone soils, while *Rhododendrons* take to more moist habitats, devoid of limestone.

The dry type is confined to the dry inner valleys of the Himalayas and is made up mostly of *Junipers* and other species of shrubs. The most interesting ground flora species in this type is *Artemisia maritima*. This type is found mainly in dry limestone formation.

From the nature of these shrubs it appears that they do not constitute climax vegetation at most places but are edaphic variations and at some places represent degraded stages of the alpine forests of silver fir, birch, etc. Since very little work has so far been done on these, the ecological status of these cannot be finally decided.

(c) **Alpine meadows or pastures:** Above the scrub zone are seen alpine pastures with a luxuriant ground flora vegetation.

Kashyap (1932) who has studied the alpine vegetation of the Himalayas and the Tibet from the Zojila in Kashmir to the Tangale at the head of the Chhumbi valley in the east has made very interesting observations on the herbaceous alpine vegetation of this region. He has shown that with the rise in altitude some plants show a reduction is size, *Chenopodium album* which may be 8–9 ft. high in the plains is reduced to nearly 1 or 2 inches at 14,000 ft. Many plants become larger, bearing large flowers at higher altitude, for example, *Anemone rivularis*. In *Euphorbia tibetica*, the flower bud or the fertile shoot was replaced by a vegetative shoot above an altitude of 10,000 ft. Similar cases were found in *Anemone rivularis* above 10,000 ft. in the western Himalayas and in *Rhododendron lepidotum*, above 12,000 ft. in Sikkim. In the latter case the flower bud was replaced by a tuft of red leaves. In other countries polyploids are recorded from alpine habitats, but no such work seems to have been done in India, though Mehra and his co-workers in the Punjab University are studying chromosome numbers in Conifers and other plants in the Himalayas.

Kashmir is very rich in Alpine element, and a good deal of studies have been made on this flora by R. R. Stewart who unfortunately has not published very much on his long and continuous observations in the Kashmir Himalayas, extending over the period of 30 years.

Chopra and Kapoor (1952) have published an interesting account on botanical aspects of Kashmir and Puri (1957) has also made some observations on the Alpine region. Blatter (1926) has given a very interesting and illustrative account of some beautiful flowers of Kashmir.

The following species may be regarded as present in the Alpine region of the Kashmir Himalayas, either on moraines or on rocky substrata:—

Corydalis moorcroftiana, Corydalis longipes, Corydalis ramosa, Aquilegia vulgaris, Papaver nudicaule, Draba alpina, Draba glacialis, Draba incana, Draba tibetica, Iberidella andersoni, Anemone rupicola Camb. *var. glabriuscula, Anemone obtusifolia, Anemone rupestris, Anemone polyanthes, Anemone albana, Thalictrum alpinum, Thalictrum elegans, Thalictrum pedunculatum, Callianthemum cachemirianum, Adonis chrysocyathus, Ranunculus hyperboreus, Ranunculus affinis, Ranunculus hirtellus, Paraquilegia caespitosa, Paraquilegia grandiflora, Delphinium cashmirianum, Aconitum napellus, Aconitum violaceum, Saxifraga sibirica, Saxifraga pallida, Saxifraga flagellaris, Saxifraga diversifolia, Sedum jaeschkei, Sedum tibeticum, Epilobium latifolium, Morina longifolia, Pleurospermum densiflorum, Valeriana dioica, Aster, Erigeron multiradiatus, Anaphalis nubigena, Inula rhizocephaloides, Senecio kunthianus, Saussurea bracteata, Saussurea falconeri, Chorispora sabulosa, Chorispora clarkei, Megacarpaea polyandra, Viola biflora, Dianthus angulatus, Stellaria bulbosa, Stellaria subumbellata, Hypericum wightianum, Silene tenuis, Silene moorcroftiana, Geranium pratense, Impatiens thomsoni, Impatiens brachycentra, Astragalus strictus, Astragalus tibetanus, Astragalus heydei, Astragalus gracilipes, Potentilla sibbaldi, Potentilla leucochroa, Potentilla eriocarpa, Potentilla albifolia, Potentilla bifurcata, Potentilla pedunculoris.* Most of these plants, however, also extend into other parts of the Himalayas in alpine zone.

Chopra and Kapoor have further analysed the distribution of the Alpine species in the Kashmir Himalayas. They found that *Thalictrum alpinum, Papaver amoenum, Lychnis apetala, Astragalus frigidus, Potentilla sibbaldi, Pyrola rotundifolia* are found throughout the alpine parts of the northern hemisphere. The plants that are found in the colder parts of Europe and Asia are *Stellaria graminea, Valeriana dioica, Orchis latifolia,* etc. They similarly recorded the Central Asian and other elements in the Alpine flora of the Kashmir Himalayas. However, a detailed study of this very interesting part of India would greatly enrich our knowledge of Alpine parts of India.

Colour scheme in Alpine pastures. Interesting observations were made by Kashyap regarding the colour scheme of flowers in alpine plants. These are given in Table 27.

Table. 27

COLOUR SCHEME IN FLOWERS OF ALPINE PLANTS

(after Kashyap).

(a) TOP of the Baralacha (Lahul) 16,200 ft. July and Aug, 1928:		(b) Top of Shigon La (Zanskar) about 17,000 ft. August 1928.	
1. *Saxifraga* sp.	Yellow.	1. *Corydalis* sp.	Yellow.
2. *Ranunculus* sp.	Yellow.	2. *Saxifraga* sp.	Yellow.
3. *Sedum* sp.	Yellow.	3. *Pedicularis* sp.	Yellow.
4. *Potentilla* sp.	Yellow.	4. *Draba* sp.	Yelllow
5. *Draba* sp.	Yellow.	5. *Potentilla* sp.	Yellow.
6. *Primula* sp.	Blue.	6. *Gentiana* sp.	Blue.
7. *Pedicularis* sp.	Red.	7. *Delphinium.*	Blue.
8. Crucifer.	White.	8. *Polygonum.*	Red.
9. Caryophyllaceae.	White.	9. *Oxyria digyna.*	Red.
		10. *Epilobium* sp.	Pink.
		11. Compositae.	White.
The first three plants give the characteristic colour over large areas.		Yellow was the prominent colour at this altitude.	

(c) Chakra - tirath near source of the Alakananda (Garhwal) about 13,000 feet to 14,000 feet, Aug. 1931.

1. *Potentilla argyrophylla.*	Yellow to scarlet with all intermediate stages, various shades of orange, etc.
2. *Potentilla sibbaldi.*	Yellow.
3. *Potentilla eriocarpa.*	Yellow.
4. *Saxifraga flagellaris.*	Yellow.
5. *Ranunculus hirtellus.*	Yellow.
6. *Polygonum affine.*	Red.
7. *Oxyria digyna.*	Pink(flowers nearly over).
8. *Saxifraga stracheyi.*	Red.
9. *Sedum* sp.	Red.
10. *Geranium wallichianum.*	Blue.
11. *Primula* sp.	Blue.
12. Boraginaceae.	Purple.

Yellow colour was most predominent and red also quite conspicuous. *Potentilla argyrophylla* was particularly abundant in all the various shades from bright yellow through various grades of orange to brilliant red.

(d) Head of Chumbi Valley, a few miles from Phari about 14,500'. July to August, 1930.

1. *Ranunculus* sp.	Yellow.
2. *Primula* sp.	Yellow.
3. *Corydalis* sp.	Yellow.
4. *Aster* sp.	Blue.
5. *Labiatae.*	Blue.
6. *Polygonum viviparum.*	Pink to red.
7. *Epilobium* sp.	Pink.
8. *Geranium refractum.*	Pink to red.
9. *Pedicularis* sp.	Red.
10. *Leontopodium alpinum.*	White.
11. *Anaphalis* sp.	White.
12. A few more yellow and white Compositae.	

The patches of flowers showed a mixture of various colours. The predominant yellow colour was due to No. 1, red colour due to Nos. 6, 7, 8 and 9 and blue to Nos. 4 and 5. Some of them are found in pure patches. All the colours were about equally conspicuous.

In the alpine vegetation generally yellow colour of plants was most predominant.

In Tibetan alpine plants the mass colour effect reported in Himalayan plants was not found. A very interesting case of dark or almost black coloured flowers in *Clematis orientalis* in western and central Tibet, at about 13,000 ft, was recorded by Kashyap. In the same species yellow flowered plants were found at 14,800 ft. in Tibet. Black glands in *Euphorbia tibetica* in Ladakh, and in the western Tibet were also recorded by Kashyap.

In the Eastern Himalayas alpine plants have pendulous flowers in a number of species of *Primula, Polygonum, Geranium* and *Anemone.* This has been explained as an adaptation against rain, since no such feature was found commonly in the Western Himalayas.

A large number of species belonging to the Primulaceae, Gentianacae, Polygonaceae, Compositae, Leguminosae and Gramineae are present in the alpine vegetation. Genera like *Astragalus, Oxytropis, Arenaria, Draba, Potentilla, Saussurea* and *Polygonum* are very largely represented in flora of higher altitudes.

A very interesting description of Alpine meadow of Panch Chulhi photo 8 at an altitude of 12,000' to 13,500' has been given by Sahni and Raizada (1935). These meadows are morainic deposits and are almost always moist. On these several species of *Primula* are seen. *Primula denticulata and Primula macrophylla* are usually on the edges of melting snow. *Iris kumaonensis* (bluish flowers), *Anemone polyanthes* (creamish flowers) photo 9 are

commonly associated with *Primulas*. Along streams *Caltha palustris* is generally growing. At about 14,000' *Gentiana carinata, Fritillaria roylei* and *Kobresia hookerii* are found. The alpine meadows occur mainly mixed in forests of high altitude and they are mainly composed of flowering herbs. Photo 6 shows *Primula nivalis* and *Fragaria* from 12,000 ft. in Kulu.

Alpine flora of S. E. Sikkim along the Cho-La Range was studied by Smith (1913) during the months of October and November when frost had already "scorched" the grass and most of the herbage. The plants in flowers were *Saxifraga* sp., *Gentiana amoena*, and a stray *Erigeron multiradiatus*.

The following species had shed all or almost all their seeds:-*Anemone vitifolia, Corydalis* spp., *Meconopsis bella, M. simplicifolia, M. paniculata, M. horridula, Cathcartia villosa, Primula obtusifolia, Pedicularis* spp., *Swertia* spp., *Oxyria digyna* and *Rheum acuminatum*.

Perennial plants like some of the *Saxifraga* and *Parnassia*, many of the Compositae, *Rheum acuminatum, R. nobile, Iris clarkei*, etc., and others like *Anemone obtusiloba, A. rupicola, Meconopsis paniculata* and *M. nepalensis, Cortia hookeri, Primula sikkimensis, P. obtusifolia* had developed rosette young leaves. Still others showed small growths, with very small but fully developed leaves, clustering round the old stems. *Inula humeri, Erigeron multiradiatus, Polygonum campanulatum, Euphorbia sikkimensis* are examples of this.

The alpine plants usually have few annuals and the perennials have a long tap root with a woody root stock which remains alive during unfavourable season. They generally have thick hairy leaves of a small size. They may be spinous and are generally cushion-shaped, flowering carpet like structures. The cushions are sometimes exceedingly compact as in *Arenaria, Astragalus, Thylacospermum*. Common tufted plants belong to a number of species of *Astragalus* and *Oxytropis*.

(d) **Alpine forests.** The alpine forests of the Himalayas are classified by Champion into two climax types, namely,alpine fir-birch forest and birch-*Rhododendron* forest. The classification is given in table 28.

I. Alpine fir-birch forest. This occupies the top most tree zone in the Himalayas below the Alpine scrub. The dominant tree is *Abies webbiana* with occasionally *Pinus excelsa* and *Abies densa*. In the second storey *Betula, Quercus semecarpifolia* and *Pyrus aucuparia* are present. The shrub layer is formed by numerous clumps of *Rhododendron, Cotoneaster. Rosa, Lonicera*, etc., In the ground layer are found *Smilax, Strobilanthes, Potentilla, Polygonum*, and the ferns *Osmunda* and *Lastrea. Arceuthobium minutissimum* heavily infects *Pinus excelsa* trees in this zone.

Dudgeon and Kenoyer (1925) have described Alpine *Betula-Abies* forests from Tehri Garhwal above 10,000 ft. to 13,500 ft. In typical localities birch is more abundant than silver fir. Above 12,500 ft. birch is almost the only tree species upto timber line. In these forests it appears that *Betula, Salix* and *Rhododendron campanulatum* constitute the pioneer species to the *Betula-Abies* climax. *Pyrus foliolosa* and *Pyrus lanata* together with *Salix elegans* are associated with Birch and *Abies. Allium, Trillium govanianum, Rheum, Valeriana wallichii* are common ground flora species.

Sahni and Raizada (1955) have described high level fir forest from Panch Chulhi above an altitude of 11,000 ft. Here the community is typically fir-birch-*Rhododendron*. The high level fir is distinguished from the low level fir by shorter and thicker leaves and upcurved branches.

Table 28.

CLASSIFICATION OF ALPINE FOREST VEGETATION

(according to Champion)

Sub-type and distribution	I	II	III	IV
C. Alpine-Fir-Birch forest, top most tree forests in the Himalayas - adjoining the Alpine scrub. (about 9,500' to 11,500' and even up to 12,500')				
(i) N. Garhwal.	*Abies Webbiana* (a)	*Betula utilis* (a), *Quercus semecarpifolia* (o).	*Rhododendron companulatum* (a), *Pyrus foliolosa* (a), *Cotoneaster acuminata*, *Rosa sericea*, *Ribes glaciale*, *R. rubrum*, *Lonicera spp.*, *Rubus niveus.*	*Smilax vaginata.*
(ii) Tosnal Kulu division.	*Abies Webbiana* (a), *Pinus excelsa* (o).		*Viburnum foetens* (o), *Deutzia corymbosa* (o), *Ribes* sp.,	*Strobilanthes atropurpureus* (va), *Smilax vaginata*, *Smilacina* (va), *Trillium* (a), *Anemone obtusiloba* (la), *Osmunda claytoniana* (la), *Lastraea barbata* (a).
(iii) Above Chini, U. Bashahr	*Abies Webbiana* (la), *Pinus excelsa* (a).	*Betula* absent.	*Rhododendron companula - tum* (la), *R. lepidotum* (la), *Berberis* sp(a), *Juniperus pseudosabina* (la), *Arceuthobium minutissimum* (f), (*a parasite* on Kail - *Pinus excelsa*).	*Osmunda claytoniana* , *Anemone* sp. *Viola patrinii.*
(iv) Gompating Chu, Sikkim.	*Abies densa* (la), *Juniperus pseudosabina* (lf).	*Rhododendron wightii* (va), *Betula utilis* (f), *Pyrus aucuparia* (f).	*Salix Wallichiana* (lf), *Juniperus recurva* (lo), *Rhododendron lepidotum* (o).	*Spiraea* sp., *Cassiope fastigiata* (r), *Potentilla fruticosa* (o), *Polygonum* sp. (f).

Table 28. (Contd.)

Sub-type and distribution	I	II	III	IV
C2. Birch-*Rhododendron* forest. The whole length of the Himalayas.				
(i) Sunderdhunga valley, W. Kumaon 12,500 ft.	*Betula utilis*(a), *Pyrus foliolosa* (f).		*Rhododendron companulatum* (a), *Viburnum nervosum* (f), *Rhododendronlepidotum*(o), *Berberis* sp., (f), *Lonicera parvifolia* (f), *Gaultheria trichophylla* (lf).	*Primula denticulata* (va), *P. stuartii* (o), *Corydalis strachyi*, *Macrotoma benthami*.
(ii) N. Garhwal.	*Pyrus foliolosa*, *Betula utilis*, *Quercus semecarpifolia*.		*Rhododendron companulatum*, *Berberis* spp., *Cotoneaster* sp., *Lonicera*, *Rhododendron lepidotum*.	*Polygonum vacciniifolium*.
(iii) Dzongri ridge Sikkim 12,500 ft.			*Rhododendron wightii* (va), *R. companulatum* (f) *R. molle* (f), *R. thomsoni* (lf), *R. setosum* (o), *R. anthopogon* (o), *R. lepidotum* (o) *Berberis* spp.	*Primula stuartii*.

a. = abundant. v.a. = very abundant. l.a. = locally abundant. f. = frequent. o. = occasional. r. = rare

Rhododendrons occur in almost pure groves over extensive areas both under the shade of fir as well as in the open. Other shrubs in these forests are *Pyrus foliolosa, Juniperus recurva, J. wallichiana, Salix fruticulosa, Berberis umbellata, Lonicera parvifolia* and *Myricaria bracteata.* At about 12,000 ft. *Rhododendron hypenanthum* replaces *R. campanulatum.*

The ground flora species in these forests are usually *Anemone tetrasepala, Corydalis govaniana, Fritillaria roylei, Primula denticulata, Primula macrophylla, Lloydia serotina, Rheum moorcroftianum* and *Macrotomia benthami.*

Above the fir forest pure forests of birch occur in which *Juniperus recurva* forms an under-growth.

II. **Birch-Rhododendron forest.** Occurs throughout the length of the Himalayas almost in the same altitudinal zone as the first type. This may, however, be found a little higher than the fir zone.

In the birch-*Rhododendron* forest *Betula* is almost the only tree species except *Quercus semecarpifolia* which may also be present in some cases. The second storey is formed by *Rhododendron* in which *Pyrus foliolosa* may also be present. Shrubs of *Berberis, Contoneaster* and *Lonicera* constitute the shrub layer and a number of ground flora species like *Corydalis, Primula,* etc. are present in luxuriance. Photo 7 shows a *Rhododendron campanulatum* community in silver fir-Birch forest of the Bashahar Himalayas. In Kashmir *Sambucus niger* occurs in similar situations (photo 10)

From Panch Chulhi the following scrub species have been listed in *Salix-Juniperus-Rhododendron* community:- *Rhododendron hypenanthum, Juniperus recurva, Salix fruticulosa, Lonicera parviflora.* The ground species occurring in grassland are *Anemone, Fritillaria* and *Corydalis.*

Smith (1913) has given an account of alpine and sub-alpine vegetation of S. E. Sikkim. Above the region of Oaks, maples and laurels the vegetation consists of *Rhododendrons* and *Abies webbiana.* Above 10,000-12,000 feet *Pyrus, Salix, Viburnum* and a majority of *Rhododendrons* are found. Above 12,000 feet *Rhododendron* and *Salix* are chiefly present. The following species are also met with: *Codonopsis, Mandragora, Cortia, Cochlearia scapiflora, Arisaema, Habenaria, Polygonatum, Allium, Fritillaria, Lloydia.* Along the ridges a few hardy forms like *Chrysosplenium carnosum, Primula tenviloba, P. muscoides* occur. Other species are *Corydalis lathyroides, Meconopsis bella, Potentilla eriocarpa, Primula gambeliana, Primula soldanelloides,* etc.

Ranunculaceae are represented chiefly by *Anemone, Caltha, Trollius* and small *Ranunculi.* Of Berberidaceae, *Decaisnea* frequented the moist woodlands, just below 9,000 feet. *Meconopsis* was plentiful and the species of *Corydalis, Cardamine, Cochlearia,* and *Draba elata* are most conspicuous.

Other species found here are *Potentilla* sp., *Rosa sericea, Geum elatum,* species of Compositae, *Mandragora caulescens.*

The mixed forests in S. E. Sikkim at an altitude of 9,000-13,000 feet present a gorgeous appearance in consequence of the brilliant colouring of the fading leaves during September-October. The most noticeable being golden yellow of *Acer campbelli, Acer sikkimensis,* and an Araliad; bronze of *Pyrus sikkimensis,* silver grey of *Pyrus vestita,* scarlet of *Rosa sericea* and *Acer hookeri,* and shades of brown of the *Rhododendrons.*

ECOLOGICAL STATUS AND SUCCESSIONAL RELATIONSHIP.

Although, sufficient data on the ecological status and successional relationship among various plant communities of the Alpine vegetation is not available, it seems that the following four distinct types can be recognised in the alpine vegetation of the Himalayas:-

(1) **Stony deserts**:- Developed on rocky substrata and having the vegetation of lichens, *Androsace, Sedum, Saxifraga,* etc. The plants are cushion-shaped and it appears that this type is climatic climax at these altitudes.

(2) **Alpine scrub:-** Two types of alpine scrub have been recognised by Champion, viz. Moist and Dry types. The moist type has *Rhododendrons* predominant and is developed on schists or other rocks which do not have high amounts of calcium. Although, this appears to be climatic climax, it seems more to be controlled by edaphic features and the nature of the underlying rocks than by climate.

The dry type is dominated by *Junipers* which are developed on limestone rocks. This type also seems to be an edaphic community and it is not possible to say definitely whether these two alpine scrubs can be called climatic climax, or not.

(3) **Alpine meadows**:- Are developed on two types of habitats, viz. glacial moraines and other types of soil *in situ* or transported by glacial nalas. Both are degraded from the alpine forests and are therefore bio-edaphic communities.

(4) **Alpine Forests**:- Alpine forests are again of two types according to their habitat. The one designated as Silver fir - Birch community is developed mainly on glacial moraines and has a preponderant mixture of other broad-leaved species. In this type regeneration of Silver fir is abundant and on disturbance the new seedlings found are mainly *Pinus excelsa,* thereby showing that the glacial moraines are colonised by *Pinus excelsa,* which community changes to Silver Fir - Birch community. Although, Champion considers this community to be climatic climax, I feel that this is an edaphic community which may not reach the climax stage so long as the moisture available from the glaciers above exercises a great influence on the growth of the species. Mr. N. P. Mohan, the Chief Conservator of Forests, however, considers that the climatic climax of this habitat is *Betula* community. I have not seen any such community in the Western Himalayas, however.

Birch- *Rhododendron* community developed on the rocky substrata is the other type of alpine forests met within the Himalayas. This community is bio-edaphic and not climatic climax as considered by Champion. The presence of *Quercus semecarpifolia, Pyrus* and other species indicates that the climax of such a community would be a *Quercus semecarpifolia* community. I have seen a number of such communities in the Bashahar Himalayas.

The conclusions given above, it is believed would induce others to undertake the very interesting study on the alpine vegetation of our country, which would undoubtedly help in evolving a more satisfactory classification and successional relationship.

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7

TEMPERATE FORESTS OF INDIA

'Champion' uses the term temperate for those forests that occur on mountains either in South India above an altitude of 5,000 ft. or in the Himalayas above 5,000 ft. The term temperate is used, though, the climate in these areas is not typically humid, as is found in true temperate forests of the Northern Hemisphere. A reference has already been made to the objection raised by Burtt Davy for the use of the term temperate for the Indian forests that are essentially developed under monsoonic climate. The temperate forests of India are, therefore, truly monsoon temperate. The apparent climatic humidity in some of the forests developed on dip slope in the Himalayas is due to favourable soil features and seepages in the rock strata. The climate is, otherwise, on a drier side and does not favour the development of a truly podsolic soil profile, which is generally a characteristic feature of the northern temperate forests of Europe and America.

HIMALAYAN MOIST TEMPERATE FORESTS.

This type is characterised by the presence of the development over extensive areas of Oaks and conifers, especially in the north western parts. Unlike the European and North American conifer forests the Himalayan conifers are almost always seral in nature, the climax forests being one, or the other, species of Oaks. The Himalayan Oaks are evergreen in contrast to North Temperate Zone species. These Oak forests are mixed variously with a number of dicotyledonous deciduous species, depending upon soil features and biota. In the Himalayas the oaks are more predominant on southern scarp slopes and conifers, or mixed oak-conifer forests are the characteristic features of the northern dip slopes. While in the pure oak forests trees are not very high, the mixed oak conifer forests are generally open, with trees of 100 - 150 feet height. The second storey species in these vary a good deal, depending upon the altitude, aspect, geology and soils. The oak forests are mainly pure, composed of single species and have usually a low height of 30 ft. to 60 ft.. The oaks have extensive branching of crowns and poorly developed boles often covered over with mosses, if rain is excessive. The undergrowth is usually shrubby with deciduous species and regeneration of oaks, and its luxuriance depends mainly on the biotic pressure, chiefly grazing, fire, etc. and the soil features. *Cotoneaster, Berberis, Spiraea,* etc. are found with evergreen shrubs of *Skimmia, Sarcococca,* etc. *Strobilanthes* and *Impatiens* form gregarious growth; and a sparse development of herbaceous ground flora to almost bare patches in the forest are found.

The luxuriance of ground flora is also dependant on the intensity of grazing and soil moisture. Climbers are few and relatively unimportant, belonging to species of *Hedera, Clematis, Vitis, Rosa,* etc. In the undergrowth ferns are found, especially on wet and moist soils. Epiphytes are few. However, ferns and Orchids are present. Tree branches are almost always covered by mosses, especially in Oak forest. In the undergrowth, dwarf bamboos may form extensive patches in some localities. The seasonal luxuriance of herbaceous vegetation in these forests is well marked. There are very few grasses.

The temperate forests zone provides very favourable conditions for human habitation, consequently forest growth has been very greatly disturbed Felling, lopping, fire and grazing have reduced some of the high forest areas to open scrubs, or grassy meadows, which have become a more or less permanent feature in the vegetation of the Himalayas. Shifting cultivation in the past has resulted in the formation of pure conifer forests, where Oaks grew before. Abandoned cultivation areas, with terraces, and trees in rows abound the Himalayas. Virgin and undisturbed Oak climaxes occur only in remote places or steep precipitous slopes.

Both the primary and secondary types of forests are distributed all along the entire length of the Himalayas in the Punjab, Kashmir, Uttar Pradesh, Nepal, Bengal, Sikkim and Bhutan, between altitudes of 7,000 ft. and 11,000 ft., both in the outer and inner ranges. They are conveniently classified into western and eastern subtypes. In the western and also in some parts of the central Himalayas the forests are distinguished into the following altitudinal zones:-

1. Lower Oak Zone *Quercus incana* between 3,000 ft. - 6,000 ft. In this zone *Quercus dilatata* also occurs frequently and associated conifers are *Cedrus deodara, Pinus excelsa* and sometimes *Pinus roxburghii.*

2. Middle Oak Zone between 5,000 ft. - 8,000 ft. mixed oak - *Acer* forest. In this type, though, *Quercus dilatata* is predominant, *Q. incana* is fairly common and the two may form a gregarious mixture with *Acer, Aesculus, Litsaea,* etc. Mixed conifer forests constitute the glory of the Himalayas and are composed of the deodar, blue pine and spruce. The broad leaved species present among these are deciduous in nature.

3. Upper Oak Zone between 7,500 ft - 9,500 ft. *Quercus semecarpifolia* forest is predominant over scrap slopes and undisturbed areas. *Q. semecarpifolia - Abies* forest in which Yew and spruce form at places an important mixture is present throughout. *Abies* forest occurs in pockets here and there, with only broad leaved species of *Betula* and *Prunus* on glacial moraines in glaciated parts of the Himalayas. The Pleistocene glaciation has mainly affected vegetation in the Kashmir and the Kulu Himalayas, replacing the oak forests by pure Silver fir communities on glacial moraines and out-wash deposits. Old flood plain deposits belonging to the glacial age also carry conifers, especially, deodar forests in the Himalayan Valleys.

The forest types in the western and the eastern Himalayas are compared in table 29.

Table 29.

MAIN TYPES OF FORESTS IN THE WESTERN AND THE EASTERN HIMALAYAS.

Western Himalayas		Eastern Himalayas	
Broad leaved forest.	Coniferous forest.	Coniferous forest.	Broad leaved forest.
Rhododendron campanulatum, Betula utilis, on sheet rock and thin dry moraine.	*Abies webbiana* on moraines. *Junipers* on sheet rock.	—	*Rhododendron* spp., *Betula utilis* on sheet rocks.
Q. semecarpifolia on scarp slope of schists and stabilis-	*Abies pindrow* on moraines or dip slope of schists,	*Abies densa* on glacial moraines.	*Q. pachyphylla* on stabilized soils mainly

Table 29 (contd.)

Western Himalayas		Eastern Himalayas	
Broad leaved forest.	Coniferous forest.	Coniferous forest.	Broad leaved forest.
ed scree masses with a dry head.	etc. *Pinus excelsa* on scarp slope of schist or early seral stages on moraines.		developed *in situ*.
Q. dilatata on flood plains of fine granite or scree masses with wet head.	*Abies pindrow*, *Picea morinda*, *Cedrus deodara* on flood plain deposits, dry or moist.	*Picea spinulosa*. *Tsuga brunoniana*.	*Q. pachyphylla*, *Q. lamellosa*, on well developed soils.
Q. incana on quartzite, schists, limestone, screes and flood plain deposits, also in the Siwaliks on sandstone.	*Cedrus deodara* on abandoned cultivation, dip slopes of schists, *Pinus excelsa* on scarp slopes, *Pinus roxburghii* on quartzite, sandstone, also in the Siwaliks.	*Tsuga brunoniana*.	*Q. lamellosa*, *Q. lineata*.
Q. ilex on granite or other rocks in inner valleys.	*Pinus gerardiana* on flood plain deposits, abandoned cultivation in inner valleys.	A little *Pinus roxburghii* on quartzite, *P. khasya*, etc.	

Indian temperate forests occur on mountains above an altitude of 5,000 ft. or so. These have been differentiated into a number of types depending upon the amount of annual rainfall, geology, soils and biota. Taking the moisture content as the main criterion, Champion has classified temperate forest into wet, moist and dry types. The wet types are mostly confined to South Indian hills or in the Eastern Himalayas. These two are respectively called the Southern wet and Northern wet types.

Southern Wet temperate forests. These forests are developed on the Nilgiris at Ootacamund, Anamalai, Palni and Tinnevelly hills, above an altitude of 5,000 ft. and are popularly called "sholas". The sholas are evergreen forests of close canopy, with most of the trees attaining a height of 50 to 60 ft. The leaves which are grown in dense crowns are generally coriaceous, red in colour when young, and produce an interesting range of colours when fully developed. The tree trunks are mostly covered with epiphytic ferns, mosses and other plants and have a number of climbers. The canopy in the forest is not differentiated into layers and there is a great deal of mixture of species.

The sholas are generally developed in sheltered sites on steep slopes (Photos 11, 12). Fire and grazing being practised almost to the edge of these forests it seems certain that the present position of these is due to the biotic factor.

Ramaswami (1912) has given an interesting description of the sholas of the Tinnevelly Hills, where the vegetation is somewhat uniform at foot of the hills, reminding plains forests at the foot of the Nilgiris.

Compositae and hill grasses are abundant. Up to an elevation of 2,000 ft., *Stenosiphonium russellianum* is abundant with shrubs and herbs of Rubiaceae and Compositae. Above 2,000 feet the herbaceous vegetation on clearings in the coffee states consists of chiefly patches of *Kalanchoe, Vernonia* sp. *Barleria, Asystasia,* several shrubs of Rubiaceae and Acanthaceae and leguminous herbs. The silver Oak *Grevillea* is largely planted in this area in coffee and tea plantations. From 3,000' to 4,000' a very dense evergreen forest occurs. These evergreen forests generally get the full force of the south west monsoon as well as heavy showers during the north east monsoon so that they are exceedingly damp, nearly throughout the year. The trees composing this forest are very tall and of many different species. Among the most common and conspicuous species are *Hopea parviflora, Balanocarpus utilis, Artocarpus hirsuta, Gordonia obtusa, Bombax malabaricum, Elaeocarpus oblongus, Elaeocarpus tuberculatus, Pterocarpus marsupium, Ormosia travancorica, Hardwickia binata, Pithecolobium subcoriaceum, Myristica attenuata, Myristica laurifolia, Tectona grandis, Litsaea sebifera, Villebrunea integrifolia,* and others too numerous to mention.

Climbing and twining plants are of *Mucuna atropurpurea, Derris scandens, Piper nilghirianum, Hoya pauciflora,* several species of *Jasminum, Thunbergia fragrans, Dunbaria ferruginea, Rubia cordifolia* and *Dioscorea pentaphylla, Dioscorea spicata,* etc.

The shrubby undergrowth of the forest is composed of chiefly a number of species of Leguminosae, Rubiaceae and Acanthaceae, such as *Crotalaria albida, C. verrucosa, Indigofera pulchella, I. tinctoria, Tephrosia tinctoria, Desmodium scalpe, D. latifolium, Rhynchosia cana, R. rufescens, Wendlandia notoniana, Hedyotis purpurascens, H. viscida, Mussaenda frondosa, Pavetta indica, P. breviflora, Psychotria congesta, P. elongata, Strobilanthes pulneyensis, Barleria nitida, Crossandra undulaefolia, Diotacanthus albiflorus, D. grandis,* as well as a few other species such as, *Polygala arillata, Hypericum mysorense, Chloranthus brachystachyus,* several species of *Cinnamomum, Lasiosiphon eriocephalus, Sauropus albicans, Agrostistachys indica* and *Debregeasia velutina.*

The herbaceous vegetation is extremely rich, consisting of several species of Compositae, Leguminosae, Rubiaceae, Gramineae, Scitamineae and Campanulaceae. Ferns and Selaginellas are abundant in moist hollows. Parasites *Loranthus* and *Viscum* occur on several species of trees. *Balanophora indica* is invariably present on the ground near the base of several tall trees. Minor forest produce in the sholas, are cardamoms and turmeric.

Fringing the margins of a number of small hill streams are found *Impatiens grandis, I. subcordata,* two or three small shrubs of *Osbeckia,* a very small leaved *Elatostema, Polygonum chinense, Arisaema leschenaultii, Anaphyllum beddomei* and several species of sedges and ferns - prominent among the former being *Scirpus mucronatus* and *Cyperus corymbosus.* Within and mixed up with the fringe of sedges occur *Viola distans, Laurembergia* (*Serpicula*) *hirsuta* and an *Utricularia.*

Sholas of the Nilgiris have been described by Ranganathan (1938), who stated that both the sholas and the grasslands are two distinct climatic climaxes (Photo 11). By age old methods of grazing, fire, etc., by the Todas the grasslands have now come to stay as distinct stable communities. Similar grassland communities in the other South Indian hills have been designated as climatic climax.

Champion (1938) whose description of the shola forests (Photo 13) in the Nilgiris is given in table 30, was however, of the view that the sholas alone are climatic climax and the grasslands are a biotic community. In order to find out the exact ecological status of the grasslands a number of

planting experiments were done in the Nilgiris. A number of exotic and indigenous species were planted. Experimental areas were closed to grazing and fire and in those areas seedlings of trees appeared, thereby showing that the grasslands are merely biotic in nature and if the biotic interference is excluded these areas would return to forests. This view has made the improvement of the Nilgiri Downs a practical proposition.

The Nilgiri flora includes both tropical and temperate species and the presence in these of *Rhododendron arboreum*, a Himalayan species has raised an important phytogeographical question which has already been discussed in chapter 3. The Nilgiri flora also includes several plants that are found in the Deccan trap hillsides. For example, Mahableshwar, Matheran and Bhimashankar in the Sahayadris have *Sideroxylon tomentosum, Lasiosiphon eriocephallus, Elaeagnus latifolia*, etc. common with the Nilgiris.

Northern wet temperate forests. The Northern wet temperate forests are developed in the East Himalayas, eastwards from eastern Nepal, being present also on the hills of Assam between an altitude of 6,000' - 9,000'. The designation northern is a misnomer for these forests as the term southern for the Nilgiris forests. Both these are governed by the monsoons and at the best they may be called the Eastern and Western monsoon types.

The Assam Bengal forests are also evergreen, closed, high forests, but the trees attain somewhat higher height growth upto 80 ft. than the forests in the Nilgiris. There are a number of deciduous species forming a small proportion. Oaks and laurels tend to form gregarious patches in an otherwise mixed forest. Trees are covered with epiphytes and mosses. Woody climbers are present and a dwarf bamboo forms an undergrowth at higher altitudes. Although, there has been some biotic interference in these forests, these have not suffered to a considerable extent and may be considered truly climatic climax. The Oaks and chestnuts are predominant at high altitude and laurels occur generally at lower levels. An oak-chestnut forest is shown in Photo 14. Magnoliaceae are common features and *Acer, Prunus, Ulmus*, etc. are some of the common deciduous genera.

The vegetation of the Eastern Himalayas is divided by Cowan (1929) into two regions, viz., snow range and the outer Himalayas. The snow range vegetation constitutes an alpine type but the outer Himalayas between 6,000 - 12,000 feet have a temperate vegetation, which is differentiated into altitudinal zones as follows:-.

1. *Machilus-Michelia* Hylium, occurring between 6,000 and 7,000 feet and having commonest trees of *Machilus edulis* and *Michelia cathcartii;* smaller trees in the second storey are *Eurya acuminata, Symplocos theaefolia, S. ramosissima*, many *Aralias*, several species of *Ilex, Acer thomsoni, Turpinia nepalensis, Mahonia sikkimensis*, and *M. acanthifolia*. Under these there are many species of *Strobilanthes*, Balsams, *Begonias*, Nettles, *Thunbergias* and *Selaginellas*. Some times the lower storey consists entirely of small bamboos, particularly *Arundinarias*.

2. *Quercus* Hylium, occurring between 7,000 and 9,000 feet with the dominant species of *Quercus lamellosa* and *Quercus pachyphylla*. Other plants in the community are the following:- *Acer campbellii, Michelia excelsa, Echinocarpus dasycarpus*, and *Michelia cathcartii*. The second storey contains many laurels, principally *Machilus* and *Litsaea spp*. The under growth is bamboo, *Arundinaria maling. A. griffithiana* and *A. pantlingi* are also common species.

3. *Rhododendron* Hylium, the common species in the association are *Rhododendron arboreum, R. campanulatum* and *R. grande*. Other

Table 30.

VEGETATION OF SHOLAS OF THE NILIGIRIS

(after Champion)

SOUTHERN WET TEMPERATE FOREST

Sub-type and distribution	I	II	III	IV
Hills of South India, such as, Nilgiri, Anamalai, Palni etc. at about 5,000 feet. above sea level.	*Ternstroemia japonica, Eugenia calophyllifolia, E. montana, Michelia nilagirica, Gordonia obtusa, Sideroxylon tomentosum, Ilex wightiana, Meliosma wightii, Elaeocarpus* spp., *Photinia montana, Cinnamomum wightii, Litsaea wightiana, Rhododendron arboreum, Euonymus crenulatus. Glochidion neilgherrense, Symplocos spicata,* etc.	*Turpinia nepalensis, Rhamnus wightii, Viburnum erubescens,* etc., *Psychotria congesta, Vaccinium leschenaultii, Ligustrum* spp.. *Lasiosiphon eriopcephallus, Mahonia leschenaultii.*	*Rosa leschenaultiana. Clematis wightiana, Rubus* spp., *Schefflera* spp., *Elaeagnus latifolia, Toddalia asiatica, Gaultheria fragrantissima,*	*Impatiens* spp. *Cymbopogon polyneuros, Ischaemum ciliare, Chrysopogon wightianus, Tripogon bromoides.*

occasional species are *Sorbus cuspidata* and *Andromeda villosa*. *Viburnum cordifolium* is also not uncommon in open places.

The following consociations and societies in these forests have been recognised:-

Associations.

1. The *Machilus-Michelia* Hylium,
2. The *Quercus* Hylium.
3. The *Rhododendron* Hylium and
4. The *Tsuga-Abies* Hylium.

CONSOCIATIONS.

Michelia cathcartii.
Quercus lamellosa.
Quercus pachyphylla.
Rhododendron arboreum.
R. barbatum
R. campanulatum.
R. grande.
Tsuga brunoniana.

SOCIETIES.

Actinodaphne sikkimensis.
Ardisia macrocarpa.
Arundinaria aristata.
A. griffithiana.
A. pantlingi.
A. hookeriana.
A. maling.
A. racemosa.
Berberis aristata.
B. insignis.
Boehmeria polystachya.
Bucklandia populnea.
Cephalostachyum capitatum.
Croton tiglium.
Dichroa febrifuga.
Edgeworthia gardneri.
Eurya japonica.
Girardinia palmata.
Indigofera hebepetala.
Laurocerasus acuminata.
Leucosceptrum canum.
Leycesteria formosa.
L. stipulata.
Macaranga pustulata.
Maesa chisia.
Pilea smilacifolia.
Piptanthus nepalensis.
Pittosporum nepalensis.
Polygonum molle.
Populus gamblei.
Rubus andersoni.
Rubus rosaefolius.
Rubus thomsoni.
Rhus semialata.
Strobilanthes spp.
Symplocos theaefolia.
S. ramosissima.

Gammie (1895) described botanical features of Sikkim during his tours. Besides temperate forests he has considered alpine and high level vegetation also. These descriptions have been retained in this section to maintain the regional character of Gammie's description.

The Singalelah Range in which he botanised first is an elevated mountain mass springing from the face of Kinchinjunga extending southwards to the plains of India. *Taxus baccata* was found along the road beyond Tonglu, and *Abies webbiana* was first seen on the last ridge between Tonglu and Sandakphu from whence onwards it exists in profusion on mountains sides with dense and sombre forests. There are trees of *Tsuga brunoniana* below Phalut, and *Juniperus pseudosabina* abounds near the path to Cheabhanjan. The ground flora species in these forests at an altitude of 11,000 feet, are *Aconites, Meconopsis wallichii,* and a few species of each of the genera *Ranunculus, Anemone, Potentilla, Primula, Fragaria daltoniana,* etc.

The road from Sandakphu to Phalut passes through a forest of *Abies webbiana,* associated with *Pyrus foliolosa, Betula utilis, Acer caudatum* and *Prunus,* with an undergrowth of various species of *Rhododendron* and *Arundinaria spathiflora.* Photo 15 shows a view of forest floor in such a forest with ground flora and a thick mantle of forest litter.

On the slopes immediately below the summit of Phalut, the characteristic species are *Anemone rivularis, Primula rotundifolia, P. sikkimensis, Meconopsis wallichii, Allium wallichii,* etc.

From Cheabhanjan onwards to Kinchinjunga, at elevations of 11,174 feet, chief species are *Rhododendron arboreum, R. cinnabarinum, R. falconeri, R. barbatum, R. hodgsoni, Acer caudatum, Betula utilis, Pieris ovalifolia, Juniperus pseudosabina, Abies webbiana, Arundinaria spathiflora,* etc. The plants found between Evanangi and Megu are *Gentiana stylophora Swertia hookeri, Rhododendron anthopogon, Juniperus recurva, Spiraea bella, Pyrus rhamnoides, Clematis montana, Meconopsis simplicifolia* and *Chrysosplenium alternifolium,* etc.

Primula pusilla, Delphinium alpinum, Rhododendron anthopogon, Saxifraga imbricata, Primula stuartii, Salix wallichiana, Abies webbiana, etc. occur between Megu and Gambothan at 12,400 feet.

The characteristic vegetation at elevation of 13,300 feet comprises of *Abies webbiana, Juniperus recurva, Rhododendron campanulatum, Betula utilis, Rhododendron anthopogon* and *R. setosum.*

On the Kanglalma path and the valley towards the northwest *Astragalus* sp., *Anemone* sp., *Primula denticulata* and *P. reticulata* were found. On the way to Tegyap La, through Ratong the common plants were *Cryptogramme crispa, Potentilla peduncularis* and many other *Potentilla* species, *Ranunculus affinis, Meconopsis simplicifolia,* etc. A variety of ferns is a notable feature of Yokson, the commonest being *Polypodium rostratum, Nephrodium hirtipes, Aspidium aculeatum, Oleandra nerriiformis, Pteris aquilina,* etc. The chief orchids are *Malaxis sikkimensis, Microstylis biloba, Coelogyne ochracea, Dendrobium chrysanthum,* etc.

In the Lachung Valley near Choongtam a remarkable transition from tropical to temperate vegetation takes place with no great increase in elevation. Chief plants are *Cnicus involucratus, Astragalus pycnorhizus, Eupatorium cannabinum, Anemone vitifolia, Leptocodon gracilis* and *Pleopeltis rhyncophylla,* etc. A large proportion of subtropical trees and plants ascend to a short distance above Keadom. These are succeeded by a dense shrubby vegetation of *Hydrangea, Rosa macrophylla, R. sericea, Prinsepia utilis, Pyrus, Pieris ovalifolia, P. formosa, Zanthoxylum, Rhododendron arboreum, R. ciliatum,* etc. Other plants are *Leycesteria formosa, Buddleia macrostachya, Goniophlebium ebenipes, Abies webbiana,* etc.

On the Tankra Mountain the vegetation was composed of *Lilium roseum, Roscoea alpina, Drosera peltata,* etc. At 9,500 feet *Rhododendron lindera, Betula utilis, Daphniphyllum himalayense,* ferns like *Polypodium trichomanoides, Goniophlebium subamaenum* are found.

To its upper skirts ground flora species found were *Polygonum vacciniifolium, Oxyria digyna, Potentilla fruticosa, Lactuca macrantha,* etc.

In the Donkia pass the following ground flora species were met with: *Allardia glabra, Delphinium glaciale, Aconitum napellus, Ranunculus laetus, Cremanthodium reniforme, Lactuca dubyaea, Crepis glomerata, Antennaria muscoides, Rhododendron nivale, Ephedra vulgaris,* etc.

In Yakcha near the Sebu the vegetation comprised of *Picea morinda, Tsuga brunoniana, Larix griffithii,* in which *Woodsia lanosa, Ainsliaea pteropoda, Galeopsis tetrahit,* etc. were present. At 11,000 feet large trees of *Juniperus recurva* were found.

From 13,000 to 15,000 feet there is an impenetrable growth of *Rhododendrons* and Willows, with numerous small trees of *Pyrus foliolosa, P. microphylla* and herbs of *Aconites, Senecios, Saxifraga, Primulas, Potentillas, Polygonums;* and the thistle *Cnicus eriophoroides* is very common.

The vegetation above 15,000 feet in the Sebu valley is very scanty with *Sedum* sp., *Saxifraga, Allardia, Meconopsis horridula, Cyananthus, Gentiana, Saussurea, Ephedra, Rhododendron nivale,* etc.

Burkill (1913) gave an interesting account of the temperate vegetation of Nepal. Thin forest on the south of the pass above Sisaghari comprises of *Pinus* and *Quercus semecarpifolia,* with *Rhododendron arboreum.*

During the month of December *Anaphalis contorta* was found in grasses. On the north side of the pass there was less grass, and vegetation was scrubby, comprising of *Luculia gratissima, Viburnum stellulatum, Rhus succedanea,* with red autumn leaves, and two species of *Rubus,* together with trees of *Prunus puddum* and Lauraceae. Mosses just at the Chessapani Pass festoon the trees; and epiphytes are abundant, chiefly the Orchid *Otochilus alba, Pepromia reflexa.* The ground flora species just at the pass were *Hypericum patulum, Boenninghausenia albiflora, Galium aparine, Galium mollugo, Valeriana hardwickii, Dipsacus inermis, Gerbera macrophylla, Myriactis nepalensis, Swertia nervosa, Cuscuta reflexa, Cynoglossum furcatum, Strobilanthes glutinosus, Craniotome versicolor,* and *Calamintha umbrosa.*

The forest above Chitlong on Chandagiri begins with *Quercus semecarpifolia, Rhododendron arboreum, Pyrus pashia;* and *Prunus puddum,* and *Quercus glauca* in the upper parts is very common. The shrubs were of *Jasminum humile, Hypericum patulum, Berberis aristata, B. nepalensis, Buddleia macrostachya, Viburnum stellulatum, Randia tetrasperma, Neillia thyrsiflora* and *Eurya acuminata.* Climbers are *Vitis semicordata, Smilax prolifera, Trachelospermum fragrans* and *Euonymus vagans;* and sprawling bushes of *Rubus acuminatus, Senecio scandens,* and *Asparagus racemosus.* The ground flora comprised of *Ranunculus pennsylvanicus, Thalictrum* sp. *Sanicula europea, Pimpinella diversifolia, Heracleum* sp., *Galium* sp.,, *Dipsacus inermis, Valeriana hardwickii, Senecio vagans, Artemisia vulgaris, Cnicus wallichii, Lactuca hastata, Lindenbergia grandiflora, Dicliptera roxburghii, Girardinia heterophylla,* and *Polygonatum. Viscum articulatum* was parasitic on Oaks.

In the cut over forest *Rhododendron arboreum* is plentiful on shady slopes, mixed with trees of *Quercus lanuginosa, Pieris ovalifolia, Viburnum coriaceum* and *Rhus wallichii.*

On sunny slopes grasses occur plentifully with *Anaphalis contorta, Phyllanthus parvifolius, Aechmanthera wallichii.* Groves of *Alnus nepalensis, Carpinus* and *Berberis nepalensis* were found. Orchids, *Peperomia, Polypodium coronans* and *Usnea* are present as epiphytes. Shrubs of *Jasminum humile, Viburnum coriaceum, Cornus oblonga, Coleus barbatus* and *Astilbe rivularis* were present in these forests.

The small plants in the forest round Kalni were chiefly *Prinsepia utilis, Maesa ramentacea, Gaultheria fragrantissima, Luculia gratissima, Daphne cannabina, Crataegus crenulata, Viburnum coriaceum, Randia tetrasperma, Ilex excelsa, Gliechenia longissima* and *Pteris aquilina.*

There are a few indigenous Nepal plants that are common between Chota Nagpur plateau and Paras Nath hills in Orissa rising to 5,000 feet, e.g., *Hypericum japonicum, Rubia cordifolia, Calamintha umbrosa, Peperomia reflexa, Loranthus scurrula, Viscum articulatum, Girardinia heterophylla* and *Andropogon assilmilis.*

The following Nepal plants are also found in Chittagong hills: *Hypericum japonicum, Eurya acuminata, Schima wallichii, Maesa ramentacea, Aechmanthera wallichii, Loranthus scurrula* and *Gleichenia linearis.*

In the Nepal flora the following species constitute the eastern element:- *Schima wallichii, Euonymus vagans, Priotropis cytisoides, Mei-*

llia thyrsiflora, Dichroa febrifuga, Tiarella polyphylla, Oxyspora paniculata, Begonia laciniata, Luculia gratissima, Senecio densiflorus, Senecio vagans, Pratia begonifolia, Gaultheria fragrantissima, Maesa ramentacea, Maesa macrophylla, Myrsine semiserrata, Myrsine capitellata, Symplocos theaefolia, Buddleia macrostachya, swertia dilatata, Swertia nervosa, Strobilanthes pentstemonoid, Leucas ciliata, Loranthus odoratus, Loranthus scurrula, Loranthus umbellifer, Otochilus alba.

The following species constitute the western element:- *Rhus wallichii, Swertia paniculata, Strobilanthes glutinosus.*

The most outstanding feature of the Nepal flora studied by Burkill, is the easternness of the vegetation which is more like Darjeeling district than like north west Himalayas.

Comparing the flora of Nepal and Sikkim Burkill gave the following account:-

1. Its Sal forests on the flat are not quite like those of the Sikkim Terai, nor as those of Kheri.

2. The pine forests of the Chorea Ghati are unrepresented in Sikkim, though a few of their plants are distinctly Eastern.

3. The Sal forests of the Hettaunda mari are like the Sal forests of lower Sikkim Himalayan slopes.

4. The vegetation of the wet gorge of *Bhainsa Duhan* is very like that of corresponding places in Sikkim.

5. The vegetation of the cultivation belt is rather diverse from that of Sikkim.

6. The vegetation of the wet hill tops is like that of corresponding places in Sikkim.

Champion classifies the East Himalayan forests in table 31.

The descriptions of the East-Himalayan wet evergreen forests given above including the types described by Champion in table 31 are too inadequate. These forests are extremely rich and have a very great variety of ground flora species, which will be evident in Photo 16. Epiphytic orchids, ferns and tree ferns are very abundant in these forests, the adequate account of which is unfortunately not available at present.

Very little information is available also about the ecological classification of these forests, nor do we know the successional relationship of various plant communities. In order to fill this big gap concentrated work has now been started on the vegetation of these areas by botanists of the Botanical Survey of India, Gauhati University in Assam and some studies in fern flora is taken up by the Punjab University.

WEST HIMALAYAN TEMPERATE FORESTS.

The temperate forests of the west Himalayas are the climatic climax of the one, or the other, species of oaks, namely, *Quercus semecarpifolia. Q. dilatata, Q. incana* and *Q. ilex.* A view of *Q. semecarpifolia* climatic climax forest is shown in Photo 17.

The first three species of oak occur in the outer zone of high monsoon rainfall. *Q. ilex* is found in dry temperate regions in the inner Himalayas. In the oak zones a number of conifers, namely *Abies, Picea, Cedrus* and *Pinus,* forming pure or mixed communities, occur in seral stages. The distribution of the Oaks and conifers depends upon altitude, aspect, geological formation, structure and composition of the soil.

Table 31.

EAST HIMALAYAN WET TEMPERATE FORESTS

(After Champion)

Sub-type and distribution	I	II	III	IV
E. Himalayan wet temperate forest in the outer Himalayas in W. Nepal, Sikkim, Bengal, Bhutan and N. Assam between 6,000 and 9,000 feet.				
(a) Laurel forest . (i) Kalimpong division 7,000–8,000 feet.	*Machilus edulis, Beilschmiedia* spp., *Michelia cathcartii, Engelhardtia spicata, Schima Wallichii*, etc.	*Eurya acuminata, Symplocos theaefolia, Turpinia nepalensis, Mahonia* etc.		
(b) Buk Oak forest. (ii) Kalimpong division 7,000–8,000 ft.	*Quercus lamellosa, Castanopsis tribuloides. Acer campbellii, Michelia excelsa, M. Cathcartii, Echinocarpus dasycarpus.*	*Machilus* spp., *Litsaea* spp.,	*Arundinaria* spp., *Rubus* spp., *Strbilanthes spp*	
(iii) Darjeeling division 7,000–8,000 ft.	*Quercus lamellosa, Q. linea'a, Michelia excelsa, Acer campbellii.*	*Sympolocos theaefolia, Machilus gammieana, Betulaalnoides, Carpinus viminea.*	*Daphne sp. Viburnum spp. Polygonum* sp. & many ferns.	
(c) High level oak forest. (iv) Darjeeling division 8,000–9,000 ft.	*Quercus pachyphylla, Q. lamellosa, Castanopsis tribuloides, Acer campbellii, Magnolia campbellii.*	*Symplocos theaefolia, Taxus baccata.*	*Arundinaria* spp., *Rubus, Strobilanthes.*	
Assam wet temperate forest Higher hills of Assam from 5,000' upwards.				
i) Assam.	*Magnolia, Michelia, Quercus, Acer, Prunus, Pyrus, Bucklandia populnea, Alnus nepalensis, Betula alnoides, Carpinus viminea, etc.*		Evergreen shrubs with bamboos.	

1. Eastern moist temperate forest, Eastern oak-hemlock forest, Outer portions of the Sikkim Himalayas, E. Nepal and Bhutan.				
(i) Darjeeling division	*Tsuga brunoniana, Abies densa*	*Quercus pachyphylla, Q. lineata, Acer campbellii, Magnolia campbellii, Betula utilis, Taxus baccata, Rhododendron arboreum, R. grande,* etc.	*Daphne cannabina, Rubus niveus, Berberis aristata, Piptanthus nepalensis.*	Ferns abundant.
(ii) Rithu, Darjeeling. division.	*Quercus pachyphylla, Rhododendron falconeri, Betula utilis, Magnolia campbellii, Acer pectinatum, Sorbus, Litsaea sericea, Rhododendron arboreum*	*Arundinaria aristata, A. racemosa.*		
2. Eastern mixed coniferous forest. Inner hills of Sikkim and adjoining country.				
(i) Chumbi valley Tiber 10,000' -11,000'	*Picea spinulosa, Pinus excelsa, Larix griffiithii.*	*Juniperus pseudosabina.*		
3. Eastern Oak-fir forest. The high ranges of the Sikkim Himalaya eastwards to the N. E. frontier.				
(i) Below sandakphu, Darjelling division	*Abies densa.*	*Rhododendron arboreum, R. hodgsoni, Betula utilis,*	*Rosa sericea.*	
		R. cinnamomum, R. barbatum Arundinaria aristata.	*Berberis aristata, Rubus spp.*	
(ii) Ramam, Darjeeling division.	*Abies densa. Tsuga brunoniana.*	*Rhododendron arboreum R. grande, R. spp. Enkianthus*		
(iii) North East Frontier	*Similar to (ii) above.*	*deflexus, Arundinaria aristata.*		

Dudgeon and Kenoyer (1925) recognised three climate-vegetation zones, namely tropical, temperate and alpine for Tehri Garhwal and the same seem to hold good for the other parts of the W. Himalayas. The main features of temperate vegetation in these regions are summarised in table 32.

Table 32

CLIMATIC AND VEGETATION ZONES OF THE GARHWAL HIMALAYAS

(Compiled from Dudgeon & Kenoyer, 1925)

Climatic zones.	Vegetation zones.
Temperate between 5,000 to 11,000 or 12,000 ft. with 70 to 80 percent of precipitation during summer; short and more moderate spring and autumn; cool winter with considerable snow.	*Broad leaved Sclerophyll forest* (i) *Quercus incana*, 4,500 to 8,000 feet. (ii) *Cedrus deodara* at 5,500 to 10,500 feet., edaphic climax. (iii) *Quercus dilatata*, 7,500 to 9,000 feet. (vi) *Quercus semecarpifolia* - *Abies pindrow*, 8,5000–11,000 or 12,000 feet. (v) *Coniferous* and *winter deciduous* forest, dominated by *Betula utilis* and *Abies webbiana*.

These authors consider that in this region broad leaved sclerophyll forests constitute climax vegetation. Among the different communities *Cedrus deodara* is believed to be an edaphic climax, which is rather doubtful. Deodar is an edaphic community but cannot be called a climax.

Besides the types given above riverain vegetation is considered under a distinct hydrosere on flood plains, terraces, talus slopes, ravines, etc., at lower levels between 5,000 and 7,000 ft. The pioneer trees to deodar on this habitat are *Alnus nepalensis, Betula alnoides, Ulmus wallichiana, Acer pictum*, etc. At higher levels *Ulmus* disappears giving place to *Alnus* and *Betula*. Maples, usually *Acer caesium, A. pictum, A. caudatum, Corylus colurna, Populus ciliata, Carpinus viminea*, etc. become more prominent along moist localities somtimes forming extensive groves. This pioneer winter deciduous forest produces dense shade during summer and is very humid, with a rich herbaceous undergrowth of ferns, Ranunculaceae, Urticaceae, etc.

The authors distinguish a distinct xerosere in which conifers are the pioneer species. *Pinus excelsa* is by far the commonest conifer to precede *Cedrus deodara*, both at higher as well as lower altitudes. The blue pine characteristically covers alluvial deposits and unstable slopes. Towards the upper parts of the deodar zone, the pioneer shrubs to occur in the xerosere are *Spiraea sorbifolia, Lonicera quinquelocularis, Abelia triflora, Rosa webbiana* and *Ribes grossularia*.

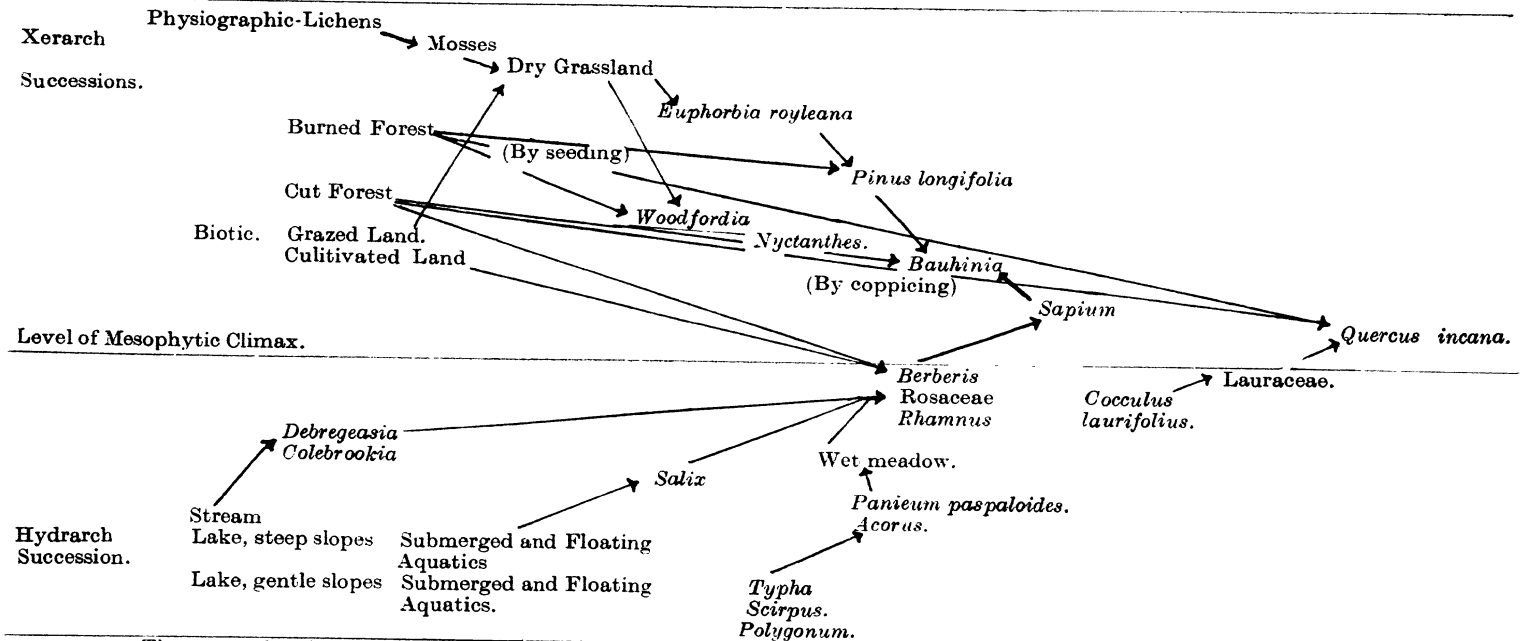
Kenoyer (1921) studied forest formation and succession in the sat Tal valley of the Kumaon Himlayas, where the average annual rainfall varies between 85" to 97.5", with frost at above 4,000 ft. He recognised communities similar to Dudgeon's. The succession of the vegetation according to Kenoyer is given in Table 33 on p. 129.

Kenoyer recognises two types of xerarch successions, namely topographical and biotic. The biotic succession is due to fire and other adverse effects of man on vegetation.

Table 33

CHART SHOWING SOME OF THE MORE FREQUENT SUCCESSIONS IN THE SAT TAL VALLEY

(After Kenoyer, 1921).



The vegetation, its development and succession in the Himalayas is governed by geology and soil features. Kenoyer does not recognise these basic features but emphasises only on physiography, biota and moisture content. The successional relationship given by him therefore, cannot be accepted as authoritative. In most of the areas *Quercus incana* is the climatic climax and *Pinus roxburghii* (*P. longifolia*) is an edaphic community, preserved permanently on quartzite. On limestone, sandstone, schist and slate *Q. incana* climax community has different composition. Being seral in nature on geological formations other than quartzite *Pinus roxburghii* appears as a seral community on burning felling or shifting cultivation. *Berberis*, Rosaceae and *Rhamnus* come with it as a result of biotic interference. It is, therefore, doubtful if it can be considered as a successional stage from wet meadow.

Osmaston (1922) described temperate vegetation from Tehri Garhwal under the following two formations:-

Pinus-Cedrus formation occurring within dry and arid zones, between 6,500' and 12,000' elevation. Here the annual precipitation varies between 10" and 40" and snow falls from November to April. On the north aspects there is generally sufficient moisture in the soil. Here also physiologic dryness is found owing either to low soil temperature or acid humus, or both. On south aspects the soil is often very shallow and dry and periodic fires cause additional dessication of the soil. Atmospheric temperature is generally low.

The vegetation is more xerophytic than mesophytic, though on north aspects whole of the hardwood association composed of deciduous broad leaved species is almost mesophytic.

Quercus-Abies formation occurs in the moist zone between 5,000' and 11,500'. The annual precipitation varies from 50" to 80" of which about 1 to 10 percent falls as snow. The climate is mainly temperate. The soil is usually moist. There is a high degree of relative atmospheric humidity throughout the monsoon period. There is a distinct layer of humus. Forests on southern aspects are much effected in density and composition by fires.

The vegetation on the whole is mesophytic. As already pionted out the climax vegetation in the Himalayas is only Oaks and not conifers. *Pinus-Cedrus formation* mentioned by Osmaston is a secondary succession, clearly a seral community.

Coventry (1929) divided the temperate vegetation of the Punjab Himalayas in accordance with altitude into lower and upper zones. The Forest vegetation of the lower temperate or blue pine zone comprises of (i) Blue pine (*Pinus excelsa*), (ii) Deodar (*Cedrus deodara*), (iii) mixed forests of broad leaved deciduous species of walnut, chestnut, elm, poplars, *Prunus*, etc. and (iv) Oak forests of *Quercus dilatata*.

Forest vegetation of the upper temperate or fir zone comprises of (i) Spruce (*Picea morinda*), (ii) Silver fir (*Abies pindrow*), (iii) Mixed broad leaved deciduous species, and (iv) Oak (*Quercus semecarpifolia*) forests.

The distribution of the different types of forests within the same zone depends upon the natural regeneration, which takes place in some species in the open on mineral soil, with full exposure to sunlight; and in others on humus soil under shade. Some species regenerate on moist soil which is well aerated also and still others regenerate on very dry soil, under more or less arid conditions, or on badly aerated soil.

Coventry studied edaphic and biotic features of these forests and concluded that in the Punjab hills, the forests still in existence almost everywhere, with the exception of comparatively small areas, chiefly in the higher hills, are undergoing deterioration, there being a general tendency for the climax or other mesophytic types to get replaced by more xerophytic types indicating a gradual change from moist to drier soil conditions.

Forest management types of temperate vegetation: In order that proper management practices may be given the forest vegetation of the temperate regions of the Punjab, and Himachal Pradesh has been classified into a number of management types according to the factors of locality, regeneration behaviour of species and succession. Suri (1933) was probably the first to give such a classification which has since been accepted by Aggarwal (1949-50). The management types are:—

(i) **Hardwood sub-type.** Tree layer consists of spruce and Silver fir, with hardwood species of *Aesculus indica, Juglans regia, Acer spp., Corylus colurna, Celtis australis, Ulmus wallichiana, Alnus nitida, Populus ciliata, Prunus padus, Symplocos crataegoides*, etc. forming the second storey. A view of the type is shown in Photo 18.

The common shrubs are *Viburnum foetens, Rubus niveus, Indigofera* sp., *Salix elegans*, etc., and the ground flora consists of *Senecio rufinervis, Ainsliaea aptera, Oxalis corniculata, Valeriana hardwickii, Strobilanthes* spp., *Impatiens* spp., *Smilacina pallida, Polygonum amplexicaule, Pteris, Salvia glutinosa*, etc. In this type regeneration of Silver fir and spruce is adequate as this is a seral type.

(ii) **Taxus sub-type.** The tree layer is formed by *Abies* and *Picea*, with a second storey of *Taxus*. The common shrubs are *Deutzia corymbosa, Lonicera angustifolia, Rosa macrophylla, Indigofera gerardiana*, and *Viburnum foetens*. In the ground layer *Strobilanthes wallichii, Smilacina pallida, Trillium* spp., are abundant. The regeneration of *Abies* is difficult in this sub-type, since this community is in an advanced stage of succession and would lead to *Quercus semecarpifolia* climax. The soil in this type is usually rich in humus.

(iii) **Arundinaria sub-type.** The tree layer is formed by *Abies-Picea-Cedrus* and the shrubs and ground layers are formed by thickets of *Arundinaria falcata, A. spathiflora*, with *Strobilanthes* sp. The regeneration in this type is also difficult to obtain for *Abies*.

(iv) **Indigofera - Desmodium sub-type.** This occurs mostly in the *Picea-Pinus-Cedrus* type. *Indigofera-Desmodium* and bracken form the main shrub and ground layers. This type is biotic and the regeneration of conifers is abundant. The soil is on the drier side.

(v) **Spiraea-Viburnum sub-type.** This again is found in belts of spruce forests. The ground layer is grassy with bracken, *Iris* and *Salvia glutinosa*, occurring in small pure patches.

(vi) **Plectranthus rugosus sub-type:** This is found in pure spruce-fir forests which are heavily grazed. *Plectranthus rugosus* with grasses is the only undergrowth.

Both the subtypes (v) & (vi) are biotic and have fairly good regeneration of conifers. The communities are seral.

(vii) **Senecio sub-type:** This occurs in mature Silver fir forests where other ground layer species are *Ainsliaea aptera* and *Strobilanthes atropurpureus*. The regeneration of Silver fir is difficult to obtain as the community is progressing to *Taxus* and *Quercus semecarpifolia* climax.

(viii) **Bracken sub-type.** This occurs in felled, grazed or burnt silver fir, spruce, deodar and blue pine forests. This is associated with *Indigofera-Desmodium* and *Spiraea-Viburnum* subtypes. This type is clearly biotic and when secondary succession is started as a result of biotic interference regeneration of conifers is abundant.

(ix) **Iris sub-type.** This occurs in *Picea-Pinus-Cedrus* type, with shrub layer of *Viburnum, Spiraea sorbifolia*, etc. Patches of *Iris* occur in moist or wet places usually. These are also associated with disturbed forests and in such conditions regeneration is usually inhibited.

(x) **Strobilanthes-Balsam sub-type.** This type occurs mainly in very moist and grazed Silver fir forests, with almost only *Indigofera gerardiana* in the shrub layer. *Strobilanthes* and *Impatiens* species constitute the ground layer.

Coniferous forests, which are developed on dip slope of rocks, are usually very rich in ground flora species, as is shown in Photo 19.

In the Kulu Himalayas, which have been glaciated the Oak climaxes have been mainly destroyed at most places and on glacial moraines at higher levels and on flood plain deposits at lower levels conifers have taken possession.

Vegetation communities in temperate forests of the Bashahar Himalayas. Gorrie (1933) and Mohan and Puri (1955) have given a detailed account of the Oak and conifer communities from the Bashahar Himalayas. From the outer zone of high monsoon rainfall they described the following forest communities:

1. **Quercus semecarpifolia community**: *Q. semecarpifolia* is the high level west-Himalayan oak occupying all aspects and slopes (Photo 20). The shrub layer consists of *Cotoneaster* spp., *Viburnum* spp., *Berberis*, etc., and the ground layer species are *Fragaria vesca, Geranium wallichianum, Rumex* sp., *Viola canescens, Potentilla* sp., etc. The invasion of conifers in this community occurs as a result of coppicing, felling and grazing. A heavily coppiced forest of *Q. semecarpifolia* is seen in Photo 21.

2. **Quercus-Pinus-Picea-Abies community:** This is an intensely disturbed climax oak community in which *Abies webbiana, Picea smithiana* and *Pinus excelsa* have successfully invaded. *Taxus baccata* also occurs sometimes. The most common ground flora species are *Fragaria, Galium, Geranium, Polygonum, Viola,* etc., in a grassy undergrowth.

3. **Pinus excelsa community:** The blue pine is a most common conifer in the Bashahar Himalayas occurring from elevations of 4,000 to 12,000 feet, or even higher. It occupies all sorts of habitats and occurs as a pioneer in *Quercus semecarpifolia, Q. incana, Abies, Picea* and deodar communities. In pure blue pine forests shrub layer consists of *Cotoneaster bacillaris, Cotoneaster microphylla, Berberis* sp., etc. and the ground layer is usually grassy with clumps of *Pteridium* and *Salvia glutinosa.*

4. **Abies webbiana-Taxus baccata community on glacial moraines:** This community occurs on glacial moraines at 9,300 feet height and seems to be a little more developed form of a pure silver fir community. In this *Picea smithiana* and *Pinus excelsa* are also present and the ground flora chiefly consists of *Ainsliaea aptera, Geranium wallichianum, Lonicera* sp., *Valeriana* sp., *Galium* sp., etc. Regeneration of silver fir is abundant.

5. **Abies webbiana-Taxus baccata community in unglaciated region:** This community is developed on old scree masses in which the soil is cut up into small gullies and spurs. The silver fir community in gullies has broad leaved species, such as *Aesculus indica, Juglans regia, Acer caesium, Prunus padus,* etc. *Taxus baccata* is mostly present on spurs with a sparse undergrowth of *Ainsliaea aptera.* In moist areas, in gullies *Strobilanthes* and *Impatiens* are common.

6. **Abies-Taxus-Quercus semecarpifolia community**: Is developed on scarp slopes at Daran Ghati and Nankhari and is mixed with numerous broad leaved species such as *Juglans regia, Corylus colurna,* and *Acer* spp., In drier places *Taxus* and oak with *Cotoneaster* and *Viburnum* are present. Ground flora chiefly consits of *Anisliaea aptera, Adiantum* sp., *Fragaria* sp., *Geranium* sp., *Galium* sp., *Senecio* sp., *Viola* sp., etc. with a grassy layer.

7. **Quercus incana community:** *Q. incana* occupies the middle zones in the Himalayas between the altitudes of 4,000 to 8,000 feet and seems to be a stable climax vegetation of this region. In gullies

Machilus, Cornus, Phoebe and some other species are found in fair numbers, otherwise *Rhododendron arboreum* is the usual associate of this oak. *Desmodium tiliaefolium* and *Quercus incana* seedlings are present in abundance in a grassy ground layer.

8. **Quercus incana - Rhododendron arboreum - Pinus excelsa community:** When a stable ban oak (*Q. incana*) community is disturbed by the human interference a large number of species which include mainly the conifers come in. The other chief associates are *Rhododendron arboreum, Pieris ovalifolia, Pyrus pashia, Litsaea umbrosa, Desmodium tiliaefolium, Myrsine africana,* etc. *Berberis* sp., *Pteridium, Salvia glutinosa, Sarcococca,* etc. constitute the lower layers of disturbed ban oak forest.

9. **Pinus excelsa secondary community** represents a secondary succession on abandoned cultivated soils which are usually dry and poor. There are a large variety of shrubs some of which show the intensity of grazing and fire. The undergrowth is mainly grassy with *Pteridium* and *Salvia glutinosa.* Patches of *Iris* are present here and there. *Fragaria, Galium,* Geranium, *Anemone, Thalictrum, Ainsliaea,* etc. are found in situations with slightly different moisture contents.

10. **Pinus excelsa - Picea smithiana secondary community:** This community is developed on well stabilized, some what clayey, brownish soil formed by the decomposition *in situ* of quartose gneissic rock. Photo 22 shows a view of mixed community. The area is cut up into gullies and spurs. Ground flora vegetation on spurs chiefly consists of *Ainsliaea aptera, Fragaria vesca, Galium aparine, Geranium wallichianum, Rumex* sp., *Viola* sp., etc., in a grassy layer. In gullies there are clumps of *Cannabis sativa, Girardiana heterophylla, Arisaema helleborifolium, Iris nepalensis,* etc.

11. **Quercus incana - Quercus dilatata community:** Is developed on the dip slope of schists which is moist and cut up into gullies, that are shallow and well stabilized. *Aesculus indica, Litsaea umbrosa, Fraxinus excelsior, Ilex dipyrena* are present in this community. The ground flora consists of mainly *Strobilanthes, Viola, Quercus dilatata* seedlings and *Aesculus indica* seedlings, etc.

12. **Quercus dilatata - Pinus - Picea - Abies community:** The mixed oak-conifer forest is developed on the dip slope which is extremely moist and is composed of alternating strata of schists and phyllite. Ground flora consists of *Ainsliaea aptera, Viola* sp., *Quercus dilatata* seedlings, *Picea smithiana* seedlings, *Adiantum* sp. etc. in a grassy undergrowth.

13. **Aesculus indica - Picea smithiana community:** This community is developed on riverain habitats on alluvial soil. In this *Juglans regia, Alnus nitida, Litsaea umbrosa, Populus ciliata, Sarcococca* and *Ilex dipyrena* are also present. The ground flora consists of *Strobilanthes, Impatiens, Salvia glutinosa, Viola sp., Thalictrum* sp., etc.

14. **Pinus excelsa - Picea smithiana community:** This community is developed on abandoned cultivation in moist type of soil. In gullies and wet situations trees of *Acer, Prunus* and *Viburnum* are far more common than the pines and spruce. In the underground *Strobilanthes* and *Iris* sp., are very common with ferns and *Geranium.*

15. **Secondry scrub community** (dry type): In places where *Quercus incana* has been very badly treated and the soil is too rocky and dry for occupation by oaks a scrubby vegetation results. It is dominated by *Desmodium, Cotoneaster, Leptodermis, Deutzia, Buddleia, Withania, Plectranthus,* etc.

16. **Secondary scrub community** (moist type): This is developed at many places above Sarahan and is composed of scattered trees of *Prunus padus, Populus ciliata, Salix wallichiana, Cedrela serrata, Pieris ovalif lia* and rarely *Quercus incana;* scattered plants of *Aquilegia, Anemone biflora, Geranium wallichianum, Viola canescens* and ferns are present. Patches of *Iris nepalensis* and Balsam are present in the moist soil.

17. **Quercus dilatata community:** Pure *Q. dilatata* community is rarely found. It is either mixed with the ban oak or with broad leaved species forming seral communities on moist soils.

A heavily disturbed *Q. dilatata* community is developed on an old alluvium at an altitude of about 7,500 feet near Ramni. In this the shrub layer consists of mainly *Desmodium tiliaefolium, Rosa macrophylla, Indigofera, Plectranthus* and *Clematis.* A dense growth of *Boenninghausenia albiflora, Geranium wallichianum, Cannabis sativa, Arisaema helleborifolium, Galium, Salvia glutinosa* and sometimes *Impatiens* and *Viola* are present in a dense grassy growth.

18. **Cedrus deodara community:** This is found at many places on flood plain deposits of the Sutlej at altitudes varying from 6,000 to 10,000 feet or above (Photo 23). Much of the forest area studied is on abandoned cultivation and it has all age classes of deodar with very good regeneration. *Desmodium tiliaefolium* is almost the only shrub present here. The ground flora consists of mainly *Arisaema helleborifolium, Fragaria vesca, Galium aparine, Geranium wallichianum, Strobilanthes, Viola* sp., *Adiantum* sp., *Anemone rivularis,* with several types of ferns in a grassy undergrowth.

20. **Cedrus deodara - Picea smithiana community:** This community is developed on alluvium of Panwi Gad on the dip slope of granites. In this, there is a dense shrub layer composed of mainly *Desmodium tiliaefolium, Rosa macrophylla, Viburnum cotinifolium, Indigofera* sp., *Cotoneaster bacillaris,* etc. The chief ground flora species are *Ainsliaea aptera, Galium aparine, Saxifraga* sp., *Adiantum* sp., etc. with seedlings of deodar, pine, and spruce in a grassy undergrowth. A mixed deodar, pine, silver fir and spruce community is shown in Photo 24.

Champion classifies the temperate vegetation from the high monsoon rainfall zone into a number of types in table 34.

Succession of forest communities in the zone of high monsoon rainfall: Champion is not quite clear about the succession of these forests since he has considered conifers, or mixed conifer forests along with oaks as climatic climax in one part and pure oak forests in another place. Recent studies of Mohan and Puri, however, have clearly shown that conifers are nowhere climatic climax but form seral stages to oak climax. The succession according to these authors in the Bashahar Himalayas is as follows:—

(A) "**Quercus semecarpifolia** zone:- 1. In the high level region pure *Quercus semecarpifolia* community is the stable climax on all aspects and slopes.

2. The stable oak community is preserved in a better condition on scarp slopes and especially if they coincide with sourthern aspects.

3. The oak stable climax on scarp slope has been disturbed variously by coppicing, lopping, felling, grazing and fire, resulting in the formation of a number of mixed oak-conifer communities.

4. The mixed oak-conifer bio-edaphic communities represent a secondary succession and always tend to develop into a stable pure oak community, if and when the adverse biotic influences are removed.

Table 34.

TYPES OF TEMPERATE FOREST VEGETATION

according to Champion (1938)

GROUP II HIMALAYAN MOIST TEMPERATE FOREST.

Sub-type and distribution	I	II	III	IV
1. Western temperate broad leaved forests.				
(a) Ban oak forest. Most extensive in the Central Himalayas of Kumaon (U. P.)				
(i) Binsar, W. Almora division 6,500 ft.	*Quercus incana*(va), *Carpinus viminea*(r), *Cedrela serrata*(la)	*Rhododendron arboreum* (a) *Pieris ovalifolia* (a) *Euonymus pendulus* (f), *Ilex dipyrena*(o), *Betula alnoides* (o), etc.	*Viburnum cotinifolium*(f) *Desmodium tiliaefolium*, (f) *Indigofera gerardiana*(f) *Rubus niveus* (f), etc.	*Vitis* spp. (o), *Hedera* (f), *Smilax parvifolia* (f).
(ii) Girichina, W. Almora 6,000 feet.	*Quercus incana*, *Rhododendron arboreum* (a), *Pieris ovalifolia* (a), *Rhus semialata* (f), *Symplocos crataegoides* (o), *Pyrus pashia*(o), *Cornus capitata* (r), *Castanopsis tribuloides* (r).		*Berberis lycium* (f) *Indigofera gerardiana* (f), *Viburnum cotinifolium* (f), *V. coriaceum* (f), *Lonicera quinqueloculari*s(f), *Reinwardtia* (f), etc. III. a *Pteris aquilina* (a), *Plectranthus* (a). *Myriactis* sp. (f), etc. *Agrimonia* (f). Thin grass.	*Vitis himalayana* (a), *Rosa moschata* (o), *Loranthus* sp. (a).
(iii) Garhwal.	Similar to (i).			
(iv) Sutlej Valley, Punjab.	Similar.			
C2. (a) *Quercus dilatata*. Acer forest. A relatively narrow belt above the ban oak about 7,000 ft. to				

a. = abundant. v.a. = very abundant. l.a. = locally abundant. f. = frequent. o. = ccasional. r. = rare

Table 34 (Contd.)

Sub-type and distribution	I	II	III	IV
8000 ft. in the C. Himalaya.				
(i) Bhatkot E., C. Almora.	*Quercus dilatata* (a), *Q. incana* (o) *Abies pindrow* (lf), *Taxus baccata* (o).	*Euonymus pendulus* (a), *Ilex dipyrena* (o), *Rhamnus purpureus* (o), *Lindera pulcherrima*(lf), *Eurya acuminata* (f), *Phododendron arboreum* (f), *Meliosma dilleniaefolia*(f), etc. II a. *Arundinaria falconeri* (f), *A. jaunsarensis* (lf).	*Rosa macrophylla*, *Rubus niveus*, *R. biflorus*, *Myrsine semiserrata*, *Viburnum* spp. *Berberis aristata*, *Strobilanthes Wallichii*, *S. alatus*. *Deutzia corymbosa*. etc.	*Hedera helix*.
(ii) Garhwal Himalaya.	*Quercus dilatata*, *Q incana*, *Q. semecarpifolia*, *Betula alnoides*, *Carpinus viminea*, *Acer cuesium*, *Machilus duthiei*.	*Euonymus pendulus*, *Ilex dipyrena*, *Rhamnus purpureus*, *Eurya acuminata*, *Buxus sempervirens* (quite small societies). etc. II a. *Arundinaria falconeri*, *A. jaunsarensis*.	*Boenninghausenia*, *Salix elegans*, *Skimmia laureola*, *Strobilanthes Wallichii*, *Viburnum cotinifolium*.	*Hedera helix*.
(iii) Sutlej valley Punjab.	Locally forms associations met within (i) and (ii).	very similar to those.		
C3 (a) *Quercus semecarpifolia* forest. All along the outer and moister ranges of W. & C. Himalaya between 8,000–11,000 ft.				
(i) Dhakuri, C. Almora division 9,500 ft.	*Quercus semecarpifolia* (va,) *Betula alnoides* (o), *Pyrus lanata* (f), *Quercus dilatata* (o), *Acer cassium* (o), *Abies pindrow* (a).	*Meliosma dilleniaefolia* (o), *Rhododendron arboreum* (f), *R. barbatum* (o). *Pyrus foliolosa* (o), *Betula utilis* (o), II a. *Arundinaria spathiflora*(va), *A. falconeri* (f).	*Rosa sericea* (f), *R. macrophylla* (f), *Viburnum foetens* (a). *Cotoneaster acuminata* (f). *Strobilanthes Wallichii* (f), *Ribes glaciale* (o) etc.	*Clematis montana*, *Vitis himalayana*, etc.
(ii) Garhwal Himalaya 11.000.	*Quercus semecarpifolia* (va). *Abies pindrow* (o).	*Rhododendron arboreum* (a). *Prunus padus* (o). *Ilex dipyrena*, *Acer* spp., *Taxus*	*Rosa sericea*, *R. macrophylla*, *Cotoneaster acuminata*, *Salix elegans*, *Ribes glaciale*,	3 deciduous lianas.

		baccata.	*Viburnum* spp., etc.		
(iii) Deoban Jaunsar U.P.	*Quercus semecarpifolia* (a), *Picea morinda* (o), *Meliosma dilleniaefolia* (r), *Abies pindrow* (r).	II a. *Arundinaria spathiflora* (va) *A. Jaunsarensis* (va). *Euonymus tingens* (o), *E. lacerus* (o). *Cotoneaster acuminata* (f), *Prunus padus* (o), *Ilex dipyrena* (o), *Viburnum* spp.	III a. Perennial herbs, mosses and ferns. *Rosa macrophylla* (a), *Lonicera angustifolia* (a), *Jasminum humile* (f). *Rubus niveus* (a), etc.	*Jasminum officinale* (f), *Clematis montana* (f), *C. connata* (o), *Hedera* (f), *Vitis himalayana* (o).	
		II. a. *Arundinaria spathiflora* (lf).	III. a. *Polygonum speciosum* (a), *Senecio rubicaulis* (a), *Fragaria vesca* (a), *Viola* sp. (a) etc., etc.		
(iv) Sutlej valley Punjab.	Identical with that of U.P. except for the presence of spruce and blue pine.				
II. Western temperate coniferous forest.					
Cl. (b) Moist deodar forest. From Garhwal westwards through Jaunsar, the Punjab hills, Kashmir, Hazara & Chitral.					
(i) Lower Bashahar sample plots.	*Cedrus deodara*, *Pinus excelsa* (r)	*Quercus incana* (r).	*Rosa macrophylla* (f), *Berberis lycium* (f), *Lonicera angustifolia* (f), *Strobilanthes Wallichii* (f), etc. III a. *Deutzia staminea* (f), *Adiantum lunulatum* (a), *Lastraea* spp. (f). *Galium asperifolium*, *Salvia glutinosa*, *Fragaria indica*, *Viola canescens*, *Fragaria vesca*, *Indigofera heterantha*, etc.	*Hedera helix* (f), *Jasminum officinale* (o), *Clematis montana* (o), *Vitis himalayana* (r).	
(ii) Kulu division. Punjab.	*Cedrus deodara*.				
(iii) Mundali and Kathyan, Chakrata	*Cedrus deodara* (va), *Abies pindrow* (r), *Picea morinda* (r).	*Quercus dilatata* (r), *Q. incana* (r), *Pieris ovalifolia* (r), *Pyrus pashia* (r).	*Desmodium tiliaefolium* (a), *Rubus niveus* (f), *Lonicera angustifolia* (r), *Strobilanthes Wallichii* (a), etc.	*Jasminum officinale* (f) *Hedera* (o), *Smilax parviflora* (o).	

a. = abundant v.a. = very abundant l.a. = locally abundant f. = frequent. o. = occasional r. = rare

Table 34 (Contd.)

Sub-type and distribution	I	II	III	IV
			III. a. *Galium* sp. (f), *Polygonum speciosum* (f), *Fragaria vesca* (o), *Viola canescens* (f), *Valeriana* sp. (a), *Salvia glutinosa* etc. (la).	
C2 (b) Western mixed coniferous forest. The Himalayas from Garhwal westwards through Jaunsar, the Punjab hills & Kashmir.	*Picea, Cedrus, Abies pindrow, Pinus excelsa.*	*Quercus dilatata, Q. incana, Q. semecarpifolia, Acer acuminatum, A. caesium, A. pictum, Euonymus lacerus, Taxus baccata, Betula alnoides.*	*Arundinaria falcata, A. spathiflora, Deutzia corymbosa, Ribes ruburnum, Viburnum nervosum,* etc. III. a. *Fragaria, Viola, Valeriana, Pteridium, Adiantum,* etc.	*Clematis barbellata, Hedera helix, Schizandra grandiflora, Vitis* spp.
(i) Spruce - deodar belt, Sutlej valley, Punjab				
(ii) Deoban, Chakrata, U.P. 8,000 feet.	*Abies pindrow* (a), *Picea morinda* (f).	*Quercus semercarpifolia* (a), *Euonymus lacerus* (o), *Rhamnus purpureus* (r), *Meliosa dilleniaefolia* (r). II. a. *Arundinaria spathiflora* (lf).	*Rosa macrophylla* (a), *Lonicera angustifolia* (a), *Strobilanthes Wallichii* (f), *Smilax vaginata* (f), etc. III. a. *Viola serpens* (va), *Fragaria vesca* (a) *Ophiopogon* (a), *Polygonum speciosum* (a), *Impatiens* sp. (a), etc.	*Hedera* (a), *Vitis himalayana* (r), *Jasminum officinale* (o).
(iii) Grahan Nal, Parbatti valley Punjab.	*Cedrus deodara* (a), *Abies pindrow* (a), *Picea morinda.*	*Acer* spp., *Juglans regia, Corylus colurna, Celtis australis, Ulmus wallichiana,* II. a. *Arundinaria falcata* (a), *A. spathiflora* (a).	*Strobilanthes* sp. (a).	
C3 (b) Western Oak-fir forest. Along the higher ranges of the W. & C. Himalaya eastwards to Nepal, between 8,500′ & 11,000′.				

(i) Dhakuri, Almora division, U.P. C.	*Abies pindrow.*	*Quercus semecarpifolia* (a), *Q. dilatata* (f), *Pyrus lanata* (f), *Rhododendron arboreum* (f), etc. II. a. *Arundinaria jaunsarensis* (lf), *A. spathiflora* (lf).	*Rosa macrophylla* (f), *Viburnum foetens* (la), *Berberis vulgaris* (f), *Strobilanthes* sp. (a), *Smilax vaginata* (f).	
(ii) Garhwal Himalaya (moist).	*Abies pindrow, Picea morinda* (r)	*Quercus semecarpifolia* (o), *Q. dilatata, Ulmus wallichiana, Aesculus indica, Acer caesium, Corylus colurna.* II. a. *Arundinaria spathiflora, A. jaunsarensis.*	*Strobilanthes* spp., *Rubus niveus, Sarcacocca pruniformis, Wikstroemia canescens, Rosa macrophylla, Skimmia laureola, Syringa emodi, Taxus baccata, Viburnum* spp.	*Vitis semicordata, Schizandra grandiflora, Hedera helix.*
(iii) Deoban Chakrata division, U.P.	*Abies pindrow, Picea morinda* (r).	*Quercus semecarpifolia* (o), *Q. dilatata* (r), *Acer caesium* (o), *Meliosma dilleniaefolia* (r), *Euonymus lacerus* (r), *Ilex dipyrena* (r). II. a. *Arundinaria spathiflora* (r).	*Rosa marophylla* (a), *Rubus niveus* (a), *Lonicera angustifolia* (r), *Smilax vaginata* (a), *Viburnum stellulatum* (f), *Strobilanthes* sp. (f), *Berberis* sp. (o), *Asparagus filicinus* (o), *Viburnum foetens* (o), etc. III. a. *Ainsliaea aptera* (a), *Ophiopogon* (a), *Polygonum speciosum* (a), etc.	*Clematis* spp. (o), *Vitis semicordata* (o), *Hedera* (a).
(iv) Pulga. Parbatti valley. Kulu 8,500 - 9,000 ft.	*Abies pindrow* (a) *Pinus excelsa* (lf), *Picea morinda* (la).	*Acer* spp., (o), *Taxus baccata* (o), *Corylus colurna* (o), *Quercus semecarpifolia* (o), *Pyrus lanata* (o).	*Rosa sericea* (f), *R. macrophylla* (f), *Viburnum faetens* (la), *Rubus niveus* (a), *Smilax vaginata* (f), *Spiraea* sp. (o), etc.	*Fragaria vesca* (f), *Ainsliaea aptera* (f), *Valeriana* (f), *Galium* (f), *Adiantum* (la)
(v) Sutlej valley.	*Abies pindrow.*	*Quercus semecarpifolia, Betula alnoides, B. utilis, Acer* spp., *Pyrus foliolosa.*	*Spiraea bella, Cotoneaster acuminata, Rhododendron campanulatum,* etc. III. *Fragaria vesca, Podophyllum emodi, Senecio* spp., *Spiraea* spp.	*Vitis semicordata, Schizandra grandiflora.*

a. = abundant. v.a. = very abundant. l.a. = locally abundant. f. = frequent. o. = occasional. r. = rare.

5. In such mixed oak-conifer communities the regeneration of the oak is always abundant and there are very few or no broad-leaved species other than the oak.

6. Due to intense biotic interference pure or almost pure blue pine community and pasture-lands have developed. These are mainly biotic-controlled seral communities and at most places show secondary succession to the oak climax through various stages.

7. The oak forms a stable climax vegetation on the dip slope as well, but on account of the higher soil humidity and deep finely divided soil, the progression to the stable climax is extremely slow. There are, therefore, a number of seral communities, with little or no oak present. The chief seral stages leading to oak climax on the dip slope are:—

(a) *Abies webbiana.*
(b) *Abies webbiana - Taxus baccata.*
(c) *Abies - Taxus* - Oak.

8. The above seral communities on the dip slope are to be distinguished from the degenerated oak communities on the scarp by the fact that the former have a much larger proportion and percentage of deciduous broad leaved species than the latter.

9. The adverse biotic factor on the dip slope brings into prominence a very early seral stage comprising of pine-spruce - poplar.

10. On glacial moraines which are almost invariably located on northern aspect the progression of the silver fir community to the stable oak climax is exceedingly slow due to the heterogeneity of the soil and higher soil humidity. The successional stages on this habitat are:

(a) *Pinus excelsa* - proper community.
(b) *Pinus - Abies* community.
(c) *Abies,* or *Abies - Betula* community.
(d) *Abies - Taxus* community.

11. The above seral communities resemble the forest communities on dip slope in unglaciated regions in the presence of a higher proportion of broad-leaved species other than the oak, but unlike the latter have an abundant regeneration of silver fir.

12. Open grassy thatches and pure blue pine communities are also present in glaciated regions on moraines. These are biotic communities and their progression to silver fir community is much faster than on the scarp.

(B) SUCCESSION IN QUERCUS INCANA ZONE.

1. In the ban oak zone pure *Quercus incana* is the stable climax community.

2. On disturbance of this climax community, various conifers, usually *Pinus excelsa, Picea smithiana* and *Pinus roxburghii,* invade the area, forming a mixed oak-conifer community which represents a secondary succession and is developmental in status. This, no doubt, would develop to the climax oak, if the biotic factor is excluded.

3. In areas from where *Quercus incana* had been completely destroyed and put under cultivation and subsequently abandoned *Pinus excelsa* or *Pinus excelsa-Picea smithiana* community develops, which represents a secondary succession and depending upon the biotic interference and the potentiality of the soil they tend to develop into the climax ban oak community, but the progress is slow.

4. The places from where *Quercus incana* has been lopped and heavily cut, a secondary scrub of wet or dry type develops which is a degenerate oak climax and remains preserved in its present stage by the peculiar biotic and edaphic features.

5. The above communities mostly occur on scarp slope or on stabilized scree deposits which are usually dry and may occur on dip slope. In all events the climax community is *Quercus incana.*

6. On dip slope or on scree deposits which are moist due to the seepage of water a mixed *Quercus incana - Q. dilatata - Acer - Aesculus* community develops and tends to remain in a seral stage on account of the special features of the environment.

7. The secondary scrub of the moist type may at some places be a degenerate mixed oak - broad leaved species community described in (6) above.

8. On riverain alluvia there are two types of communities (i) with broad leaved species other than the oaks and (ii) in which conifers have gained their foothold. These are although, seral in nature, their progression to oak climax does not take place ordinarily.

9. *Pinus roxburghii* community on quartzite formation is either progressive to the oak climax or at some places is a degenerate type and shows a secondary succession.

The above successional relationship of forest communities described from the Bashahar Himalayas is general for all glaciated regions."

Succession of forest communities in glaciated regions of the Temperate Himalayas: "In glaciated areas from where oaks have been destroyed during the Pleistocene Ice Age and do not occur as predominant crops, as is found today in the Kulu Himalayas and Kashmir valley, the succession has been described by Puri (1950) and Puri and Gupta (1952) as follows:—

(a) On residual soils the development and succession of forest vegetation depends to a great extent on the structural geology and mineralogical composition of the original rock type. On the basis of chemical composition of rocks and foliar composition of trees the forest communities are classified into non-exacting and exacting groups. The non-exacting group includes *Pinus roxburghii* and *Pinus excelsa* communities while *Cedrus deodara, Picea smithiana - Abies webbiana* and *Abies webbiana* and communities of broad leaved species other than the oaks are termed exacting. The succession on residual soils is from non-exacting to exacting forest communities and the rate of succession is determined by the geological nature of the slope. Photos 25 and 26 show views of conifers on residual soil in the Kulu Himalayas.

(b) On secondary soils the establishment, development and succession of forest vegetation seem to be influenced by the nature of edaphic complex. The following successions were seen on different secondary soils:—

(i) On Alluvial and flood plains. On dry sandy soils the forest succession is chir pine or/and blue pine - blue pine community.

On a more fertile soil derived from schists and/or phyllite, blue pine → blue pine - deodar → deodar. Photo 27 shows a view of deodar on flood plain deposits in the Parbatti Valley.

On fresh alluvium at higher elevation the forest succession is from *Populus - Alnus-Juglans - Prunus - Pinus - Pinus → Picea* or pure *Picea community.*

(ii) On rock screes, land slides and land slips the mixed community of *Pinus roxburghii* and/or *Pinus excelsa* with or without the broad leaved species of Poplar and Alder progresses to blue pine and/or deodar community depending upon the physical and biological nature of the soil and its moisture regime. Photo 28 shows a view of conifers in the Kasol valley.

(iii) On glacial moraines, which are composed of very fine clayey soils, with blocks of decomposing rock, the pioneer forest community includes invariably blue pine and broad-leaved species of *Prunus, Populus, Sorbus,* etc. The area is sooner or later covered with *Abies* community, which may have varying amounts of broad-leaved species as well. A good Silver fir community on moraines and spruce on flood plain deposits above 9,000 ft. in the Parbatti Valley, Kulu is seen in Photo 29.

On moraines with larger blocks of rock and coarse soil, the blue pine is present in larger proportion. Here *Abies* community with some broad-leaved species and abundant regeneration seems to be a late seral stage appearing as climax. Although, the community does not progress further this is not a true climatic climax for the area."

The relationship of forest communities with geological features in the Kulu Himalayas is shown after Puri (1950) in Figs. 45–49.

Vegetation of the dry temperate zone of the Himalayas: Gorrie (1933) and Mohan and Puri (1955) studied vegetation of the Bashahar Himalayas. The following forest communities in *Quercus ilex* climax have been recognised.

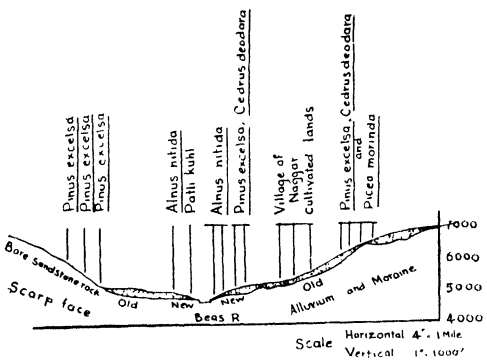


Fig. 45. Relation between Forest communities and geological features in the Beas Volley near Naggar.

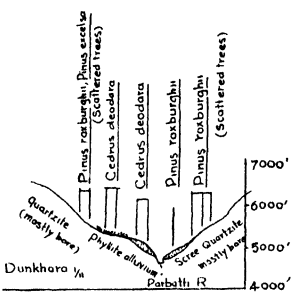


Fig. 46. Relation between Surface geology & Vegetation.

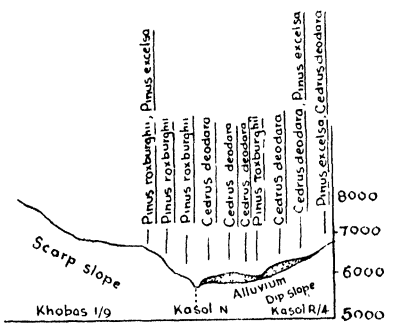


Fig. 47. Relation between Vegetation and geology in the Parbatti Valley, Kulu.

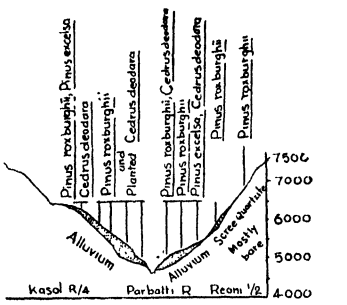


Fig. 48. Relation between geological features & forest communities.

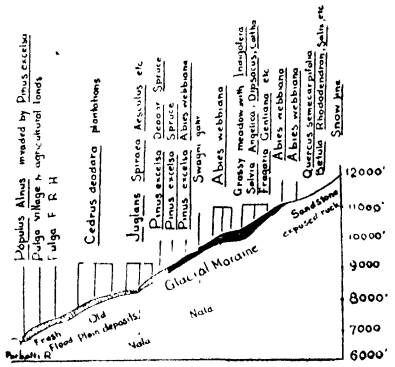


Fig. 49. Relation between tree communities and surface deposits at Pulga.

1. **Quercus ilex community:** This community occupies the inner dry valleys of the Sutlej and its tributaries above Ramni. It is most common on the scarp and steeply cut slopes of granite, which has a fair admixture of quartzite. This is a stable climax of the dry zone. Shrub layer consists of *Daphne oleoides, Desmodium floribundum* and *Indigofera gerardiana.* In the ground layer are mainly *Artemisia vulgaris, Lespedeza floribunda, Plectranthus rugosus, Polygonatum verticillatum* and *Quercus ilex* seedlings in a grassy growth.

2. **Cedrus deodara - Quercus ilex community:** This community is developed on flood plain deposits of granite at several places in the valley above Sholtu and is a late seral stage progressing to the oak climax. In this, the shrub layer is composed of chiefly *Fraxinus xanthoxyloides* and *Desmodium floribundum.* Ground flora is scanty and has *Artemisia vulgaris, Boerhaavia repens, Oplismenus* sp., *Plectranthus rugosus, Chenopodium* sp., and *Quercus ilex* seedlings.

3. **Degenerate Quercus ilex scrub:** This community results when *Quercus ilex* is heavily felled and the soil is too rocky. The scrub vegetation consists of *Desmodium floribundum, Plectranthus rugosus, Artemisia* sp., with scattered trees of *Pinus gerardiana* and *Quercus ilex.*

4. **Quercus ilex - Pinus gerardiana community:** This community is developed on old flood plain deposits of Sutlej between Shongtong and Purbani where the oaks have been very greatly damaged. Under this, a number of ground flora species such as Bracken, *Salvia glutinosa, Fragaria,* etc. appear. In somewhat moister bits of the soil balsam and *Thalictrum* are found together with grasses.

5. **Pinus gerardiana - Quercus ilex community:** This is developed on a recent flood plain deposits of the Sutlej and its tributaries that meet the river in the main valley above Shongtong (Photo 30). The chief shrubs are *Daphne oleoides, Desmodium floribundum,* and *Olea cuspidata* and the ground flora consists of *Boerhaavia repens, Cannabis sativa, Chenopodium album* and *Plectranthus rugosus* in a grassy layer.

6. **Cedrus deodara-Pinus gerardiana-Quercus ilex community:** This is developed near Purbani on flood plain deposits formed by the mixture of soil derived from quartose - granite and mica-schist rocks. Ordinarily in these forests there is very little ground flora but in grazed areas where manure of sheep and cattle is scattered *Cannabis sativa* and *Chenopodium* sp. come up in clumps.

Champion, however, classifies Himalayan dry temperate forests as given in table 35. This is mainly based on Gorrie's description, which has been modified by Mohan and Puri.

Table 35.

GROUP 12. HIMALAYAN DRY TEMPERATE FOREST

Sub-type and distribution	I	II	III	IV
C_1. Dry temperate mixed evergreen forest.		=		
The inner dry Himalayan valleys from 5,000' upwards. (i) Kilba U. Bashahar.	*Pinus gerardiana* (a), *Cedrus deodara* (o), *Quercus ilex* (a), *Acer pentapomicum* (o), *Celtis australis* (r).	*Fraxinus xanthoxyloides* (o), *Rhus succedanea* (o), *Parrotia jacquemontiana* (lf), *Olea cuspidata* (lf), *Zanthoxylum alatum* (o).	*Artemisia maritima* (a), *A. vulgaris* (a), *Daphne oleoides* (lf), *Plectranthus rugosus* (f), *Rosa webbiana* (f), *Berberis* spp. (f), etc.	*Agropyron longearistatum*, *Agrostis alba* *Eragrostis nigra*, *Perotis latifolia*, *Phleum*, *Setaria*, etc.
C_2. Dry coniferous forests. Inner dry valleys of the Himalaya. (i) Kilba U. Bashahar.	*Cedrus deodara* (va), *Pinus excelsa* (o), *Picea morinda* (o).	*Corylus colurna* (o).	*Viburnum cotinifolium* (f), *Desmodium tiliaefolium* (o), *Lonicera quinquelocularis* (o), *Smilax vaginata* (o) *Rubus niveus* (f), *Berberis* sp. (f), *Plectranthus rugosus* (f) II. a. *Fragaria vesca* (f), *Viola canescens* (o), *Thalictrum*, *Salvia glutinosa*, *Impatiens*.	
(ii) Chini, U. Bashahar.	*Cedrus deodara* (a), *Pinus gerardiana* (f).		*Artemisia maritima*, *Lonicera hypoleuca*, *Microglossa*, *Ribes*, *Rosa webbiana*, *Abelia triflora*, etc.	
(iii) Purbani U. Bashahar.	*Pinus gerardiana* (a), *Cedrus deodara* (o).	*Fraxinus xanthoxyloides*(o).	*Lonicera hypoleuca*, *Artemisia maritima*, *Daphne oleoides*, *Ephedra gerardiana*, *Caragana gerardiana*, *Prunus jacquemontii*.	

Champion has not recognised the oak as a climax in the inner Himalayas and the following summary of succession is after Mohan and Puri.

"1. On flood plain or scree deposits of mica-schist with some gneiss and granite the succession is from:— *Cedrus deodara →Cedrus deodara-Quercus ilex.*

2. On flood plain deposits or scree masses of coarse granite, with a large admixture of quartz the succession is from:— *Pinus gerardiana →Pinus gerardiana - Quercus ilex.*

3. On a new mixed alluvium of schist and granite the succession is from:— *Pinus gerardiana - Alnus nitida→Pinus gerardiana.*

4. On scarp slope of granite and steep precipitous rocks:— *Pinus gerardiana - Fraxinus→Pinus gerardiana* are found.

5. On the dip slope of mica schist, gneiss and granite the succession is from:— *Pinus gerardiana - Cedrus deodara→Cedrus deodara.*

Where the final communities are conifers the succession to the oak climax has been found to be extremely slow due to peculiar geological, soil or biotic factors. If these are removed these communities would doubtless reach the oak climax."

In discussing the vegetation of the temperate Himalayas it may be interesting to refer to the works of Indian Botanists on the distribution of Liverworts. Kashyap (1920 and 1921) gave a number of interesting conclusions which have been supported by Pande (1936).

1. In the outer ranges of the Himalayas the species of liverworts as well as the number of individuals of a particular species at a given altitude, decreases from East to West.

2. In passing vertically upwards from the plains the number of liverworts increases upto a height of 7,000 feet in the outer Himalayas after which it decreases; the same holds good for the middle and the inner ranges as well.

3. In the middle ranges the number of liverworts is lesser than that in the outer Himalayas.

4. Beyond the inner ranges there are no liverworts.

The following table shows the number of liverworts from some of the important localities in the Himalayas.

Table 36

THE NUMBER OF LIVERWORTS RECORDED FROM GIVEN LOCALITIES

(After Kashyap).

	Locality.	Height above sea level.	
Eastern Himalayas.	Sikkim.	7,000–8,000 feet.	121
	Bhootan.	6,000–7,000 feet.	44
	Nepal.	6,000–7,000 feet.	36
	Mussoorie.	6,000–8,000 feet.	65
Western Himalayas.	Simla.	6,000–8,000 feet.	36
	Kashmir Valley.	Variable.	32

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8

TROPICAL FOREST OF INDIA

The tropical forests of India are developed over most of the country, excepting the Himalayas and hills of the Peninsular India, above an altitude of 3,000 feet. Depending upon phenological conditions of the dominant tree species and the climatic factor, chiefly the amount of mean annual rainfall, the tropical forests are distinguished into moist and dry types. The moist type is further subdivided into wet evergreen, semi-evergreen and moist deciduous, whereas the dry type includes dry evergreen, dry deciduous and thorn forests. All these types excepting the wet evergreens have both northern and southern forms. Very little work seems to have been done on this type of forests in India and Champion's descriptions and examples have to be taken for most of these at present.

Moist tropical wet evergreen forests. These are typically rain forests of India with an annual rainfall above 100 inches. They are composed of very tall trees, usually above 150 feet high, forming a very dense canopy and are many storeyed and impenetrable, with a luxuriant ground vegetation. They are developed in the Andamans, the Western coast, North Kanara, the Anamalai Hills, Mysore plateau, Coorg, etc. The eastern and northern forms are developed in Assam, Bengal and in Burma.

These forests for most of the area appear to be climatic climax, being composed of a very large number of species that are generally not gregarious. Dominant trees in the upper storey may have deciduous, or semi-deciduous species, but on account of the extremely dense nature of the canopy the evergreen nature of the forest is the most prominent. The forests are generally not clearly differentiated into various strata. Climbers and woody lianes may be present, and often conspicuous. Bamboos are present especially in the southern forms. Palms, Canes and other climbers are present, forming tangled masses in the undergrowth. The ground vegetation may be typically absent, or is formed by carpets of *Strobilanthes, Selaginella,* ferns, etc. Grasses are absent in forests. Cane brakes usually replace high forest along streams. The trees have smooth bark and plank buttresses. They have usually thick and glossy leaves, showing a characteristic pink or white colour, when young. Epiphytes of all types are abundant.

The most widely distributed genus in these forests is *Dipterocarpus,* though this may be absent in some north Bengal forests for unknown reasons. The other common genus in the southern type is *Hopea;* and *Shorea* is common in the northern type.

Southern tropical wet evergreens: A brief summary of the southern wet evergreen forests, together with their successional relationships is given in table 36 after Champion (1936).

The commonest trees in the top storey of the southern type besides *Dipterocarpus* and *Hopea* are *Artocarpus, Mangifera,* and other Anacardiaceae, *Calophyllum, Eugenia,* Lauraceae, *Diospyros, Mesua ferrea,* other Guttiferae, Magnoliaceae, Meliaceae and also to some extent Leguminosae.

Table 36

GROUP IA SOUTHERN TROPICAL WET EVERGREEN FORESTS

Sub-type and distribution	I	II	III	IV
C1. Evergreen *Dipterocarp* Andamans.	*Dipterocarpus grandiflorus, D. pilosus, Artocarpus chaplasha, A. gomeziana Calophyllum, Planchonia andamanica, Hopea odorata, Endospermum malaccense, Sideroxylon longipetiolatum.*	*Xanthochymus andamanicum, Myristica andamanica, M. glauca, Baccaurea sapida, Croton argyratus, Pterospermum aceroides, Caryota mitis, Cryptocarya, Memecylon, Euphorbia epiphylloides, Mitrephora prainii, Actephila excelsa.*	*Anaxagorea luzoniensis.*	*Dinochloa andamanica, Calamus palustris, Gnetum scandens, Ancistroculadus extensus.*
C2. Eastern tropical evergreen Andamans.	Not differentiated from the foreging type.			
C3. Western tropical evergreen. Westernghatsfrom Ratnagiridistt.southwards.				
(i) N. Kanara, Bombay.	*Artocarpus* spp., *Dipterocarpus indicus, Calophyllum* spp., *Chickrassia tabularis, Eugenia gardneri, Vateria indica, Vitex altissima, Diospyros microphylla.*			
(ii) Agumbe N. Mysore.	*Poeciloneuron indicum, Dipterocarpus indicus, Mesua ferrea, Hopea parviflora, Calophyllum elatum, Machilus macrantha, Elaeocarpus tuberculatus* and many others.	*Myristica* sp. *Mephelium* sp. No bamboos.	*Rubiaccae*	*Strobilanthes, Calamus* spp., *Dalbergia* spp. Seedlings.
(iii) Makut Coorg.	*Vateria indica, Hardwickia pinnata, Dipterocarpus indicus, Cedrela* sp., *Mesua ferrea, Mangifera* sp., *Artocarpus hirsuta, Dysoxylum malabaricum, Hopea parviflora, Calophyllum elatum.*	*Elaeocarpus* spp. *Myristica* spp. *Hemicyclia elata, Dichopsis elliptica, Schleichera trijuga, Canarium strictum.*		
(iv) Chandanathode, Wynaad, Madras.	*Dichopsis. Vateria* (especially near water courses), *Calophyllum tomentosum, Cullenia, Dysoxylum malabaricum, Artocarpus hirsuta, Cedrela toona, Machilus macrantha, Mesua, Elaeo-*	*Dichopsis, Myristica* spp., *Vateria, Eugenia munronii, Actinodaphne hirsuta, Ostodes. Nephelium longana, Litsaea* sp., *Meliosma simplicifolia, Polyalthia coffeoides, Cinnamomum zeylanicum, Elaeo-*	*Leea sambucina, Rubiaceae, Areca, Strobilanthes* spp., *Psychotria, Lasianthus, Pandanus* sp., *Glycosmis, Calamus* sp., *Laportea crenulata,* Large *ferns, Arenga* becomes conspicuous with	Climbers on the whole are not heavy though locally they may be so.

	carpus tuberculatus, Bischofia, Eugenia spp., *Canarium.* Bamboos appear mainly as *Ochlandra* brakes along the large streams but occasionally Spread out on the slopes.	*carpus serratus*, etc.	*Mesua* and *Calamus* further down the Ghat.	No grass in undisturbed forest.
(v) Karian Shola, Madras.	*Hopea parviflora, Mesua ferrea, Vitex altissima, Aglaia roxburghiana, Elaeodendron glaucum, Polyalthia fragrans, Diospyros microphylla, Eugenia gardneri, Canarium strictum, Artocarpus hirsuta, Bischofia javanica, Artocarpus integrifolia, Trewia nudiflora, Alstonia scholaris, Machilus marcantha, Filicium decipiens, Tetrameles nudiflora, Carallia lucida, Mangifera indica, Beilschmiedia bourdilloni, Pygeum wightianum, Calophyllum elatum, Bombax malabaricum, Spondias mangidera, Litsaea* sp.	*Cyclostemon macrophyllus, Gomphandra polymorpha, Dimorphocalyx lawianus, Neplelium longana, Scolopia crenata, Diospyros bourdilloni, Acronychia laurifolia, Adenochlaena inaica, Garcinia* sp. *Canthium didymum, Mallotus philippinensis, Flacourtia sepiaria, Sapindus laurifolius, Harpullia imbricata, Zanthoxylum rhetsa, Hydnocarpus wightianum, Actinodaphne hirsuta, Cinnamomum wightianum, Pterospermum heyneanum, Mimusops elengi, Amoora canarana, Holigarna grahamii, Prosorus indicus, Ostodes zeylanica, Myristica laurifolia, Casearia asculenta.*	*Strobilanthes* spp., *Orophea zeylanica, Nothopegia* sp., *Ixora parviflora.*	*Entada scandens, Calamus* spp.
(iv) Palghat division Madras. (vii) Shencottah division, Travancore.	*Dipterocarpus indicus, Hardwickia pinnata, Hopea parviflora, Dysoxylum malabaricum, Calophyllum* spp., *Lophopetalum wightianum, Mesua ferrea, Eugenia arnottiana, Vateria indica, Hopea glabra, Elaeocarpus* spp., *Mangifera* sp., *Holigarna* spp. *Myristica* spp. etc.	*Garcinia* spp., *Semecarpus* spp., *Baccaurea courtallensis, Eugenia* spp., *Hydnocarpus wightianum.*		
C4. Southern low tropical evergreen Andamans.	*Dipterocarpus costatus, Mesua ferrea, Canarium manii, Harpullia cupanoides, Hopea andamanica, Cratoxylon formosum, Euphorbia trigona* and *E. epiphylloides.*		*Memecylon caeruleum, Crytocarya*, and small bamboos. *Phoenix* sp., (Local).	

In the middle canopy, Myrtaceae and Lauraceae are most common. Climbing Bamboos are sometimes present in seral forests, but canes and palms are abundant.

Among the undergrowth are present *Strobilanthes*, other Acanthaceae, *Ixora*, *Canthium*, Annonaceae, and numerous other families of plants.

Tropical forests of Palghat: Aiyer (1932) has described a number of forest communities in moist tropical evergreen forests of Palghats in table 37.

The various communities show altitudinal zonation with *Cullenia-Palaquium* at lower levels, *Mesua-Calophyllum* at intermediate altitudes and *Vateria-Mesua* at the highest altitude in the area. A typical evergreen forest from the Palghat is shown in photo 31.

Ghat forests of Mysore: A fairly detailed description of Ghat forests of Mysore has been given by Kadambi (1950). He recognises three types of habitats, namely windward valleys, leeward valleys, and table land immediately joining the wind exposed western wall of the ghats. The composition of forests in the three habitats is given in table 38 on p. 154.

The author (Puri, 1957) has recently toured the ghat forest of Mysore and has found that they are uniform in composition, but for minor differences, due to biota. In photos 32 and 33 two evergreen types at Karekette and Augumbe-Udipi Road are shown. Like all western ghat evergreen forests trees are lofty, with huge buttresses (photo 34). Undergrowth is extremely dense, especially along edge of the forests, where seepage of water through rock strata is conspicuous (photo 35). Tree ferns and epiphytic ferns of a great variety occur in these forests (photo 36). In the undergrowth *Arisaema* is often seen (photo 37). In open places, however, a dense mass of *Compositae* and other dicotyledonous herbs come up (photo 38).

The ghat forests are well known for their Orchid flora. In the months of May - June, before the setting in of the monsoon most of the species come in flower and present a glorious sight. Every tree seems to be covered up with a number of species. Some more common orchids from the ghat forests are given in photos 39, 40, 41, 42, 43 and 44.

Tropical forests of the Anamalai Hills. Evergreen type with a rainfall of 100 to 150 inches of the Anamalai Hills has been divided by Fischer (1921) into three fairly distinct sub-types:—

(a) The lower evergreen subtype ranging from 1,500 to 3,000 feet. Some of its characteristic species are:—*Hydnocarpus wightiana, Xanthophyllum flavescens, Ancistrocladus heyneanus, Achronychia laurifolia, Harpullia imbricata, Geophila reniformis, Croton caudatus, Excoecaria robusta, Panicum pilipes* and reed like bamboo *Ochlandra travancorica.*

(b) The medium evergreen subtype lying between 3,000 and 5,000 feet. Gigantic evergreen trees such as *Mesua ferrea, Calophyllum tomentosum, Palaquium ellipticum* and *Diospyros ebenum* are of great value. Besides these there are *Cullenia excelsa, Elaeocarpus tuberculatus, Canarium strictum, Kurrimia bipartita,* and *Nephelium longana.*

In the second storey there are *Unona pannosa, Holigarna beddomei, Pithecolobium bigeminum, Eugenia munronii, Premna coriacea, Macaranga tomentosa.*

There are woody shrubs, such as *Paramignya armata, Turraea villosa, Ixora nigricans, Psychotria thwaitsii, Saprosma indicum,* several species of *Strobilanthes, Cassytha filiformis,* etc.

Table 37.

COMMUNITIES OF WESTERN TROPICAL EVERGREEN FOREST OF PALGHAT

(compiled from Aiyar).

	Communities.	Altitude in ft. above sea level.	Soil conditions.	Rainfall conditions.	Vegetation and its characters.
1.	*Cullenia-Palaquium*	2,500 – 3,500	Deep, well drained.	Heavy.	Best growth of *Mesua* and *Palaquium*, other spp. are *Calophyllum elatum*, Regeneration of *Cullenia*, *Palaquium* is gregarious. Advance growth and poles are not present.
	(i) *Cullenia-Palaquium-Meusa*	3,750 up to 5,000	Slightly dried.	Less rain than (i)	*Cullenia* and *Palaquium* are not at their best. Regeneration of all these species present.
2.	*Palaquium-Mesua.*	3,000 – 3,700	Low lying area.		Codominants-*Calophyllum elatum Heritiera papilio*, *Artocarpus intergrifolia*, also present are *Hopea glabra*, *Dysoxylon malabaricum*, good grown *Mesua*. Regeneration of *Mesua* absent. At about an altitude of 3,750 ft. *Palaquium* falls in quality and tends to disappear.
3.	*Poeciloneuron-Palaquium.*	3,000 – 4,000.	Very damp soil tending to be marshy.	Heaviest rain fall.	Dominant species *Poeciloneuron indicum*, *Palaquium ellipticum*, *Calophyllum elatum*, *Mesua ferrea*. Co-dominant spp. are *Cullenia*, *Heritiera*, *Vateria macrocarpa*. In marshy localities with reeds *Poeciloneuron* and *Calophyllum* dominant. Regeneration of both these spp. abundant in all age classes.
	(i) Reed-*Calophyllum.*	3,000 – 4,000.	Marshy tracts stagnating.	Not sufficient for *Poeciloneuron.*	*Ochlandra beddomei* standing over reeds are *Calophyllum elatum*, *Hopea glabra*, *Eugenia* sp. *Bischoffia javanica*, undergrowth of *Agrostistachys indica* and *A. longifolia.*
	(ii) Reed-*Poeciloneuron.*	3,000 – 4,000 confines to banks.	Marshy.	Heavier rainfall.	In addition to above *Poeciloneuron* is present and forms the chief crop.
4.	*Mesua-Calophyllum.*	above 3,500 to 4,500.			Associates are *Litsaea oleoides*, *L.stocksii*, *Gordonia obtusa*, *Elaeocarpus munroii*, *Cinna momum zeylanicum*, *C.sulphuratum*, *Eugenia* sp., *Symplocos spicata*, *Alseodaphne* sp. *Actinodaphne* sp.
	(i) *Vateria-Cullenia.*		Soil moist and well drained.	Heavy rainfall.	*Vateria marocarpa* consociations very common. Co-dominants are *Cullenia excelsa*, *Palaquium ellipticum*, *Mesua ferrea*, *Calophyllum elatum*, *Polyalthia coffeoides.*
5.	*Vateria-Mesua*	above 4,000.	Neighbourhood of streams and moist slopes.	Neighbourhood of streams and moist slopes.	Here *Vateria macrocarpa* is of low growth and is dominant and gregarious; subordinate species are those found in *Mesua-Calophyllum* association; undergrowth of *Strobianthes. Vateria* regeneration prolific.

Table 38.

VEGETATION TYPES IN SOUTHERN TROPICAL WET EVERGREEN FORESTS OF THE WESTERN GHATS

(Compiled from Kadambi, 1950)

Wind-ward valleys.	Leaward valleys.	Table land immediately adjoining the exposed western wall
1. *Palaquium-Dipterocarpus* - occupies well drained soil, associates are *Hopea wightiana, Mesua ferrea, Schleichera trijuga, Holigarna, Garcinia, Diospyros*, etc. Underwood chiefly of *Humboldtia brunonis*, with occasional trees of *Lansium anamalayanum.*	Not much different from windward valleys except that forests on this side, have fewer epiphytic mosses, lichens, hepatics and fewer ferns and are cooler in summer. *Hopea-Palaquium* - associates *Litsaea, Mimusops elengi, Dillenia, Scheichera trijuga, Calophyllum elatum, Mastixia arborea, Diospyros, Mesua ferrea, Garcinia cambogia, Ficus nervosa, Cinnamomum macrocarpum, Elaeocarpus munroii, Dysoxylum malataricum, Chrysophyllum roxburghii, Alstonia scholaris, Artocarpus hirsuta.* Smaller trees are *Plectronia didyma, Diospyros, Eugenia corymbosa, Evodia roxburghiana, Holigarna, Garcinia morella.* Scarcity or absence of *Dipterocarpus indicus* and *Kingiodendron pinnatum* from this slope are noticeable.	1. *Hopea-Palaquium* - associates are *Mesua ferrea, Canarium strictum, Eugenia arnotiana, Litsaea wightiana, Calophyllum elatum, Diospyros, Cinnamomum macrocarpum, Mimusops elengi, Artocarpus hirsuta* Undergrowth may or may not be dense, where dense it is composed of *Humboldtia brunonis*, sometimes dense growth of *Unona pannosa.* Others are *Memecylon edule, Eugenia laeta. Celtis cinnamomea, Clausena indica.* Where there is sunlight there are *Leea asprea, Callicarpa lanata, Strobilanthes callosus, S. barbatus*, etc.
2. *Hopea wightiana* - covers steeper slopes, merging in ridges, ground well drained but being steep organic matter is lost, hence soil is shallow. Associates are *Schleichera trijuga, Mesua ferrea, Garcinia, Diospyros, Myristica, Litsaea, Cinnamomum macrocarpum, Alstonia scholaris.* Underwood - *Memecylon edule, Diospyros.* Regeneration of *Hopea* abundant.		2. *Elaeocarpus tuberculatus* - This is an edaphic variant found along streams. Associates are *Lophopetalum wightianum, Carallia lucida, Gordonia obtusa, Calophyllum wightianum, Elaeocarpus munrowii, Hydnocarpus wightiana, Lophopetalum wightianum.* **Undergrowth** is often dence *oxytenanthera* forms dense masses, there is a tangle of lianes, canes and *Pandanus.*
3. *Vateria indica.* edaphic variant of 1 & 2. *Vateria* alone on beds & banks of all streams. Associates *Gordonia obtusa, Lophopetalum wightianum, Calophyllum wightianum, Mangifera indica, Mastixia arborea, Carallia lucida, Myrsitica, Hydnocarpus.* Undergrowth - Regeneration of *Vateria,* none or where sunlight reaches *Oxytenanthera, Pandanus,* where drainage is good are present *Vitex leucoxylon, Eugenia, Musa, Alpinia.*		

(c) The upper evergreen subtype above 5,000 ft. comprises of *Michelia nilgirica, Mahonia leschenaultii, Eurya japonica, Euonymus indicus,* 3 species of *Ilex,* 3 species of *Rubus, Eugenia* sp., *Rhodomyrtus tomentosa, Senecio corymbosus, Rhododendron arboreum, Ardisia rhomboidea, Pilea wightii, Arisaema tortuosum, etc.*

A view of evergreen forests in Nilambur is given in Photo 45 and an interesting composition of evergreen forests on Manantody-Chandanthode road shows (Photo 46) a great preponderance of species.

Tropical forests of North Kanara. Tropical wet evergreen forests of Kanara have not been much studied. Santapau (1955) has given a brief botanical account of some of the evergreen forests and the author (Puri, 1957) has been making extensive studies of the evergreen forest of North Kanara and making botanical collections and taking notes of the specimens found in this area. These papers have not been completed, however. The following botanical descriptions of the evergreen forests near Jog Falls may be quite representative of the evergreen forests of this area. The Jog Falls are the world's second highest Falls (Photo 47). These are formed in the strata of siliceous rocks, which bear an extremely rich vegetation of evergreen tropical type. In the top layer of these forests are found a variety of tree species including *Hopea wightiana, Syzygium cumini, Sideroxylon tomentosum, Holigarna arnottiana, Knema attenuata, Artocarpus incisa, Lepisanthes tetraphylla* (*Hemigyrosa cancescens*), *Garcinia morella, Pithecellobium bigeminum, Garcinia cambogia, Celtis cinnamomea, Litsaea stocksii, Lophopetalum wightianum, Ervatamia heyneana,* (*Tabernaemontana heyneana*), *Artocarpus hirsuta, Lagerstroemia speciosa,* (*Lagerstroemia flos-reginae*), *Macaranga peltata, Cinnamomum zeylanicum, Caryota urens, Stereospermum personatum, Aporosa lindleyana, Vitex altissima, Terminalia bellerica, Dysoxylum binectariferum, Dillenia pentagyna.* A view of the evergreen forest is shown in Photo 48.

In the Second layer which may be 10 - 25 ft. high the main species are *Allophyllus serratus, Callicarpa lanata, Trema orientalis, Emblica officinalis, Leea indica, Mussaenda frondosa, Aporosa lindleyana,* etc.

The third layer is formed mainly of *Ardisia solanacea, Melanthesa turbinata, Psychotria sp. Ixora coccinea, Pleomele terniflora, Croton gibsonianus, Chasalia curviflora, Solanum sp., Clerodendron viscosum, Maesa indica.*

In these forests a large number of climbers are found (Photo 49). They belong to *Tylophora indica, Ventilago bombaiensis, Toddalia aculeata, Calamus pseudotenuis, Jasminum rottlerianum, Elaeagnus* sp., *Cissus discolor, Gnetum ula, Smilax zeylanica, Zizyphus rugosa, Pothos scandens, Caesalpinia mimosoides, Artabotrys zeylanicus, Hibiscus furcatus, Gouania microcarpa, Rubia cordifolia, Ancistrocladus heyneanus, Raphidophora, sp., Schefflera venulosa, Premna coriacea, Entada phaseoloides, Cayratia auriculata,* etc.

One other good evergreen patch near Sirsi has the following composition. In the top layer are found *Mangifera indica, Beilschmiedia fagifolia, Hopea wightiana, Strychnos nux-vomica, Dillenia pentagyna, Cleidion spiciflorum, Knema attenuata, Myristica beddomei, Terminalia crenulata, Adina cordifolia, Cinnamomum zeylanicum.*

The middle layer, 10 - 25 ft. is usually formed of the following: *Diospyros microphylla, Ervatamia heyneana, Mussaenda frondosa, Macaranga peltata, Murraya koenigii, Vitex altissima, Randia brandisii, Allophyllus serratus, Emblica officinalis, Flacourtia montana, Ixora brachiata, Strobilanthes sp.,*

In the ground which may be about 3 ft. high *Ophiorhiza harrisiana, Murraya koenigii, Chasalia curviflora, Pleomele terniflora, Psychotria sp.* have been found. The main Climber are *Gnetum ula, Olax sp., Pothos scandens, Luvunga eleutherandra, Hoya sp., Hemidesmus indicus, Smilax zeylanica, Ancistrocladus heyneanus, Calycopteris floribunda, Piper sp.*

The Forest Department has laid one Linear Tree Increment Plot near Telgiri. In the upper storey, which is usually formed of trees of 75 ft. or over the following may be mentioned: *Tetrameles nudiflora, Polyalthia cerasoides, Cinnamomum zeylanicum, Macaranga peltata, Terminalia crenulata, Terminalia bellerica, Caryota urens, Pterygota alata, Dysoxylum malabaricum, Knema attenuata, Myristica sp., Aporosa lindleyana, Terminalia arjuna, Diospyros microphylla.*

The middle layer is composed of *Leea indica, Ardisia solanacea, Allophyllus serratus, Murraya koenigii, Emblica officinalis, Cordia macleodii, Randia brandisii.*

In the ground level are found *Chasalia curviflora, Rauwolfia serpentina, Nervilia infundibulifolia, Curculigo orchioides, Elephantopus scaber, Psychotria* sp.

The Forests near Dandelli have the following composition: *Pothos scandens, Piper subpeltatum, Mallotus stenanthus, Harpullia arborea, Ardisia solanacea, Capparis heyneana, Gnetum ula, Pristimera indica, Tetrameles nudiflora, Callicarpa lanata, Holigarna grahamii, Solanum ferox, Radermachera sp., Barleria courtallica, Sarcochilus sp., Solanum verbascifolium, Pouteria tomentosa, Ancistrocladus heyneanus, Alstonia scholaris, Elatostema lineolatum, Mallotus albus, Naravellia zeylanica.*

Puri and Jain during 1956-57 have made interesting observations on the evergreen forests of North Kanara in the vicinity of Yellapur (Photo 50).

The forest at Sasreli near Yellapur is dense evergreen forest with tall trees. Trees of 15-20 meters height are common. The girth of mature trees is often about 2-3 meters. Number of trees have clean bole upto 8-10 meters. The middle storey is rather poor or absent. Shrubs and ground flora also is poor. Seedlings of the tree species usually cover the ground.

In the first storey species of *Lagerstroemia, Sideroxylon tomentosum* R., *Holigarna arnottiana* Hk. f., *Holigarna grahmii* Hk. f., *Vitex altissima* L. var. *alata, Macaranga indica* Wt., *Garcinia indica* Ch., *Pterocarpus marsupium* R., *Actinodaphne* sp. are quite common.

In the second storey trees of *Strychnos colubrina* L., Strychnos *nux-vomica* L., *Ochrocarpus longifolius* Benth., *Syzygium spp., Cinnamomum zeylanicum* Berj., *Ixora coccinea* L., *Ixora parviflora* Vahl.. *Randia brandisii* Gamble, *Stereospermum personatum, Alstonia scholaris* Br., *Dillenia pentagyna* R.. *Actinodaphne hookeri* are common.

The third storey is formed of smaller trees and shrubs such as species of *Callicarpa, Calycopteris floribunda* Lam., *Clerodendron inerme* Gaertn., *Aporosa lindleyana* Baill., *Leea indica* Merr., *Elaeagnus latifolia* Linn., *Tabernaemontana heyneana* Wall., *Tabernaemontana coronaria* Willd., and *Ixora* spp.

Gnetum sp. *Pothos scandens* L., *Piper sp.*, and *Calycopteris floribunda* L., (Photo 51) are the commoner climbers.

Petalidium barlerioides Nees., *Daedalacanthus* sp., *Leucas stelligera* Wall., and grasses such as *Cynodon dactylon* Pers., species of *Eragrostis*, mixed with a large number of seedlings of tree species cover the ground.

Dense bushes of *Melastoma malabathricum* (Photo 52) grow along small ponds. Trees of *Careya arborea* (Photo 53) are commonly met with their conspicuous and large white flowers in open situations nearer to habitations.

Tropical forests of Kerala. The tropical evergreen forests of Kerala are developed on the Western ghats and are the least studied. Bourdillon (1908) and Rama Rau (1914) have prepared forest floras of some parts of Kerala State, but a great wealth of herbaceous vegetation has never been studied. The author (Puri, 1957) has undertaken floristic and ecological studies of these forests, but the work has not progressed much as yet. Photo 54 shows a good forest of *Dipterocarpus, Vateria, Terminalia, Tetrameles,* etc. at Deviar. Large trees possess huge buttresses (Photo 55).

Large areas of evergreen forests in Kerala have been felled for coffee, tea (Photo 56), and rubber plantations. Cardamon is also cultivated on a large scale in these forests. Trees of *Baccaurea courtallensis* (Photo 57) with red flowers all along the bark lend a very interesting sight in evergreen forests during the month of Feb.-March.

Regeneration of Tropical forests. The regeneration of these forests state-wise has been discussed recently by Krishnaswamy (1952) in some detail. The general method of working of these forests is by careful selection when and if regeneration is already present on the ground. The extent to which canopy can be opened without adversely affecting the regeneration varies considerably in different habitats.

In Assam, natural regeneration of *Dipterocarpus, Shorea, Mesua, Artocarpus, Amoora, Palaquium* is generally good and can be brought to pole stage by slow opening of the canopy.

In Andamans, selection fellings and concentrated regeneration fellings regenerated the area with *Dipterocarpus, Artocarpus chaplasha, Duabanga sonneratioides, Mesua ferrea, Evodia* sp., etc.

Succession of forest communities in tropical forests. Succession in tropical evergreen forests has been studied by Aiyer in portions of the forests that have been laid bare by landslips and also in grass areas adjoining the Sholas. A summary of this is given in table 39. The general successional trends in tropical evergreen forests of India according to Champion is given in table 40.

This scheme considers that evergreen type is truly climax and the deciduous types are degraded, which change to the evergreen climax through semi-evergreen communities when the biotic factors are excluded from the environmental complex. This observation seems to be quite correct, as semi-evergreen and even deciduous types that occur in adjoining localities to the evergreen are biotic and sometimes bio-edaphic. But these types rarely progress to the original climax, even with all the biotic factors excluded. The riverain, beach, tidal, swamp and inland plains, fresh water types are seral stages to the climax. In fact, these seral stages are edaphic in nature and do not get transformed into the evergreen climax forests but are preserved as such.

Northern tropical wet evergreens. The northern tropical wet evergreens are the result of the north-easterly monsoons, being developed in eastern India, Assam, Bengal, etc. The top canopy is formed besides *Dipterocarpus* and *Shorea* by *Artocarpus, Eugenia, Mesua ferrea,* Meliaceae, Anacardiaceae, Myristicaceae, Lauraceae, Magnoliaceae, *Quercus* and *Castanopsis.* A view after *Dipterocarp* forest in Bengal is given in Photo 58.

Table 39.

SUCCESSION IN MOIST TROPICAL WET EVERGREEN FORESTS OF PALGHAT

(After Aiyar)

Landslips in sholas.	Grasslands adjoining sholas.	Grassland with shallow rocky soils.
Dotted in grasses are bracken and *Wendlandia notoniana.*	The first stage in landslips may or may not be present in grasslands.	In open areas the species to first appear in grass are:—
Then appear in colonies:—	In grasses appear:—	*Phyllanthus emblica, Dalbergia latifolia, Sterculia guttata, Erythrina indica,*
Maesa perrottetiana, Glochidion malabaricum.	*Symplocos spicata, Gordonia obtusa, Linocera malabarica, Croton scabiosus,*	These are followed by:—
These in turn are invaded by:—	*Maesa perrottetiana. Acronychia laurifolia.*	*Lagerstroemia lanceolata, Sapium insigne.*
Gordonia obtusa, Symplocos spicata. } associes.		These give place to colonies of *Heritiera papilio.*
Later on appear.	These are followed by:—	
Acronychia laurifolia, Elaeocarpus munroii, Meliosma arnottiana, Litsaea stocksii. Olea dioica, Allophylus cobbe, Linocera malabarica.	*Macaranga roxburghii, Clerodendron infortunatum* and are succeeded later by:— *Elaeocarpus munroii, Elaeocarpus serratus, Meliosma arnottiana, Canarium strictum.*	latter appear *Calophyllum elatum* and then *Mesua ferrea.*
Finally the forest passes into one of the climax communities of *Calophyllum elatum, Meusa ferrea.* { forest entrants.	Climax followed with the invasion of *Calophyllum elatum, Mesua ferrea.*	
These then yield to. *Palaquium ellipticum, Cullenia excelsa* { climax forest.	And finally climax of *Cullenia, Palaquium.*	

The successional trends given above are theoretical and in actual conditions a good deal of destruction of soil takes place by monsoon and intervening period of dryness, as a result of which the advanced seral communities do not come in. The biotic interference in high forest, almost always results in the formation of a scrub and the scrub when further disturbed degrades into a grassland of a Savannah type.

Table 40.

THE SUCCESSION OF FOREST COMMUNITIES IN MOIST TROPICAL FORESTS ACCORDING TO CHAMPION

General scheme of succession on moist tropical forests

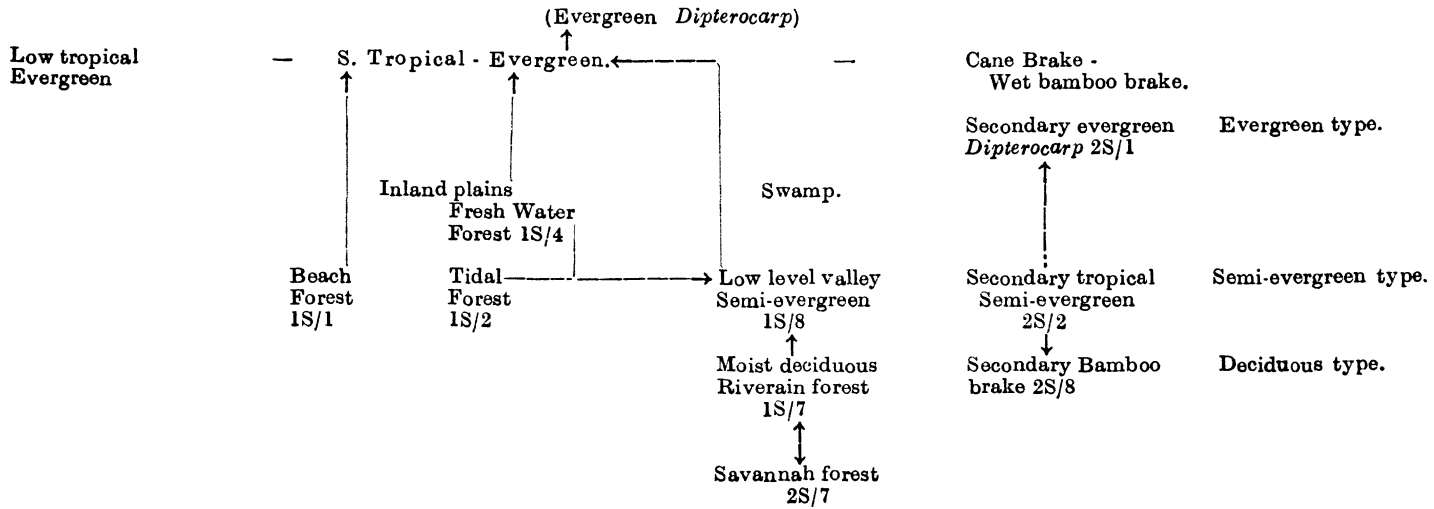


Table 41.

GROUP 1 B. NORTHERN TROPICAL WET EVER-GREEN FOREST

(After Champion)

Sub-type and distribution	I	II	III	IV
C_2 U. Assam tropical evergreen. Assam-Lakhimpur and Sibsagar.	*Dipterocarpus pilosus, Artocarpus chaplasha, A. integrifolia, Shorea assamica, Cinnamomum cecicodaphne, Dysoxylum binectariferum, Altingia excelsa, Mesua ferrea, Eugenia* spp., *Sterculia alata, Michelia champaca, Manglietia insignis, Talauma phellocarpa, Amoora wallichii, Garcinia* spp., *Carallia lucida, Aquilaria agallocha, Cedrela toona, Ficus* spp., *Kayea assamica, Phoebe hainesiana, Vatica lanceaefolia, Gynocardia odorata.*	*Dendrocalamus hamiltonii, Bambusa pallida, Livistonia jenkinsiana.*	Dense evergreen undergrowth in the plain forests, less on the hills.	Climbers including canes, very heavy in low lying land, less so on slopes.
C. Cachar tropical evergreen Lower hills and hillslopes of Cachar hills and Khasi and Jaintia hills around the Surma Valley, Assam.				
(i) Srimangal, Sylhet division L. Assam.	*Dipterocarpus turbinatus, Artocarpus chaplasha,* Meliaceae (*Amoora* and *Dysoxylum*), *Talauma, Michelia, Quercus, Castanopsis, Mesua ferrea.*			
(ii) Loharaband, Cachar, L. Assam.	*Dipterocarpus turbinatus, Artocarpus chaplasha. Michelia montana, Mangifera sylvatica, Cinnamomum cecicodaphne, Alseodaphne owdenii, Machilus* spp.,	*Melocanna bambusoides, Bambusa balcoca.*	Evergreen undergrowth with a few palms.	Climbers relatively few, *Entada scandens, Acacia* spp., *Combretum* spp.

		Eugenia cymosa, Eugenia praecox, Palaquium polyanthum, Amoora spp., *Chickrassia tabularis, Mesua ferrea, Calophyllum polyanthum, Aquilaria agallocha, Sterculia* spp., *Canarium* spp., *Lophopetalum wightianum, Podocarpus Nerifolia.*			
C_5	N. Bengal tropical evergreen forest. In the heavy rainfall tract of N. Bengal and the adjoining parts of E. Assam and Bhutan. At present confined to the vicinity of Tarai Streams.				
	(i) Kalimpong division.	*Jambosa formosa, Beilschmiedia* spp., *Dysoxylum* spp., *Jambosa ramosissima, Castanopsis indica. C. tribuliodes, Litsaea* spp., *Terminalia myriocarpa, Michelia champaca, Cinnamomum* spp. *Elaeocarpus* spp. *Tetrameles nudiflora, Ailanthus grandis, Talauma hodgsonii, Mangifera indica, Canarium sikkimensis.*	*Meliosma simplicifolia. Amoora wallichii, Gynocardia odorata, Turpinia pomifera. Styrax* sp., *Atinodaphne* sp.	Evergreen shrubs including many Rubiaceae.	Numerous shrubs and climbers.

Table 42.

DIPTEROCARPUS FORESTS OF INDIA

(Modified from Sen Gupta (1938)

Species.	Types of forest (According to Champion's classification	Locality and Altitude.	Climate				Rock and Soil.
			Rainfall and drought	Temperature (F)			
				Mean	(Mean) Max.	(Mean) Min.	
D. macrocarpus.	Upper Assam tropical evergreen (1b/c2) and northern secondary semi-evergreen (M. Tr./2s/2b)	Assam Upper. Assam.(Lakhimpur Sibsagar & Sadiya), 100' – 1,500'	100" – 115" No pronounced drought localised in Sibsagar.	73°	96°	40°	(a) Hills of Tertiary sand stone and shale (b) plains of Dehing alluvium forming (a) Sandy loam of recent alluvial formation; (b) deep and fertile loam.
D. turbinatus.	Cachar tropical evergreen (1b/c3)	Lower Assam (Sylhet and Cachar). 50' – 1,000'	115" – 160" Feb- March droughty.	76°	90°	50°	(a) Low isolated hills of old alluvial red sand; (b) high hills of upper Tertiary sandstone forming layers of sand with occasional bands of clay and gravel often indurated with ferruginous cement; (b) Sandy soil.
D. pilosus and *D. turbinatus*	Chittagong tropical evergreen (1b/c4).	Bengal Chittaggong. Hill tracts 25' – 1200'.	100" – 120" Pronounced drought between mid-February to mid-April.	77°	89°	55°	Sandstone forming yellow sandy loam.
D. alatus. D. costatus, D. pilosus and *D. turbinatus*	Chittagong tropical evergreen (1b/c4), Chittagong tropical semi-evergreen (2b/c3) and Chittagong gurjan forests (M. Tr /25/3).	Chittagong 25' – 1,000'.	100" – 135".	77°	89°	55°	Soft Tertiary sandstones with occasional thin shaly clayey bands forming porous, sandy soil, tending to harden on flats.
do		Cox's Bazar	– do –	79°	91°	57°	– do –
D. alatus. D costatus, D. grandiflorus. D. kerrti and *D. pilosus*	Southern low tropical evergreen (1a/c4), Southern tropical semi-evergreen riverian (M.Tr·18/8/a),	Andamans, North Middle and South.	120" – 170" (150") February and March are	80°	91°	70°	Non-micacesus, hard coarse-grained sandstone ,and conglomerates with serpentine intrusions

	Southern tropical evergreen *Dipterocarp* (la/c1).		droughty.				forming deep fertile sandy to clayey loam and in places stiff clay.
D. indicus.	Western tropical evergreen (cla/c3).	Mysore Shimoga and Saugor (Agumbe, Bale halli, etc).	100" – 300" (350" at Agumbe) Pronounced drought between March to May.	79°	97°	58°	Granite and gneiss with hornblendic flows and magnetite quartz schists.
do	do	Coorg Ghat forests (south coorg).	160" – 280" (214") Pronounced drought between Feb. to April.	79°	90°	65°	Gneiss of granitic nature forming red loam, stony and shallow.
do	Western tropical evergreen (la/c3).	Madras Wynaad.	108" – 156" Drought between Feb. to April.	79°	90°	65°	Gneiss coarse-grained and highly quartoose forming ferruginous sandy loam, fairly deep.
D. indicus	Western tropical evergreen (la/c3).	North & South Mangalore.	145" – 200" Pronounced drought between Feb. to April.	80°	93°	68°	Gneiss, interspersed occasionally by quartzite, micaschists and granite forming pale red felspathic clay or loam of moderate depth.

Bamboos are usually present, the most characteristic species being *Dendrocalamus hamiltonii, Bambusa tulda* and *Melocanna* present in the undergrowth, mostly in the deciduous communities. In the undergrowth canes and palms are generally present with occasionally tree ferns. Rubiaceae and numerous other species form shrubby undergrowth. A summary of the forest types, together with successional relationships of various communities is given in table 41, after Champion on p. 158 & 159.

Dipterocarpus forests of India: An interesting description of the *Dipterocarpus* forests of India has been given by Sen Gupta (1938). There are as many as 9 species of *Dipterocarpus* distributed mainly in the wet evergreen type, though some are present in the semi-evergreen type as well. The composition of *Dipterocarpus* forest together with notes on factors of locality are given in table 42 after Sen Gupta (1938). *Dipterocarp* forests of south Coorg are shown in Photo 59. Other species associated with *Dipterocarpus* are *Calophyllum, Artocarpus, Mesua* etc. In the undergrowth canes, reeds and ferns are conspicuous. Photo 60 shows another *Dipterocarpus* forest.

Tropical forests of Assam: Rowntree (1954) has recently given a description of the tropical forests of the Assam valley, in which he has deviated from the plan of classification adopted by Champion and Bor (1938).

His classification is given in table 43.

Table 43.

CLASSIFICATION OF TROPICAL VEGETATION OF ASSAM ACCORDING TO THE THREE GIVEN AUTHORS.

Rowntree (1954)	Bor (1938)	Champion (1936)
Dipterocarpus - Mesua-Michelia association.	—	Upper Assam tropical evergreen.
Cinnamomum-Amoora association.	*Laurus* Hylium.	Upper Assam tropical semi-evergreen.
Mesua and other species post climax.	*Mesua* and other species post climax.	—
Bischofia-Dillenia association.	—	Upper Assam moist deciduous riverain.
Tetrameles-Stereospermum-Cedrela association.	—	North eastern moist deciduous.
Shorea-Lagerstroemia association.	—	Dry *sal.*
Dillenia-Lagerstroemia association.	—	North tropical dry mixed deciduous.
Shorea-Schima-Lagerstroemia pro-climax.	*Shorea-Schima-Stereospermum* climax.	Moist *sal,* Wet *sal,* Wet hill *sal,* Eastern Terai *sal.*
Pinus insularis pro-climax.	*Pinus insularis* pro-climax.	Assam-Burma pine.
Imperata-Saccharum-Themeda associes.	*Imperata-Saccaharum Themeda* associes.	North Indian upper alluvial Savannah.
Alpinia-Pharagmites-Saccharum associes.	*Alpinia-Pharagmites-Saccharum* associes.	North Indian lower alluvial Savannah.
Bombax-Albizzia associes.	*Bombax-Albizzia-Lagerstroemia* Hylis.	East Himalayan moits deciduous.

Table 43. (Contd.)

Rowntree (1954)	Bor (1938)	Champion (1396)
Acacia-Dalbergia associes.	*Acacia-Dalbergia* Hylis.	*Khair-Sissoo* forest.
Duabanga-Pterospermum-Terminalia associes.	*Duabanga-Pterospermum-Terminalia* Hylis	Moist Riparian forest.
Terminalia-Phoebe associes.	—	North tropical semi-evergreen riverain (*Terminalia-Phoebe*).
Bombax-Lagerstroemia-Sterculia associes.	—	Eastern Himalayan moist deciduous.
Pterospermum-Ailanthus-Albizzia associes.	—	Variety of North Tropical semi-evergreen riverain.
Macaranga-Mallotus-Trema associes.	—	Variety of North Tropical semi-evergreen riverain.
Altingia-Machilus-Eugenia associes.	*Altingia-Machilus-Syzygium* Hylis.	Variety of Tropical valley frost water swamp forest.
Cephalanthus-Glochidion associes.	*Cephalanthus-Glochidion* Hylis.	Variety of Tropical valley fresh water swamp forest.
Swamp and Creeper forest.	Swamp and creeper forest.	Variety of Tropical valley fresh water swamp forest.
Bamboo forest.	—	Variety of Tropical valley fresh water swamp forest.

A brief description of the various types is given below:—

I. The tropical *Cinnamomum-Amoora-Michelia* formation.

This formation has the following associations:-

1. The *Dipterocarpus-Mesua-Michelia* association is found along the foot of the Patloi range and Naga hills from the Noa-Dehing river to Mariani and is mostly confined to upper Tertiary sandstone of the Tipam series This has the following consociations and societies:—

Consociations.

Altingia excelsa.
Endospermum chinense.
Sapium baccatum.
Mesua ferrea.
Dipterocarpus macrocarpus.
Shorea assamica.

Societies.

Bambusa pallida.
Dendrocalamus hamiltonii
Macaranga denticulata.
Polyathia jenkinsii.
Pseudostachyum polymorphum.
Talauma hodgsoni.
Vatica lanceaefolia.
Alpinia sp.
Blastus cockinchinensis and
Calamus sp.
Laportea crenulata.
Mallotus roxburghianus.
Pinanga gracilis.
Acanthus leucostachyus.
Asplenium bantamense.
Asplenium multicaudatum.
Phrynium capitatum.
Malastoma malabathricum.

2. The *Cinnamomum-Amoora* association.

This association occurs in almost all parts of the area, and has the following consociations and societies:—

Consociations.

Ailanthus grandis.	*Amoora wallichii.*
Canarium bengalense.	*Canarium resiniferum.*
Dysoxylum hamiltonii.	*Mesua ferrea.*
Michelia champaca.	*Michelia montana.*
Phoebe cooperiana.	*Phoebe goalparensis.*

Societies.

Bambusa pallida.	*Dendrocalamus hamiltonii.*
Macaranga sp.	*Meliosma simplicifolia.*
Pseudostachyum polymorphum.	*Sambucus javanica.*
Talauma hodgsoni.	*Vatica lanceaefolia.*
Alpinia allughas.	*Calamus* sp.
Coffea bengalensis.	*Forrestia hookeri.*
Impatiens sp.	*Laportea crenulata.*
Leea sp.	*Livistonia jenkinsiana.*
Phlogacanthus thyrsiflorus.	*Pinanga gracilis.*
Phrynium capitatum.	*Selaginella* sp.
Strobilanthes sp.	

3. The *Mesua* and other species post clamax.

This association is of local occurrence and is found in the Balipara frontier tract. It has the following consociations and societies:—

Consociations.

Altingia excelsa.	*Mesua ferrea.*
Quercus lamellosa.	*Sterculia alata.*
Cleid-on javanicum.	*Dendrocalamus hamiltonii.*
Dillenia indica.	*Laportea crenulata.*
Pandanus furcatus.	*Pseudostachyum polymorphum.*
Saurauja cerea.	*Talauma hodgsoni.*
Begonia gigantea.	*Begonia rubrovenia.*
Dalhousia bracteata.	*Psychotria calocarpa* and *P. denticulata.*
Pteris quadriaurita.	*Strobilanthes* sp.
Tacca cristata.	*Zingiber zerumbet.*

4. The *Bischofia-Dillenia* association.

This occurs in low lying areas subject to being flooded and submerged for some length of time and has the following consociations and societies:—

Consociations.

Bischofia javanica.	*Dillenia indica.*
Lagerstroemia flos-reginae.	*Vatica lanceaefolia.*

II. The *Tetrameles - Stereospermum-Cedrela* formation.

This formation has only one association which occurs on ridges and slopes throughout the area. *Tetrameles nudiflora, Stereospermum chelonoides* and species of Meliaceae which are all tall trees occur in this association. The following consociations and societies are recognised from this association:—

Consociations.

Cedrela toona.	*Diospyros variegata.*
Garuga pinnata.	*Lannea grandis.*
Stereospermum chelonoides.	

Societies.

Bauhinia purpurea.	*Dendrocalamus hamiltonii.*
Dillenia scabrella.	*Drypees elliptica.*
Macaranga sp.	*Mallotus* sp.

Clerodendron infortunatum.
Ageratum conyzoides.
Eupatorium odoratum.
Holmskioldia sanguinea.
Microstegium ciliatum.
Saccharum arundinaceum.
Coffea bengalensis.
Daedalacanthus nervosus.
Gynura crepidioides.
Ipomaea cymosa.
Phlogacanthus thyrsiflorus.
Trema orientalis.

III. The Deciduous *Shorea-Dillenia-Lagerstroemia* formation.

This formation occupies the plains around Lanka and Hojai which are surrounded on the north and east by the Mikir hills and on the south and south west by the Cachar and Jaintia hills. It has the following associations, consiciations and societies:—

Associations.

Shorea-Lagerstroemia.
Dillenia-Lagerstroemia-Albizzia.

Consociations.

Bauhinia purpurea.
Dillenia scabrella.
Erythrina stricta.
Shorea robusta.
Bombax malabaricum.
Eugenia operculata.
Lagerstroemia parviflora.

Societies.

Eupatorium odoratum.
Saccharum spontaneum.
Imperata cylindrica.

In addition the following pre-climax types are recognised from Assam:—

The *Shorea-Schima-Lagerstroemia* Pro-climax.

This community is found on the foot hill slopes both to the north and south and in the plains as far east as the Bhoreli river and Salona in the Mikir hills. In fact this is the chief community of the western half of the valley.

Consocies.

Dillenia pentagyna.
Schima wallichii.
Lagerstroemia parviflora.

Socies.

Dendrocalamus hamiltonii.
Melocanna bambusoides.
Calamus sp.
Coffea bengalensis.
Ferns.
Leea sp.
Morinda angustifolia.
Ageratum conyzoides.
Alpinia allughas.
Clerodendron infortunatum.
Eupatorium odoratum.
Imperata cylindrica.
Microstegium ciliatum.

The *Pinus insularis* Pro-climax.

Pinus insularis is found in the Khasi hills but its growth is not good at lower levels. The associate tree species of the pine in grassy areas are *Careya arborea, Callicarpa arborea, Glochidion* sp. and *Schima wallichii,* all fire resistant species.

Consocies.

Pinus insularis.

Succession in wet evergreen forests:—

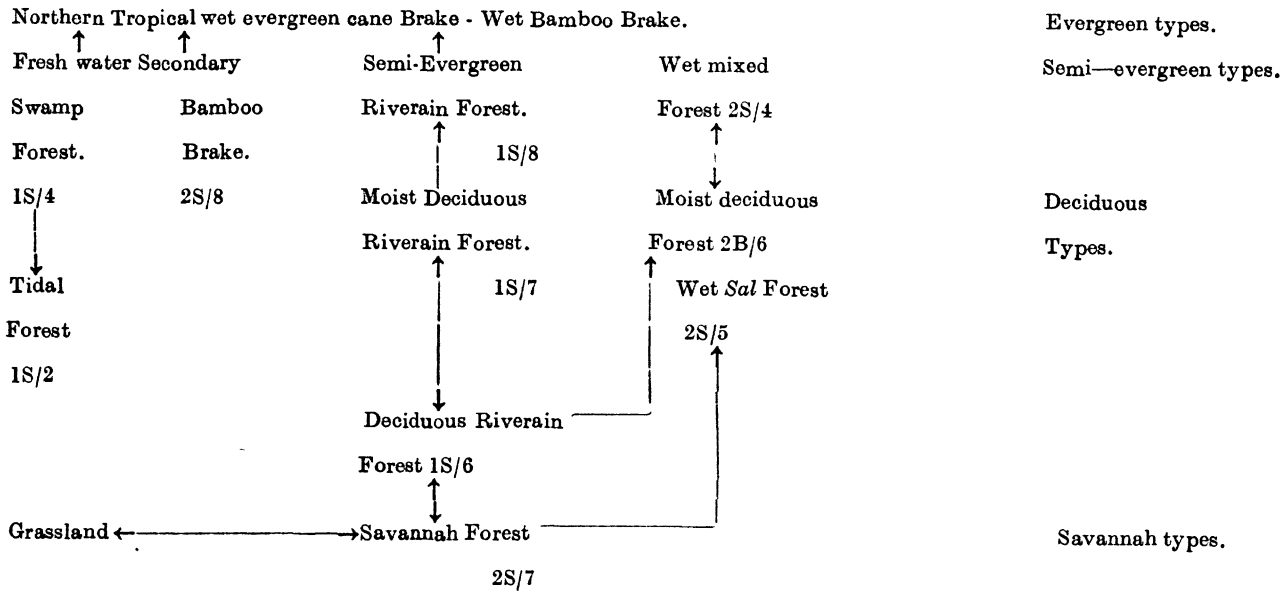
The succession of various communities in the northern evergreen forests is given in table 44 after Champion.

Other features of wet evergreen forests. Evergreen forests exhibit very interesting features which are generally absent in other types of vegetation. The conditions of light intensity, atmospheric humidity,

Table 44.

The Scheme of succession in northern forests is similar to that of the southern type.

SCHEME OF SUCCESSION OF FOREST COMMUNITIES IN NORTHERN TROPICAL WET EVERGREEN FORESTS.



air temperature and soil moisture, etc. assume great importance in them, unfortunately, there are no specific data for Indian forests but a perusal of Richard's (1952) book on rain forests shows the importance of these factors.

In virgin condition wet evergreen forests present a great contrast from those that have been slightly opened. There is a great difference in the vegetation of hollows and wind swept ridges and tops. At tops, the same species which usually attain large dimensions in depressions assume a stunted stature. The rate of growth of evergreen trees is not very high as compared to other types, although, conditions for growth throughout the year are favourable.

Some notes on leaf bud opening, leaf fall, flowering and fruiting of some of the common species of wet evergreen forests are given in table 45.

Kadambi (1954-55) has recently published data on a number of evergreen species including *Dillenia indica, D. pentagyna, D. aurea, Mesua ferrea, Cullenia excelsa,* etc. He finds that in *Mesua ferrea* there appears to be a varietal difference in trees of different localities which becomes obvious in colour of the earliest leaves of germinating seeds. Dark blue leaves occur in the Kadamadi region of Tirunalvely district of Madras and deep pink in Silent valley reserve of Palghat.

Moist tropical semi-evergreen forests. This type is subdivided into southern tropical semi-evergreen and Northern tropical semi-evergreen.

Southern moist tropical semi-evergreens. The southern moist tropical semi-evergreen forest is intermediate between the tropical evergreen and tropical moist deciduous forest types. Its distinction is rather difficult on account of the presence in patches or groups of species characteristic of the two other types. A summary of data on the type is given after Champion in table 46 on p. 169.

In physiogonomy, this type forms a dense forest with both deciduous and evergreen trees growing to large sizes. It is composed of a large number of species as well. The biggest evergreen species are absent but buttressed stems frequently occur (Photo 61). The bark of trees tends to be thicker and rougher and cauliflory becomes rare. The undergrowth is evergreen with a large number of climbers (Photo 62). Bamboos are present and so are epiphytes including numerous species of Orchids and ferns.

Semi-evergreen forest is distributed along with the wet evergreen type, occupying only limited areas. As a climax formation it is well marked only on the Western ghats but occurs as a sub-climax due to special features of the soil in Burma.

This type is confined mostly to low hills or flat plateau on red soils which are formed from crystalline rocks in the Western Ghats with an annual rainfall of 80" to 100".

The common tree species in the upper storey in these forests are *Xylia* and *Terminalias,* though *Dipterocarpus, Balanocarpus* and *Hopea* occur frequently.

Evergreen species of Myrtaceae, *Schleichera trijuga, Lauraceae, Bambusa arundinacea, Bambusa polymorpha* and *Cephalostachyum pergracile* constitute the middle canopy.

Evergreen shrubs of Rubiaceae and Acanthaceae form the ground layer largely. In south Kanara *Strobilanthes, Ixora malabarica* and *Webera* are recorded in the ground layer.

The regeneration in these forests does not seem to be deficient. *Xylia* and *Hopea* regenerate without much difficulty.

Table 45.

PHENOLOGICAL FEATURES OF VEGETATION OF WET EVERGREEN FORESTS OF THE WESTERN GHATS

(Compiled from Kadambi, 1950)

Vegetation	Leaf bud opening	Leaf fall.	Flowering.	Ripening of fruit.
Bryophytes-liverworts, Mosses	During rainy season - June to September the thalli grow and sporocarps are present during			
Pteridophytes-Ferns.	May to October with a short break in the rainy season.	—	—	September-October and Fungi Spores ripening in November-December.
Phanerogamic epiphytes.	September to December.	January - March.	January - February	May - June
Actinodaphne hookeri.	December - January.	Summer.	March - April.	June - July.
Artocarpus hirsuta.	—	December.	January - February.	May - June.
A. integrifolia.	—	December.	December - January.	May - June.
Bombax malabaricum.	March.	January - February	January - February.	April - May.
Calophyllum-elatum, C. wightianum.	—	—	February - March.	May - June.
Canarium strictum.	—	—	—	December - January.
Cedrela toona.	January - February.	December - January.	January - February.	April - May.
Cinnamomum (2 species.)	March - April.	—	February.	May - June.
Dichopsis elliptica.	April.	March.	January - February.	May.
Dipterocarpus indicus.	April - May.	March.	December - January.	May.
Dysoxylum malabaricum.	April - May.	February - March.	February - March.	June - July.
Diospyros spp.	—	—	January - March.	June.
Elaeocarpus spp.	February - March.	December - January.	January - March.	May - June.
Eugenia spp.	—	—	January - February.	May - June.
Gordonia obtusa.	—	—	February.	June.
Garcinia spp.	—	—	March.	June - July.
Holigarna spp.	—	December.	January.	April - May.
Hopea spp.	—	—	January - February.	May.
Kingiodendron pinnatum.	—	—	January - February.	May - June.
Lagerstroemia lanceolata.	—	March.	April - May.	December.
Litsaea spp.	January - February	December - January.	March.	June - July.
Lophopetalum wightianum.	—	—	February - March.	June - July.
Mesua ferrea.	January - February.	December.	March - April.	June - July.
Myristica spp.	—	—	March.	June - July.
Poeciloneuron indicum.	January - February.	December.	March - April.	June - July.
Sapium insigne.	March.	December.	February.	April - May.
Sterculia guttata.	February - March.	December - January.	February - March.	December.
Schleichera trijuga.	February - March.		February.	June.
Vateria indica.	—	March.	March.	June.

Table 46

SOUTHERN TROPICAL SEMI-EVERGREEN FORESTS

(After Champion)

Sub-type and Distribution	I	II	III	IV
C2. West coast tropical Semi-evergreen forest. The western ghats generally between the wet evergreen and moist deciduous.				
(i) Ghat slopes above Nilambur.	*Terminalia paniculata, Xylia xylocarpa, Stereospermum chelonoides, Trewia polycarpa, Eugenia* spp. *Vateria indica* (b). *Canarium strictum, Hopea parviflora* (1), *Calophyllum elatum* (1).	IIa. *Bambusa arundinacea*		
(ii) S. Kanara.	*Terminalia paniculata. Dios-pyros* spp.. *Lagerstroemia lancoelata. Holigarna arnottana. Lophopetalum wightianum cinnamomum.* sp., *Hopea parviflora, Artocarpus hirsuta.*	*Elaeocarpus serratus, Mallotus philippinensis, Diospyros assimilis.*	*Webra. Strobilanthes* spp., *Ixora malabarica.*	Climber and canes numerous.

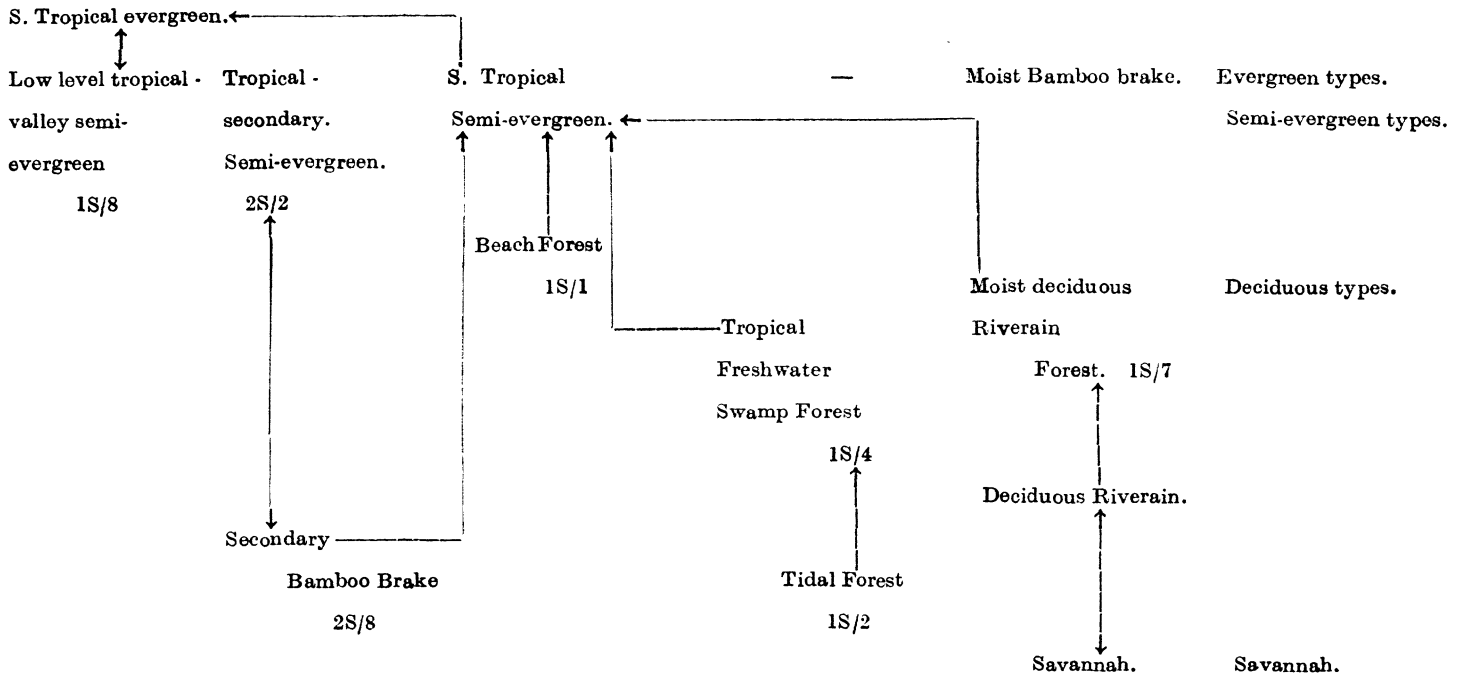
SUCCESSION OF FOREST COMMUNITIES IN SOUTHERN TROPICAL SEMI EVERGREEN FORESTS

Succession of forests is given in table 47, but the fixing of the ecological status of these forests is not clear on account of the biotic factor involved.

Table 47

SCHEME OF SUCCESSION OF FOREST COMMUNITIES IN SOUTHERN MOIST TROPICAL SEMI-EVERGREEN FORESTS

(After Champion)



Moist tropical forests of Kerala. The forest around Deviar is typically - evergreen (Photo 63). Many trees reach the height of about 40-50 meters or more. There is a dense shade under the canopy. The presence of climbing shrubs, ferns, etc. is very clearly seen. Orchids are present in large numbers. Herbs, grasses, etc. are found mostly in openings and on the outskirts of the thicket. Bamboos and reeds, ferns and mosses are found in a very high percentage. On living trees and on rotting barks of dead fallen trees, fungi of different species flourish.

The Common tree species of this forest are:— *Baccaurea courtallensis* Muell., *Vernonia arborea* Ham., *Ostodes zeylanic* Blume., *Cinnamomum iners* Rein., *Cinnamomum zeylanicum* Blume., *Holigarna arnottiana* Hk. f., *Cryptocaria anamalayana* Gamble., etc. The common bamboo is *Dendrocalamus strictus* while *Calamus pseudotenuis* Berk. is the cane species found in abundance in the area.

The second storey plants are- *Rauwolfia* sp., *Leea aspera*, *Pavetta indica* Linn., *Ixora coccinea* and a few more. These shrubs are found growing mostly on the outskirts of the forest or where the density of the shade is rather low.

There are many climbers. The commonest are *Pothos scandens* Linn., *Piper hookeri* Miq., *Melothria heterophylla* Cogn., *Vitis reticulata* Thw., *Daemia extensa* etc., and a climbing species of fern which almost goes upto about 8 to 9 meters.

The third storey plants are few; some of them being *Blumea spectabilis*, *Curculigo orchioides*, *Elettaria cardamomum*, *Zingiber* sp. etc. The last named is found in abundance under the shade of tall trees.

There are a number of fern species found in this forest. Of these *Thamnopteris nidus* Linn. is an epiphytic species while the rest are terrestrial (Photo 64).

Fungi are present in large numbers on dead rotting barks and on barks of living trees. The prominent species amongst these are *Ganoderma incidus Leyss* fr., *Polystictus versicolor* Fr. etc.

Amongst the orchids species of *Dendrobium* and *Aerides* are the most prominant found growing on trees.

Northern moist tropical semi-evergreens: The northern moist tropical semi-evergreens are better developed than the southerns. The forests are dense with 80–120 feet high trees predominantly of evergreen species. The deciduous species are leafless for a short time. Bamboos may or may not be present but canes and climbers are common. The dominant species tend to be gregarious.

These forests are developed in upper Assam, north Bengal and Orissa in areas with heavy rainfall.

By far the largest area on which this type is present is of alluvial origin. It also occurs on soils derived from gneiss and other metamorphic rocks in Bengal. The soil is loamy or clayey of yellow to red colour but black humid soils have also been recognised.

The northern types are composed of evergreen genera like *Eugenia*, *Cinnamomum*, *Artocarpus* and various *Magnolias* and deciduous trees of *Terminalia*, *Tetrameles* and *Stereospermum*. It includes a number of *Dipterocarpus* species. *Shorea robusta* may also be present in drier areas or in burnt sites forming a stable sub-climax.

The second storey is formed by *Phoebe*, *Machilus*, *Actinodaphne*, *Polyalthia*, *Amoora*, *Mesua*, etc. The characteritics bamboos are *Bambusa arundinacea*, *Dendrocalamus hamiltonii and Melocanna bambusoides*. The ground flora is formed by Rubiaceae; and mono–cotyledons being absent under dense canopy. Grasses appear only in burnt areas.

Tropical forests of Kalimpong: Tropical forests of the eastern Himalayas have been studied from Kalimpong by Cowan (1929). The chief tree species in these are *Shorea* and *Terminalia*. The distribution of these is governed by geological features. *Shorea robusta* Gaertn. forms 34 percent of the crop on the Dalings in the Tista valley, but only 13 percent in the Nahans and is absent on the alluvial plateaux east of the Chel River. Again *Terminalias, Albizzias, Lagerstroemia parviflora* Roxb., *Bombax malabaricum* DC. and *Cedrela toona* Roxb. are exceedingly prominent. *Stereospermum tetragonum* DC., *Dillenia pentagyna* Roxb. and *Sterculia villosa* Roxb. are also prominent.

In the understorey there are a number of evergreen species such as *Meliosma simplicifolia, Mangifera sylvatica, Glochidion lanceolarium, Albizzia lucida and Garcinia stipulata.*

In these forests there are a large number of epiphytes, orchids, aroids, etc. There are many huge climbers such as *Aspidocarya uvifera, Bauhinia vahlii, Beaumontia grandiflora, Beuttneria pilosa,* many species of *Combretum, Cissampelos pareira, Entada scandens, Hiptage madablota, Millettia pachycarpa,* and *Tinospora cordifolia.*

Cowan distinguishes the following associations, consociations and societies from these forests:—

Associations.

1. The *Shorea-Terminalia-Garuga* Hylium.
2. The *Shorea-Stereospermum* Hylium.
3. The *Schima-Bauhinia* Hylium.
4. The *Eugenia-Phoebe* Hylium.

Consociations.

Acrocarpus fraxinifolius W. and A.
Albizzia marginata Merr.
Dillenia pentagyna Roxb.
Duabanga sonneratioides Ham.
Firmiana colorata Br.
Jambosa ramosissima Cowan.
Phoebe attenuata Nees.
Schima wallichii Choisy.
Shorea robusta Gaertn.
Sterculia villosa Roxb.
Terminalia crenulata Roth.
T. myriocarpa Heurck and Muell. Arg.

Societies.

Andropogon assimilis Steud.
Calamus acanthospathus Griff.
C. erectus Roxb.
C. leptospadix Griff.
Camellia drupifera Lour.
Casearia vaereca Roxb.
Crotalaria tetragona Roxb.
Daemonorops jenkinsianus Mart.
Dendrocalamus hamiltonii Nees.
Desmodium dioicum DC.
D. latifolium DC.
Jambosa proecox Cowan.
Leea crispa Willd.
L. robusta Roxb.
Licuala peltata Roxb.
Mesua ferrea Linn.
Micromelum pubescens Bl.
Desmodium Benth.
Dillenia indica Linn.
Endospermum chinense Benth.
Flemingia bracteata Wight.
F. drupifera Roxb.
F. stricta Roxb.
Gleichenia linearis Burm.
Homonoia riparia Lour.
Imperata arundinacea Cyrill.
Indigofera pulchella Roxb.
Inula eupatorioides DC.
Phlogacanthus thyrsiflorus Nees.
Pinanga gracilis Bl.
Pseudostachyum polymorphum Munro.
Saurauja roxburghii Wall.
Woodfordia floribunda Salisb.

A summary of types in the northern tropical semi-evergreen forests are given in table 48.

Table 48.

NORTHERN TROPICAL SEMI-EVERGREEN FOREST.

(After Champion)

Sub-types and distribution	I	II	III	IV
C1 U. Assam tropical semi-evergreen forest. The plains of U. Assam centring on Sibsagar. (i) Sola R., Suffrai, Sibsagar.	*Altingia excelsa, Manglietia insignia, Talauma phellocarpa, Cinnamomum cecicodaphne, Artocarpus chaplasha, Mesua ferrea*, etc.			
C2 Cachar tropical semievergreen forest. Lower slopes of the Cachar hills and in the Surma valley, the Lushai and Manipur hills.	As in the foregoing type.			
(i) Bhimoriaghona, Cox's Bazar division.	*Dipterocarpus costatus, D. turbinatus, Swintonia* spp., *Holigarna* sp., *Mangifera longipes, Quercus acerminata* and spp., *Castanopsis, Eugenia grandis, Bombax insignis.*	*Quercus* spp., *Eugenia* spp., *Meliosma pinnata, Eurya* spp., *Xanthophyllum flavescens*, etc., *Veronia arborea, Vitex* sp. *Oxytenanthera nigrociliata.*	Rubiaceae (Psychotria etc.) *Malastoma* sp.	Climbers not conspicuous.
(ii) Cox' Bazar division.	*Dipterocarpus turbinatus., D. costatus. D. pilosus. Artocarpus chaplasha, Bombax insigne. B. malabaricum. Albizzia procera, Spondias mangifera, Sterculi alata. Buchanania lancifolia.*	*Quercus* spp., *Castanopsis, Eugenia* spp., *Odina wodier Dysoxylum binectariferum. Dillenia pentagyna, Stereospermum chelonoides, Pterospermum semisagittatum.*		
C4 Subhimalayan tropical semi-evergreen forest. (i) Lower hill slopes Kalimpong division.	*Schima wallichii, Bauhinia purpurea, Cedrela toona, Stereospermum tetragonum, Castanopsis indica, Ailanthus grandis. Duabanga sonneratioides. Jambosa formosa. Dysoxylum* spp., *Michelia champaca, Tetrameles nudiflora, Gmelina arborea.*	*Pheobe lancolata, Turpinia pomifera. Meliosma simplicifolia, Actinodaphne obovata, Mallotus* spp., *Gynocardia odorata* II. a *Dendrocalamus hamiltonii* or none.		
C5 Orissa tropical semi-evergreen forest. On Orissa hills at 2,500 ft. or so and in lower permanently moist valley.	*Artocarpus lakoocha, Michelia champaca, Caltis tetranda Bridelia tomentosa, B. verrucosa, Dillinia pentgyna, Saraca indica, Ficus* sp.	*Amoora rohituka. Mesua ferrea, Phoebe lanceolata, Polyalthia* spp., *Macaranga peltata, Glochidion* sp. *Litsaea nitida*. etc.	Many small evergreen shrubs and perennials, *Curcuma aromatica, Leea crispa.*	

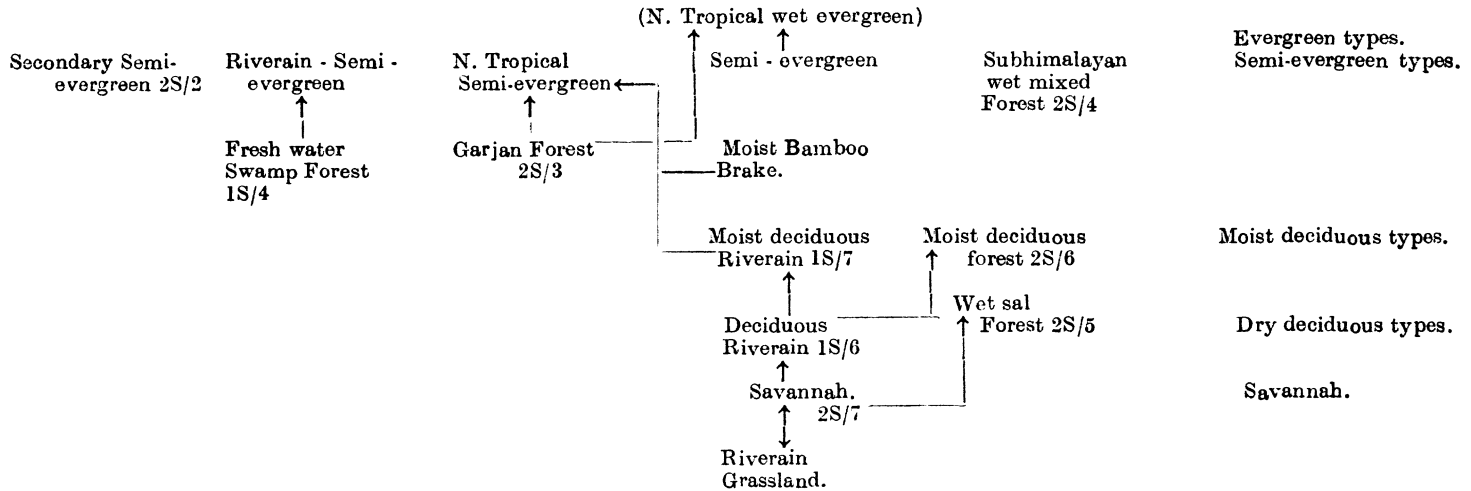
SUCCESSION OF FOREST COMMUNITIES IN NORTHERN TROPICAL SEMI-EVERGREEN FORESTS.

The Scheme of succession in these forests is given below:

Table 49.

SCHEME OF SUCCESSION OF FOREST COMMUNITIES IN NORTHERN TROPICAL SEMI-EVERGREEN FORESTS

(After Champion)



9

TROPICAL MOIST DECIDUOUS FORESTS

In the moist deciduous forests the species remain deciduous only for a short time and a number of evergreen dominants are also present. The evergreens are mostly in the understorey and the general nature of the forest is, therefore, deciduous. These are divided into southern and northern forms.

Southern tropical moist deciduous forests. These are distributed on the west coast in Kanara, Coorg, Wyanad, Nelumbore, parts of Mysore, Cochin, Travancore, parts of Madhya Pradesh and in Andamans in drier regions. The type includes the important teak forests of India.

The forests are composed of high forest tree species with an height ranging from 100 to 120 ft., or more, forming close canopies. These forests are as a rule mixed and have semi-deciduous species in the upper canopy with evergreens in the lower storey. The undergrowth has bamboo and canes on wet ground. In shady places epiphytes are present on trees. The number and size of climbers is large. On account of fire the ground flora species are few, with little grass.

The forest types are given in table 50 after Champion on p. 176.

In the characteristic patches of moist deciduous forest dominant trees become leafless during March and April, though undergrowth species are evergreens. Before the monsoon sets in most of the trees come into leaf. Leaf-fall in teak takes place early in the cold weather in drier localities, but in moister places it sheds its leaves later. Of the other important associates in this forest *Dalbergia* spp. and *Cedrela toona* come into leaf during March and April. *Terminalia tomentosa, Adina, Odina,* etc., shed their leaves during winter and leaf bud opening takes place during the rainy weather. In a number of species flowering takes place while they are still leafless, the most common being *Cassia fistula, Bombax, Sterculia,* etc.

In a deciduous type of forest studied by the author recently at Dandeli in North Kanara trees of *Terminalia* and *Lagerstroemia* occur commonly. A number of other tree species, such as *Careya arborea, Cordia myxa, Cordia rothii, Anogeissus* sp., *Pongamia glabra, Adina cordifolia, Odina wodier,* etc. are also present. In these forests some places have predominance of Bamboos and the others *Xylia* is present on red soils.

At Kulgi the forests consist of tall trees of *Terminalia tomentosa, Terminalia bellerica, Terminalia paniculata, Adina cordifolia, Stephegyne parviflora, Lagerstroemia lanceolata, Dalbergia* sp., *Cordia myxa, Careya arborea, Stereospermum,* etc. *Callicarpa* is a very common shrub in these forests. *Zizyphus rugosa* is a common climber.

There are good teak plantations at Vincholi. Here too *Lagerstroemia, Bauhinia* and *Zizyphus* are common in the forest. Bamboos are abundant in these forests also. *Bambusa arundinacea* and *Dendrocalamus strictus* are common bamboo species.

Calycopteris floribunda is a gigantic climber in these forests and is common.

Table 50.

SOUTHERN TROPICAL MOIST DECIDUOUS FORESTS OF INDIA.

(According to Champion).

Sub-type and distribution.	I	II	III	IV
C_1. S. Indian moist deciduous forest. Throughout the Peninsula. Wherever rain fall exceeds 56" (except on the Carnatic coast) from near Surat and Hoshangabad, southwards.				
(i) Muthodi, Bhadravati division, Mysore.	*Terminalia crenulata, Grewia tiliaefolia, Dalbergia latifolia, Terminalia paniculata, T. bellerica, Tectona grandis, Lagerstroemia lanceolata, Dillenia pentagyna, Adina cordifolia, Pterocarpus marsupium.*	*Xylia xylocarpa, Kydia calycina.* II a. *Bambusa arundinacea, Dendrocalamus strictus,* (high quality) *Oxytenanthera monostigma.*	Grass with *Clerodendron infortunatum, Leea.*	*Spatholobus roxburghii.*
(ii) Begur, Manatoddy, Wynadd, Madras.	*Terminalia crenulata, Garuga pinnata, Bombax malabaricum, Tectona grandis, Grewia tiliaefolia, Lagerstroemia lanceolata, Stereospermum suaveolens, Dalbergia latifolia, Terminalia bellerica,* etc.	*Phyllanthus emblica, Kydia calycina, Wrightia* sp. *Cordia obliqua, Schleichera trijuga,* etc. II a. *Bambusa arundinacea.*	*Lantana, Glycosmis pentaphylla, Ardisia* sp., Light grass.	*Dalbergia volubilis, Spatholobus roxburghii, Acacia pennata.*
(iii) Mount Stuart, S. Coimbatore.	*Lagerstroemia lanceolata, Terminalia paniculata, Grewia tiliaefolia, Mitragyne parvifolia, Stereospermum chelonoides, S. xylocarpum, Vitex altissima, Terminalia crenulata, Tectona grandis, Adina cordifolia, Dillenia pentagyna, Bombax malabaricum.*	*Cycas circinalis, Phyllanthus emblica, Zizyphus xylopyrus.* II a. *Bambusa arundinacea.*	*Lantana, Helicteres,* Finer grasses (*Andoropogon* spp. etc). *Imperata.*	Convolvulaceae, *Spatholobus roxburghii, Zizyphus oenoplia, Caesalipinia mimosoides.*
(iv) Dandeli, N. Kanara, Bombay.	*Terminalia paniculata, T. tomentosa, Lagerstroemia lanceolata, Tectona grandis, Bombax, Pterocarpus marsupium, Dalbergia latifolia, Dillenia pentagyna, Grewia litiaefolia, Xylia xylocarpa, Bauhinia lawii.*	*Xylia xylocarpa.* II. a. *Dendrocalamus strictus. Bambusa arundinacea. Oxytenanthera monostigma.*	*Lantana.*	*Acacia intsia, Mucuna pruriens.*
(v) Bori V., Hoshangabad Division, Madhya Pradesh.	*Tectona grandis, Terminalia tomentosa, Adina cordifolia, Pterocarpus marsupium, Dalbergia latifolia, Lannea grandis, Lagerstroemia parviflora.*	*Schleichera trijuga, Ougeinia dalbergioides, Phyllanthus emblica, Saccopetalum tomentosum.* II a. *Dendrocalamus strictus* (good quality).	*Helicteres isora.*	*Milletia auriculata, Cryptolepis buchanani, Bauhinia vahlii, Butea superba.*

Moist situations have trees of *Pongamia glabra. Phyllanthus* sp., and *Polygonum* are common along river banks. The ground flora in the teak forest is poor and some dried grasses such as *Chloris* are frequently met with. In moist places near banks of rivers, etc. species of *Oldenlandia, Vandellia, Centella asiatica, Bacopa monnieri, Eclipta alba, Ageratum, Portulaca, Trianthema, Blumea* and *Euphorbia* are common.

Cassia, Zizyphus, Argyreia, Calycopteris and *Lantana* are frequent near habitations and railway lines.

Succession in southern tropical moist deciduous forests. The scheme of succession of forest communities in these forests is shown in table 51 on p. 178.

According to this scheme the tropical moist deciduous forest is considered to be a sub-climax to tropical semi-evergreen type. Champion also considers that the tropical moist deciduous type is the late seral stage of fresh-water swamp forest, riverain dry and riverain moist deciduous types. Taking the Clement's terminology strictly, it is not possible to accept Champion's scheme of succession. The swamp and riverain types are distinct edaphic types, which remain in that state permanently. The moist deciduous type itself is influenced more by edaphic features than the climate. A lot of more data are, however, wanted on this type before giving an acceptable scheme of succession.

TEAK FORESTS OF INDIA.

The most important constituent of the moist deciduous forest in the south is *Tectona grandis* which is confined mainly to the peninsula, extending in the north towards the base of the Aravalli range and to the district of Jhansi in U.P. in the N. W.; following a south eastwardly direction towards the Mahanadi and up to Travancore in the south. The discontinuous distribution of teak has been a subject of interest since long and interesting relationship of the distribution of this tree with calcium content of the rock and the soil has been obtained in a number of cases (Vahid 1927, Hewetson 1941, Puri 1951, Kulkarni 1951). Recently Bhatia (1953) has further elucidated this relationship and found that soil phosphates have in addition an important part in determining the distribution of this species in the Madhya Pradesh.

Teak does not form pure or gregarious patches but occurs sporadically and has been planted at many places outside its natural zone of distribution. Rainfall does not seem to determine its limit of distribution, though temperature and frost are sometimes limiting factors. Teak is most conspicuous and best developed on deep alluvial soils, forming almost pure patches. It seems to avoid crystalline rock and sterile sandstone and laterite.

The common associates of teak are *Terminalia tomentosa, T. bellerica, Lagerstroemia parviflora, Anogeissus latifolia, Dalbergia latifolia, Pterocarpus marsupium, Ougeinia dalbergioides, Gmelina arborea, Bridelia retusa, Cassia fistula, Odina wodier,* etc. The common bamboo is *Dendrocalamus strictus,* but sometimes along river banks *Bambusa arundinacea* is also found. Photo 65 shows a teak forest in Allapalli in the Madhya Pradesh.

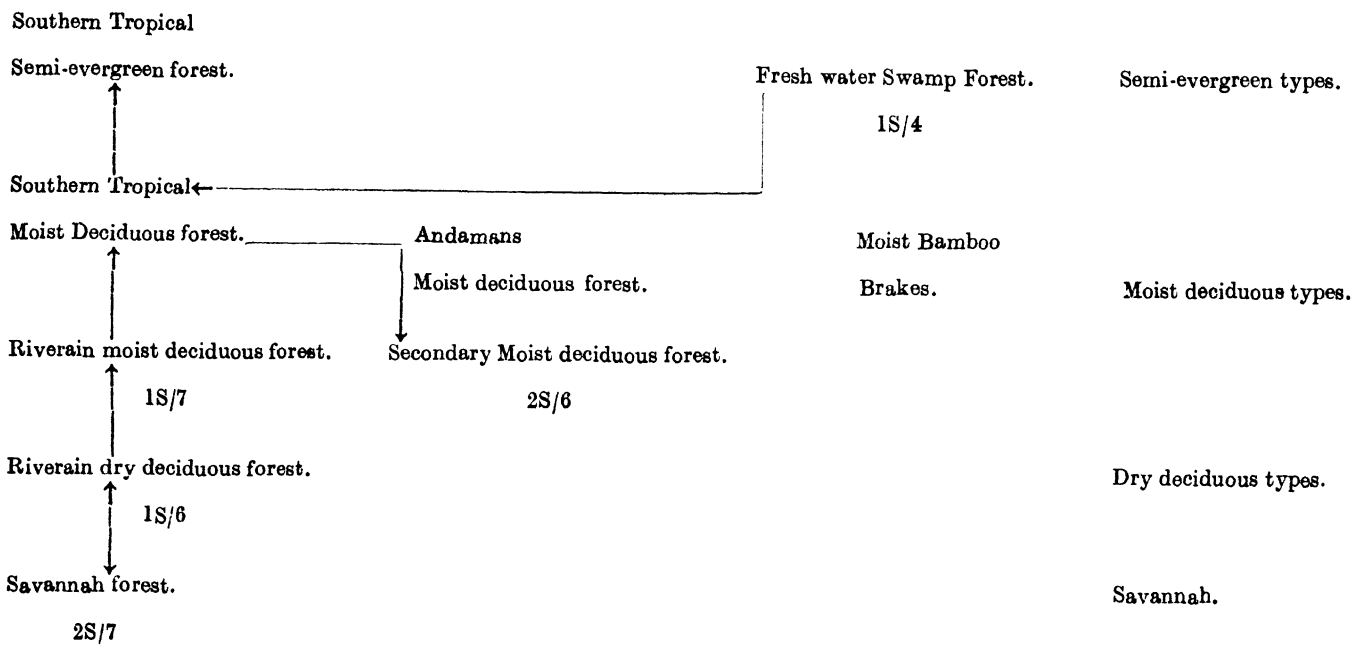
The Teak Forest of Saurashtra: In Saurashtra, teak is found around Junagadh in the Girnar and the Gir forests (Photo 66).

Both the Girnar and Gir areas are part of the Deccan Trap; the main substratum being basalt overlain by amygdaloid and red clay which is found in patches. The general colour of the soil is reddish brownish or even grayish.

Table 51.

SUCCESSION OF FOREST COMMUNITIES IN SOUTHERN TROPICAL MOIST DECIDUOUS FORESTS.

(After Champion).



The forests of Gir and Girnar are similar to *Tectona grandis-Holarrhena antidysenterica* communities, with other associates.

The first storey trees are very few. Only teak is the noteworthy species amongst them. *Eugenia jambolana Mimusops hexandra, Anona squamosa and Acacia catechu* are found occasionally. Teak shows a good development, but has been coppiced badly.

The second storey plants are *Wrightia tinctoria* and *Holarrhena antidysenterica, Grewia* sp., etc.

Amongst the climbers, *Vitis* sp. is the commonest. *Stephania hernandifolia, Phaseolus* sp., *Clitoria ternata,* Cucurbits, etc. are also found.

Herbs and grasses form the ground flora.

In the Gir forests amongst the trees *Terminalia tomentosa, Aegle marmelos, Sapindus laurifolia, Schrebera swietenioides, Sterculia* sp., *Bombax malabaricum, Diospyros* sp., *Phyllanthus emblica, Acacia leucophlaea* are also seen where as amongst shrubs *Balanites roxburghii, Dichrostachys* sp., etc. are seen.

Teak Forests in Central India: In the Bheru ghats and the Manpur ghats near Indore (Photo 67) very beautiful teak forests are present on trap rock which is seen to form tongues in the Aravalli ranges which are mainly of sandstone.

The first storey trees besides teak (Photo 68) are *Aegle marmelos, Boswellia serrata, Ougeinia dalbergioides, Lannea grandis, Diospyros* sp., *Bombax malabaricum, Sterculia urens, Phyllanthus emblica, Dalbergia paniculata, Terminalia tomentosa,* etc.

The second storey plants are few; chief amongst them being *Wrightia tinctoria, Holarrhena antidysenterica, Bambusa* sp., *Grewia* sp., *Nyctanthes arbor-tristis,* etc.

The climbers are mainly *Vitis* sp., *Dioscorea* sp. and *Cardiospermum.*

The ground flora mainly consists of *Cassia tora,* Balsam, grasses and a few other herbs.

At Gujari about 15 miles south of Manpur along the Bombay-Agra Road, a pure community of teak is present.

In Alirajpur State teak forests (Photo 69) have been very greatly damaged by local population and the same fate has been of other state forests in this region.

The Teak Forests of Poona and Bombay: The associates of teak are *Santalum album, Anogeissus latifolia, Garuga pinnata, Acacia catechu, Heterophragma roxburghii, Schrebera swietenioides,* etc. (Photo 70).

The second storey plants are *Carissa congesta, Gymnosporea montana, Lantana camara, Euphorbia antiquorum,* etc. These form tufts.

The commonest climber is *Clematis triloba* (Photo 71) with *Vitis* sp. *Cryptolepis buchanani* and *Dioscorea bulbifera* also occur to a lesser percentage.

The third storey plants are *Cassia auriculata, Woodfordia fruticosa, Lasiosiphon eriocephalus, Lavandula burmanni,* etc.

The ground flora mostly consists of herbs and grasses (Photo 72). The chief grasses are *Apluda varia, Arundinella tenella, Cymbopogon martinii, Andropogon pumilus, Heteropogon contortus,* etc.

The legumes are mostly species of *Crotalaria and Indigofera.*

This teak forest is an edaphic community preserved by the nature of the soil and geological features.

The moist deciduous forests in Kasara were recently studied by the author and S. K. Jain.

The typical deciduous forest here is composed of *Tectona grandis-Terminalia tomentosa* community. The common associates are *Anogeissus latifolia* and *Butea monosperma*. *Adina cordifolia* and *Schleichera* are frequent in some spots.

The second storey consists mainly of *Erythrina variegata* var. *orientalis, Salmalia malabarica, Butea monosperma, Wrightia tinctoria, Acacia catechu, Bauhinia racemosa* and *Zizyphus rugosa*. The shrub layer consists chiefly of *Flacourtia* species, *Woodfordia fruticosa, Meyna laxiflora, Carissa congesta*, etc.

The commonest climbers in the area are:—

Calycopteris floribunda, Combretum, Hemidesmus indicus, Mucuna prurita, Cryptolepis buchanani, Dioscorea bulbifera, Dioscorea pentaphylla and some cucurbits. *Dendrophthoe* species are commonly met with parasitising a number of trees, chiefly *Terminalia tomentosa*.

The ground vegetation shows a distinct seasonal aspect and the following species occur mainly during and after monsoons:—*Alysicarpus* sp., *Anotis lancifolia, Cassia absus, Cassia tora, Cyperus* sp., *Euphorbia parviflora, Phaseolus* sp., *Melothria* sp., *Hypoxis aurea, Crinum* sp., *Urena lobata, Justicia simplex, Phyllanthus niruri, Arthraxon* sp., and some other grasses.

Adiantum sp. is the common fern. *Habenaria grandiflora*, the ground orchid is quite common in rainy season. Seedlings of *Adina cordifolia, Butea monosperma, Carissa congesta, Acacia catechu, Bauhinia racemosa, Erythrina variegata* var. *orientalis, Tectona grandis, Cassia fistula, Terminalia tomentosa* and others are frequently met with.

Plants like *Malachra* sp., *Urena lobata, Achyranthes aspera, Cyperus* sp., *Haplanthus tentaculatus, Cocculus* sp., *Hibiscus* sp., and a number of grasses such as species of *Capillipedium, Themeda, Arundinella, Apluda, Ischaemum, and Heteropogon* grow during the hot and dry season. The teak - *Terminalia* community seems to be the climatic climax in this area.

Teak in Madhya Pradesh: In the Bori forest of Madhya Pradesh teak is associated with *Terminalia tomentosa, Ougeinia dalbergioides, Diospyros melanoxylon, Lagerstroemia parviflora, Anogeissus latifolia, Dendrocalamus strictus*, etc. The associates of teak at different places vary a good deal, according to the nature of the soil and its moisture conditions. Recently *Lantana* has become a menace in teak forests of Bombay; *Loranthus* and teak defoliater are some other maladies that affect forests and plantations of teak.

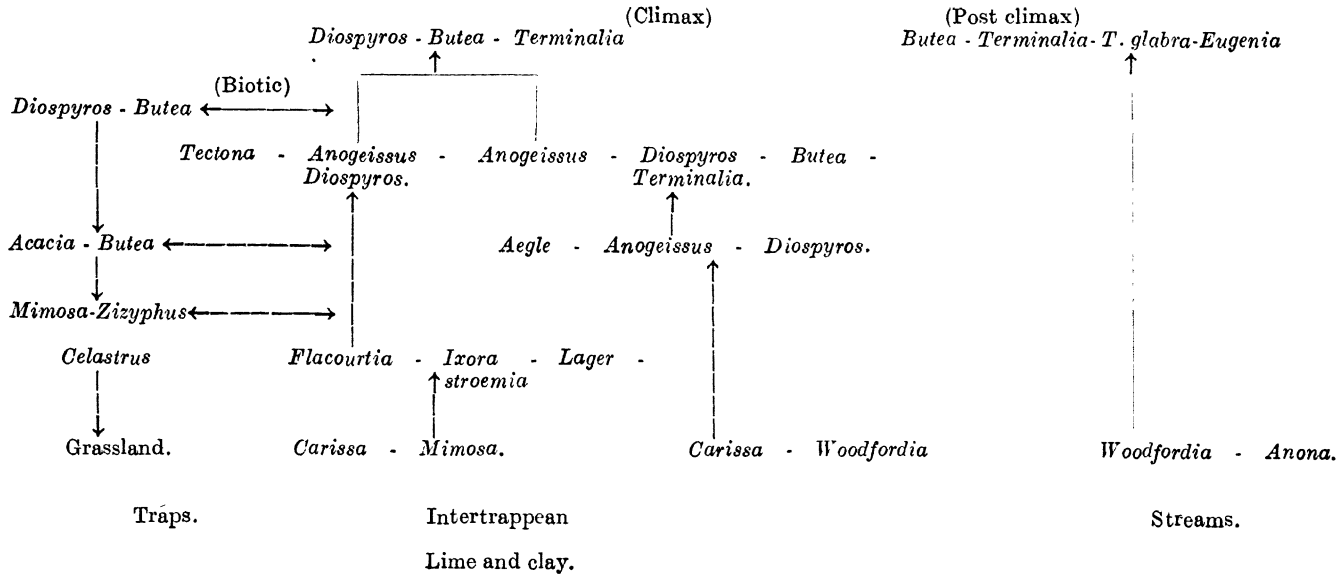
On account of its high commercial importance teak is raised in plantations wherever it has been possible to do so. The technique of teak plantation has been the subject of great interest to foresters in this country and interesting monographs have been written by Champion (1936) Laurie and Griffith (1942). In this connection effort has been made to find out plants which could be used as indicators of conditions suitable for teak. Osmaston (1929) found that *Bambusa polymorpha* and *Cephalostachyum pergracile* are indicators of good sites for teak and *Dendrocalamus strictus* of dry teak forests. Generally, in teak plantations there is hardly any ground flora vegetation and this has been a danger sign for setting in of erosion and efforts have been made to introduce some suitable species in teak plantations.

Succession of forest communities in some teak forests: Misra and Joshi (1952) recently studied the forest complex of Patharia Hill at Sagar in M.P. and described the plant succession as shown in table 52.

Table 52.

SUCCESSION OF FOREST COMMUNITIES IN TEAK FORESTS OF PATHARIA.

(After Misra and Joshi, 1952).



The climatic climax of this region appears to be a mixed deciduous forest.

In the early stages of succession the thorny shrubs like *Carissa spinarum, Flacourtia ramontchi, Zizyphus oenoplia,* etc. are present. These species have two fold functions. Firstly, they stabilise the subtratum and secondly they provide effective shelter to tree seedlings against grazing. Shrubs like *Carissa spinarum, Woodfordia floribunda, Mimosa rubicaulis, Ixora parviflora, Anona squamosa,* etc. are early colonisers on the hill sides. *Helicteres isora* in the teak forest is a late arrival which can thrive better under shade.

At the foot of hill, the soil deposition is a characteristic feature. *Zizyphus rotundifolia* plays the role of pioneer species. Shoots arise from the basal parts of the stem of this plant on being covered under the soil. Here the soil covers the shoot buds, which subsequently strike root and increase stem length.

Succession in Kanheri National Park, Bombay was studied by Das (1954), whose scheme of succession is given in table 53.

Table 53.

SCHEME OF SUCCESSION ON FOREST COMMUNITIES OF KANHERI NATIONAL PARK, BOMBAY

(after Das).

		Lateritic.	
Soil Depth.	Pre-existing Vegetation. →	Moist Deciduous Forest of *Tectona grandis* and *Terminalia tomentosa*.	
		Cutting and Pasturing.	Burning and Pasturing.
60"	Cutting.	*Adina cordifolia* facies.	
54"	Cutting and exposure to light.	*Bambusa arundinacea* facies.	
			Pogostemon parviflora.
30"	Heavy cutting.	*Holarrhena-Wrightia* facies.	
24"	Cutting and pasturing.	*Themeda pseudanthistiria-Celosia.*	Dry deciduous forest.
12"	Further pasturing.	*Pseudanthistiria-Eulalia.*	
10"	Intensive pasturing.	*Eulalia eragrostis.*	
7"	Maximum Regression.	*Eragrostis-Blumea.*	
5"	... . Closure to grazing.	*Blumea-Eragrostis.*	
24"		*Themeda pseudanthistiria-Eulalia.* *Holarrhena-Themeda.*	
30"	Closure to grazing and prevention of cutting.	*Holarrhena-Wrightia-Calycopteris.*	
54"	Closure to grazing and prevention of cutting.	*Bambusa arundinacea* facies.	Dry deciduous forest.
60"		*Adina cordifolia* facies.	
60"		Moist deciduous forest and *Terminalia tomentosa.*	*Tectona grandis.*

In the states of Bonai, Bamra, Keonjhar and Sirguja and the adjoining tracts of Bihar where teak and sal occur together, Lall (1942) describes forest succession taking place in the following stages:—

(i) The pure mineral soil is colonised by xerophyllous species which are especially adapted for growing on pure sand. The different species in the descending order of frequency, which constitute the first colonisers are *Saccharum* sp., *Tamarix dioica, Vitex negundo, Acacia catechu, Zizyphus oenoplia,* etc.

(ii) When the pioneer species have transformed the soil into sandy loam teak comes in, its seeds being dispersed by the action of water. In due course, it dominates, and drives out the pioneer species and reaches its best development.

On soils with lateritic composition there develops in teak forest an understorey of *Cleistanthus collinus, Holarrhena antidysenterica, Bauhinia racemosa, Kydia calycina,* etc. This is followed in due course, by the invasion of *sal* seeds which are dispersed through wind. The climbers begin making their appearance with the development of understorey of miscellaneous species and become conspicuous with the eastablishment of *sal.* Important climbers are *Ichnocarpus frutescens, Dioscorea* spp., *Butea superba, Bauhinia vahlii* and *Smilax macrophylla.*

Due to the cumulative effect of climate and vegetation on the site and the hardy silvicultural characteristics of *sal,* teak gradually begins losing ground and in due course, is driven out, leaving a climatic climax formation of *sal.* The reasons for the occurrence together of teak and *sal* are still unknown. Teak is a calcicole, while *sal* appears to be a calcifuge. The presence of teak in *sal* forests of Baster was recently considered by some foresters be due to old cultivation of teak trees, a point, which has been disputed by others.

Sandal forests: Sandal occurs in a number of forest types in south India, in the states of Mysore, Madras, Bombay and in some parts of M. P. Nanayya (1949) has given the associated vegetation and types of forests in Coorg. In other states vegetation is not very different from Coorg, the distribution given for Coorg may, therefore, be more or less representative for sandal areas.

The sandal bearing areas in Coorg lie between the altitudes of 2,000' and 4,000', where rainfall varies between 40" to 100".

The composition of forest crop at different types is as follows:—

In areas with a rainfall of 60" to 80" sandal grows well, often reaching a height of 60' and a girth of 40" in association with *Artocarpus hirsuta, Eugenia jambolana, Lagerstroemia lanceolata, Casearia tomentosa, Dalbergia latifolia, Melia dubia, Albizzia* spp., *Bombax, Vitex negundo, Pterocarpus marsupium, Pongamia glabra, Acrocarpus fraxinifolius, Cedrela toona, Flacourtia montana, Careya arborea, Gmelina arborea, Grewia* sp., *Bambusa arundinacea,* etc.

In regions with a rainfall of 40" to 60" semi-evergreen type of forest changes gradually to a deciduous one, and sandal grows to a fair height, often reaching 40' and a girth of 36". The danger from suppression to sandal from its associate species is less in this area than in the semi-evergreen forest. The forests are fairly open and *Dendrocalamus strictus* usually occurs in the under storey. The associate species of sandal are *Diospyros montana, Zizyphus* sp., *Cassia fistula, Garuga pinnata, Schleichera trijuga, Stereospermum chelonoides* and *Albizzia* sp. The occurrence of *Dendrocalamus strictus* may be taken roughly to differentiate the deciduous from the semi-evergreen type.

In areas where rainfall is less than 40" and the climate is very hot in summer and the soil is poor and gravelly, the deciduous type is replaced by scrub forest, wherein the growth and development of sandal is poor. The associated trees are *Acacia suma, Diospyros montana,* stunted *Anogeissus,* occasional *Melia, Terminalia chebula* and *Phyllanthus,* and the soil covering is a kind of dense grass which prevents soil evaporation throughout the year. In the trap country sandal occurs in teak area. Photo 73 shows the habitat of a mixed teak-sandal forest near Poona.

"Plantations have also been formed in reserves, mostly in the semi-evergreen and deciduous types. In plantations where tending has been neglected in the past, especially in the semi-evergreen type, sandal has been badly suppressed and in many cases killed by the dense shade of fast growing species, resulting in its patchy stocking and poor development."

In these areas sandal suffers from spike disease. Extensive research has shown that the following forests of sandal are spike resistant.

(1)	*Cassia siamea.*	Most resistant.
(2)	*Melia indica.*	,,
(3)	*Semecarpus anacardium.*	,,
(4)	*Strychnos nux-vomica.*	,,
(5)	Bamboos.	,,
(6)	*Anogeissus latifolia.*	Resistant.
(7)	*Canthium didymum.*	,,
(8)	*Dichrostachys cinerea.*	,,
(9)	*Eugenia* sp.	,,
(10)	*Ixora parviflora.*	,,
(11)	*Zizyphus oenoplia.*	,,
(12)	*Zizyphus jujuba.*	Fairly resistant.
(13)	*Webera corymbosa.*	,,
(14)	*Dodonaea viscosa.*	Fairly susceptible.

Northern tropical moist deciduous forests: These are distributed in Uttar Pradesh, Bihar, Orissa, Madhya Pradesh, Bengal and Assam and constitute the most important forests. This type includes the important *sal* forests of India as compared to teak in the southern type.)

These are composed of high forests in which *sal* constitutes a high percentage of the top canopy which is 80–120 ft. high. In virgin forests the canopy is fairly close and regular. The undergrowth has mostly semi-evergreen shrubs and it is replaced by grass on burning. There are a few climbers which include several large and common species. Canes and bamboo do not occur usually but bamboo may be found on specially dry or wet sites.

The floristic composition of the type from a few localities is given in table 54 after Champion.

The *sal* forests of India are gregarious with only a few species in the top canopy. In localities where *sal* is not absolutely pure the forest management practices have tended to make it so. Selective shrub cutting, removal of species of less economic value have all made the *sal* forests appear more pure than what they actually are.

Succession in northern tropical moist deciduous forests. The successional relationship of various types of forests is given in table 55 on p. 190.

Table 54.

NORTHERN TROPICAL MOIST DECIDUOUS FORESTS.

(After Champion).

Sub-type and distribution.	I	II	III	IV
C1. Moist Sal Forest. More or less throughout Northern India with rainfall not less than 40".				
B1. Moist Siwalik Sal, Kumaon hills, U.P.	*Shorea robusta, Anogeissus latifolia* & *Terminalia tomentosa.*		III a. *Dendrocalamus strictus, Colebrookea oppositifolia.*	Regeneration adequate.
B2. Moist peninsular Sal, Ganjam, Orissa.	*Shorea robusta, Pterocarpus marsupium.*		III a. *Anthistiria ciliata, Indigofera pulchella, Phoenix acaulis.*	Regeneration good.
B2a. Supkhar Sal, M. P. Balaghat division.	*Shorea robusta, Terminalia chebula, Eugenia jambolana.*	*Bauhinia vahlii.*	III a. *Anthistiria ciliata, Phoenix acaulis, Dendrocalamus strictus.*	Regeneration adequate but frost risk.
B2 b. South Raipur Sal. Madhya Pradesh.	*Shorea robusta, Pterocarpus marsupium, Terminalia tomentosa.*	*Phyllanthus emblica.*	III a. *Anthistiria ciliata,* (no large *Saccharum*).	Regeneration satisfactory.
B2 c. Singhbhum Valley Sal, Bihar.	*Shorea robusta, Terminalia tomentosa.*		*Flemingia chappar, Indigofera pulchella.*	
B2. App. Frosty valley Sal.	Frosted *Sal* Regeneration.	—	III. a. *Imperata arundinacea.* —	Regeneration excellent.
B3 High level alluvium, Kumaon Bhabar, U.P.	*Shorea robusta, Terminalia tomentosa, Lagerstroemia parviflora,* etc.	*Mallotus philippinensis.*	*Saccharum narenga, Clerodendron infortunatum, Imperata arundinacea.*	Regeneration difficult with protection, slow in burnt grass.
B4 S. Kheri Sal, U.P.	*Shorea robusta, Terminalia bellerica, Lagerstroemia parviflora.*	*Mallotus philippinensis.*	III a. *Anthistiria gigantea, Saccharum* spp.	Regeneration, Young crop adequate.
B4 Chander Sal, U.P.	*Eugenia operculata.*	—	III a. *Anthistiria gigantea.*	Regeneration abundant but frosted.
B5 Old alluvium Sal.	*Shorea robusta, Dillenia pentagyna, Eugenia jambolana.*	—	—	Regeneration fair, but coppice usually relied on.

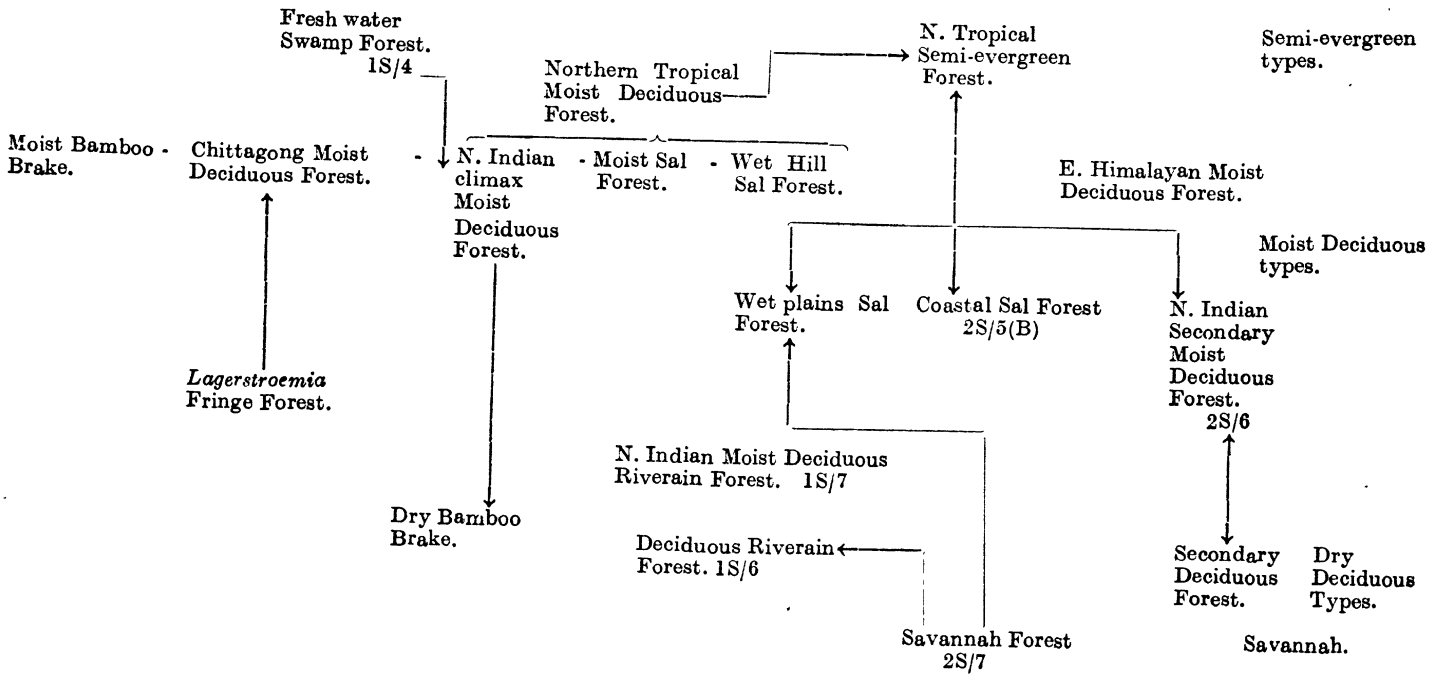
Table 54 (Contd.)

Sub-type and distribution.	I	II	III	IV
B5.a. Gorakhpur Sal, U.P.	*Shorea robusta, Terminalia tomentosa, Dillenia pentagyna.*	—	*Flemingia chappar.*	Regeneration, enough small poles, etc., for coppice working.
B5.b. Dacca Sal.	*Shorea robusta, Albizzia procera, Dillenia pentagyna.*	—	*Pennisetum setosum, Desmodium* sp.	Regeneration coppice.
B5. Kamrup alluvial Sal, Assam.	*Shorea robusta, Dillenia pentagyna Lagerstroemia parviflora*, etc.	*Careya arborea, Glochidion* spp.	III a. *Imperata arundinacea.*	Regeneration good in burnt grass. Stopped by protection.
B6. W. Tarai Sal, U.P.	*Shorea robusta, Eugenia jambolana.*			Regeneration; coppice fair.
C2. Wet hill Sal forest. E. Sub-himalayan upper Bhaber tract including the lower slopes of the range and the lower slopes of the Garo, Khasi, Mikir, and Jaintiahill s of Assam, South of the Brahmaputra.				
D1. Eastern hill Sal.	*Shorea robusta.*	*Dendrocalamus hamiltonii.*	III a. *Pollinia ciliata. Imperata arundinacea. Desmodium* spp.	Regeneration difficult in *Pollinia*, fair otherwise.
D1 a. E. Himalayan Sal, Kalimpong division Bengal.	*Shorea robusta, Schima wallichii, Stereospermum chelonoides.*	*Dendrocalamus hamiltonii.*		Regeneration satisfactory.
D1 b. Khasi hill Sal, Kamrup division Assam.	*Shorea robusta, Schima wallichii, Adina cordifolia.*	*Dendrocalamus hamiltonii.*	III a. Heavy *Pollinia ciliata, Imperata arundinacea.*	Regeneration quite inadequate and difficult to induce.
D2. E. Bhabar Sal.	*Shorea robusta, Schima wallichii, Lagerstroemia parviflora.*	Lauraceae.	III a. *Imperata arundinacea, Pollinia ciliata.*	Regeneration impossible with fire protection.
D2 a. Bamba Sal, Buxa division, Bengal.	*Shorea robusta, Schima wallichii, Lagerstroemia parviflora.*	*Polyalthia simiarum, Amoora rohituka.*	III a. *Pollinia ciliata.*	Regeneration very slow with burning.
D2 b. Sivok Sal.	*Shorea robusta, Terminalia tomentosa.*	*Machilus* spp. Meliaceae.	III a. *Imperata arundinacea,*	Regeneration impossible with fire protection.
D3. E. Terai Sal.	*Shorea robusta, Michelia champaca, Castanopsis.*	*Machilus* spp.	III a. *Anthistiria gigantea,* etc., with burning.	Regeneration impossible with fire protection.

Table 55.

THE SCHEME OF SUCCESSION IN NORTHERN TROPICAL MOIST DECIDUOUS FORESTS.

(After Champion).



THE SAL FORESTS OF INDIA

Shorea robusta is a gregarious species, forming pure or almost pure forests. In its zone, *sal* is mostly dominant in the upper storey and is described as a climax vegetation, except in moist forests of Bengal and Assam, where they probably represent seral communities. A brief description of these forests statewise is given here:—

In U.P. *sal* is generally of III and IV quality, with only a few areas with I and II quality growth.

The common associates of *sal* in the top canopy are - *Buchanania latifolia, Pinus longifolia, Aegle marmelos, Anogeissus latifolia, Terminalia tomentosa, Lagerstroemia parviflora, Eugenia jambolana, Dillenia pentagyna.*

In the lower canopy are *Woodfordia floribunda, Indigofera pulchella, Limonia acidissima, Colebrookea oppositifolia, Mallotus philippinensis, Clerodendron infortunatum, Croton oblongifolius, Flemingia chappar,* etc.

The common grasses in *sal* forests are: *Ischaemum angustifolium, Dendrocalamus strictus, Thysanolaena, Saccharum* spp., *Imperata arundinacea, Anthistiria gigantea.*

The outstanding features of these forests are the presence of Bhabar grass, dense *Mallotus* and *Clerodendron,* heavy grass, dry sub soil, frosted regeneration, pure low quality crops on clay alluvium, wet subsoil, presence of *Calamus* and drought mortality.

The various subtypes of the U.P. *sal* forest are given below after Champion:

(i) A_1 — dry Siwalik.
(ii) A_2 — dry gangetic.
(iii) B_1 — Moist Siwalik.
(iv) B_3 — Moist high level alluvium.
(v) B_4 — Moist low level alluvium.
(vi) B_4 — sal chanders.
(vii) B_5 — (a) Old alluvium.
(viii) B_5 — (b) W. Tarai.

Photo 74 - 76 give some types of *sal* forests in U.P.

Sal in Bengal is of I, II quality but III, IV is also met within Dry peninsular type. On the whole *sal* is of good quality. The percentage of *sal* is high and it may be exceptionally pure in some cases. In lower Bhabar *sal* is with admixture of its usual deciduous fire resistant associates as is seen in Photo 77 in Ramnagar.

Top canopy consists of *Anogeissus latifolia, Boswellia serrata, Albizzia procera, Dillenia pentagyna, Schima wallichii, Stereospermum chelonoides, Lagerstroemia parviflora, Terminalia tomentosa, Michelia champaca, Castanopsis.* In the lower canopy are *Gardenia* spp., *Wendlandia tinctoria, Desmodium* spp., *Dendrocalamus hamiltonii, Polyalthia simiarum, Amoora rohituka, Machilus* spp., Meliaceae, mixed evergreens, etc.

Grasses are *Ischaemum angustifolium, Imperata arundinacea, Pollinia ciliata, Anthistiria gigantea.* In some types the grasses are very little. Photo 78, 79 and 80 give some *sal* types in Bengal.

Various types—(i) Dry peninsular, (ii) Moist eastern low level clayey alluvial, (iii) East Himalayan, (iv) Eastern Lower and Upper Bhabar, (v) Eastern Tarai.

Sal in Assam is of II - III quality, but I quality is also met with in Eastern Bhabar (Bama) type. It is of high quality,i.e. Q.C. II/I in the Eastern Bhabar type, and is relatively or even exceptionally pure. The associated Species are *Dillenia pentagyna, Lagerstroemia parviflora, Terminalia bellerica, Adina, Gmelina, Vitex peduncularis, Schima wallichii, Michelia champaca* and *Artocarpus* spp. In the lower canopy are *Careya arborea, Glochidion* spp., *Dendrocalamus hamiltonii, Phyllanthus emblica, Milletia, Clerodendron, Mallotus philippinensis, Machilus* spp., etc.

Grasses are *Imperata arundinacea and Pollinia. Saccharum narenga* is common. Ferns are abundant in Eastern Tarai type.

Sal in Bihar and Orissa is mostly of II, III quality, though IV is also met with in dry areas.

Top canopy has *Anogeissus latifolia, Pterocarpus marsupium, Terminalia tomentosa, Adina, Lagerstroemia parviflora, Dillenia pentagyna, Bridelia retusa, Boswellia serrata,* etc. In the lower canopy are *Gardenia* spp., *Phyllanthus emblica, Wendlandia tinctoria, Flemingia chapper, Indigofera pulchella, Phoenix acaulis, Milletia, Casearia* spp., *Croton oblongifolius, Actinodaphne angustifolia,* evergreen Rubiaceae.

The *sal* in M.P. is mostly of III-IV quality. It is usually very pure in moist peninsular low level *sal* forests.

Top canopy consists of *Anogeissus latifolia, Diospyros melanoxylon, Terminalia tomentosa, T. chebula, Bassia latifolia, Eugenia jambolana, Pterocarpus marsupium.* Along nalas in moist peninsular high level *sal, Cedrela toona, Mangifera indica, Ardisia solanacea* are characteristic.

The lower canopy has *Bauhinia vahlii, Phyllanthus emblica, Diospyros malanoxylon, Buchanania latifolia, Mallotus philippinensis and Clerodendron infortunatum.*

A great deal has been written on *sal* forests of India. After Troup (1921), Champion (1933), Mooney (1941), Hewetson (1954), Waheed Khan (1953) and Puri (1951) have written papers on ecology of *sal.* It is still not quite clear whether *sal* forest is a climax over most of the area it occupies or it has attained its present state by the aid of the human factor. The status of *sal* is different in different parts of the country and as climatic climax it may be found in some parts of Bihar and Orissa only.

NATURAL REGENERATION OF SAL FORESTS.

The problem of the natural regeneration of *sal* forests consists of:

(i) Recruitment and
(ii) Establishment.

Recruitment of *sal* seedlings is generally present in most areas, excepting in some parts of the Gangetic alluvium of Uttar Pradesh. Establishment problems occur in all the areas as seedlings die out in the first year, or die back and persist for a number of years before shooting up to form healthy saplings. In some parts of Bihar, where it was generally believed that clear felling induced *de novo* regeneration of *sal,* it was observed in field that the seedlings, that had grown up into saplings after clear felling had really been stagnating for a number of years. Their rootstock was thick, though they had tiny stems. The establishment period may vary from one to two or even three decades in different areas, making the successful regeneration of *sal* forests under management, unpredictable. As a result of this, the exploitation of *sal* cannot be properly planned.

A great deal of work has been done on this problem. The data prior to 1933 has been summarised by Champion (1933). The latter work was summarised by Puri (1950–51). The regeneration studies in the *sal* forests may be divided into the following types:—

(i) I–II quality *Sal* forests with a mixed tree canopy and middle storey, mixed, with little undergrowth; which may be climax or pre-climax in some areas, have adequate regeneration of *Sal*. Establishment period seems to be generally short. This type occurs on light soils derived *in situ* from schists, gneisses, sandstones and quartzites and also on light grey or red soils which are transported and occur at the bottom of hills. These are usually well drained areas, and may suffer sometimes from drought. Frost damage is little. Humus is acidic, with little exchangeable Calcium and low organic matter. In M.P., this type occurs at Muki, Motinala, and Lamni; also in some areas of Bihar and some areas of U.P., e.g., in Bahraich and N. Kheri. The ideal system for this will of course be selection but some of the areas with advance whippy growth seem to have responded well for *sal* regeneration when worked under conversion and clear felling systems.

(ii) Low quality *Sal* forests with little or no undergrowth and mixed canopy, which may be climax, have *Sal* and other spp. Establishment period of *Sal* regeneration in these forests is variable, generally long, but sure. These occur on somewhat heavier soils formed *in situ* from ferruginous strata of the Siwaliks, pisolitic laterites in M.P. and Bihar. These soils are somewhat basic, but are well drained, aerated, loose and rich in iron oxide, manganese and Aluminium. When mixed with quartzite seams the quality of *Sal* on these soils improves slightly. In some places these have greater mixtures of miscellaneous species and sometimes in small patches have bamboos in understorey. Here some difficulty in regeneration is seen. But the best method of getting regeneration in these was considered to be by selection system.

(iii) Mature *Sal* forests with regular and unbroken canopy, with or without any undergrowth, and with no regeneration of *Sal* are probably post-climax. These occur on soils derived from trap and basalts or bauxite, and heavy laterites *in situ*, or on transported soils in valley bottoms. These soils are poorly drained, deep black, or deep black chocolate in colour, and are very clayey and compacted. These seem to become water-logged in rains and suffer from drought in summer. Frost damage is intense on these. When clear felled, grasses come in this type. Regeneration dies out in rains, or in post-rainy dry period in this type. Humus is very basic, with high organic matter, high exchangeable Calcium. Fire damage is disastrous on this type. It is difficult to say whether or not this type can again be successfully brought under *Sal* forests. Experiments on this type have to be conducted to study succession. Effects of deep trenching to leach out bases from the surface layer of the soil would throw some light on the probable treatments that have to be given to get regeneration of *Sal*. It seems that if these soils could, somehow or the other, be made acidic *Sal* crop may flourish on these. Planting of non-exacting species could also be tried, but only after some data have been collected.

(iv) Mature or immature *Sal* forests with regular canopy, with heavy or moderate evergreen undergrowth have recruitment, but unestablished regeneration. The exact ecological status of these is difficult to assess. These occur mostly on transported soils on flat areas in U.P. Soils are deep and show zonation with clayey black layer at the top and sandy layer below. The humus is somewhat basic, with high organic matter. These are badly drained and suffer from drought in summer.

When canopy is opened, grasses come in profusion. Fire does help but not always; shrub cutting, weeding, hoeing, etc. have been tried but not with much success. These are the most difficult areas in U.P. Deep trenching so as to leach out bases from the surface layer and expose the sandy layer may prove beneficial and bring in *sal* regeneration. Fire or any other drastic treatment which is likely to increase basicity of the surface layer may be extremely harmful for *sal* regeneration in this type.

The detailed ecological studies on the *sal* forests have only been attempted recently by Puri (1955). He has studied forests in some divisions of Madhya Pradesh and on the basis of floristic composition, soil and other data, have further classified Champion's types occurring in those areas and has attempted to correct successional status as follows:—

(i) *Champion's* B_2 (*c*) *type* is C. P. I–II quality *sal* forest at Motinala, Kisli and Muki. These are *Shorea-Eugenia* edaphic associations on reddish or grey clayey soils which are at some places micaceous and light. The associations regenerate themselves adequately.

The soils are deep at most places and are moist. The average pH value varies in a profile between 5.5 to 6.12. These soils are characterised by having low exchangeable calcium throughout the profile. The mean calcium figures in the profile range between 11 to 22.2 m.e. The mean loss on ignition of the soil is also low varying in the profile between 2% to 6%.

(ii) B_2 (*b*)1 *type* is a *sal* forest of C.P. II quality at Lamni and other places. This is an edaphic consociation showing a fairly good regeneration of *sal* on deep red soils that contain small amounts of coarse material and appear to be somewhat dry in comparison to (i). The mean pH range in the profile in this type is 5.4 to 6.3. The mean exchangeable calcium at different depth in the profile varies between 12.8 to 25.3 m.e. Organic matter content in the profile varies between 1.6% to 6.1%.

(iii) B_2 (*b*)2 *type* is a *Shorea-Anogeissus latifolia* community at Kota and Lamni ranges. The type is an unstable seral community, confined mainly to slightly black, dry and calcium-rich soils in *sal* forest. The regeneration of *sal is* appearing in this community showing that it may progress to a mixed *sal* association with probably a higher proportion of miscellaneous deciduous species. The mean pH value in this type is somewhat higher, varying in the profile between 6.1 to 6.4. The mean exchangeable calcium in this profile varies between 22 and 38.3 m.e. There is an increase in mean soil organic matter as well, which varies between 4.8 to 13.7%.

(iv) B_2 (*b*) 3 *type* is a mixed *sal*-Bamboo community at Muki on slightly black soils along banks of rivers. The type does not seem to be well defined, but is fairly stable since the regeneration of *sal* and other species is present in fair abundance. The mean pH values at different depths in the profile vary between 6.3 to 6.5. The mean exchangeable calcium at different depths in the profile varies between 20 and 32.3 m.e. The mean loss on ignition figures at different depths in the profile vary between 2.8% and 1.8%.

(v) *Champion's* B_2 (*a*) *type* is a mixed *sal* forest of C.P. III and IV quality occurring on red lateritic soils at Supkhar and other places. Although, the soil is red, it is rich in exchangeable calcium, having been derived from granite. It is dry, coarse, hard and shallow. The type seems to be stable regenerating itself adequately. The mean pH value for di-

fferent depths in the profile varies between 5.9 to 6.1. The exchangeable calcium at different depths in the profile varies between 26.9 to 47.4 m.e. The loss on ignition figures vary between 10.7% to 12.4%.

(vi) B_2 (*b*) 4 *type* is a pure *sal* community at Kanha. The part of this forest has become unstable due to the loss from the surface in erosion of less basic soil and the exposure of the underlying calcium-rich rocks. This type probably represents a post-climax *sal* community. The mean pH value at different depths in the profile varies between 6.1 and 6.37. The mean exchangeable calcium at different depths in the profile varies between 39.4 to 46.8 m.e. The percentage loss on ignition varies between 7.3% to 18.1%.

(vii) B_2 (*a*)1 *type* is a deciduous forest with little, or at places, no *sal* trees in the Karanjia range and in hilly portions of Motinala. The type seems to be an edaphic association in a mixed deciduous forest on dry black soil, which is very hard and compacted. The mean pH value at different depths in the profile varies between 6.23 to 6.27. The mean exchangeable calcium at different depths varies between 54 to 57.8 m.e. The mean loss on ignition in the profile varies between 11.6% to 14.9%.

Dry tropical forests. The dry tropical forests are formed by species which remain deciduous for greater part of the dry season. Most of the species occur in moist deciduous forest but they have much better development than in the dry deciduous type. The species are usually not particularly gregarious, though pure communities have been found as a result of human factor, or particular soil features. These are divided into southern and northern types.

Southern tropical dry deciduous forests: These are chiefly distributed in the peninsular India in areas either with low rainfall, or with dry soil conditions. The forest is formed by typically deciduous species which have a height of 50–70 ft. The canopy is uneven, formed of a large number of species and, although it becomes close it is not particularly dense. Deciduous species are present in the lower canopy as well, the few evergreen species are either found in moister localities, or are generally inconspicuous in the body of the forest. The undergrowth consists of a few shrubs and grassy growth, which becomes more prominent when burning is resorted to. Canes and palms are absent. Climbers are few, also epiphytes and ferns. In heavily disturbed areas the forest assumes the appearance of savannah or park like.

The floristic features of some of the typical types are given in table 56 and succession in these forests is given in table 57 on p. 195.

Northern tropical dry deciduous forests. These are chiefly distributed in Northern India except in too moist and too dry areas. These occur extensively in the Uttar Pradesh, Bihar and Orissa, and the Punjab and Bundelkhand. This forest is formed by trees of poor form and a height, rarely over 50 feet. The canopy is light and is formed entirely of deciduous trees. The undergrowth consists of a few shrubs which include some evergreen xerophytic species. Bamboo is an important feature in some subtypes but usually only one species occurs. Grass is present and is burnt off every year.

The floristic features of some of the typical types are given in table 58 on pp. 196–197.

Succession in northern tropical dry deciduous forests. The succession in these forests is given in table 59 on p. 198

Table 56.

SOUTHERN TROPICAL DRY DECIDUOUS FORESTS.

(After Champion).

Sub-type and distribution.	I	II	III	IV
C1. Dry teak forest. In South India extending a few degrees north of the tropic.				
(i) Taloda Range, Satpura hills, N. Khandesh division. Bombay.	*Tectona grandis, Ougeinia dalbergioides, Dalbergia latifolia, Acacia catechu, Pterocarpus marsupium, Stephegyne parvifolia,* etc.	III a. *Dendrocalamus strictus,*		
(ii) Dharwar Taluka, Dalghati and Hangal Bankapur, N. & E. Kanara division.	*Dillenia pentagyna, Kydia calycina, Terminalia* spp., *Lagerstroemia lanceolata, Adina cordifolia, Tectona grandis,* etc.	III a. *Dendrocalamus strictus, Bambusa arundinacea.*	*Lantana. Santalum album.*	
(iii) Madras dry deciduous teak bearing forest.	*Terminalia tomentosa, T. bellerica, T. chebula, Anogeissus latifolia, Pterocarpus marsupium, Tectona grandis.* etc.	II a. *Dendrocalamus strictus.*	III a. Grass usually heavy.	
(iv) Seoni division, Madhya Pradesh.	*Tectona grandis* (40%). *Terminalia tomentosa, Diospyros melanoxylon, Anogeissus latifolia,* etc.	II a. *Dendrocalamus strictus.*	*Indigofera pulchella. Flemingia* spp.	*Milletia auriculata.*
(v) Tenduchua, N. Raipur division, M.P.	*Tectona grandis* (20–90%), *Terminalia tomentosa, Diospyros melanoxylon, Anogeissus latifolia,* etc.		*Helicteres isora, Strobilanthes* sp., etc.	*Bauhinia vahlii.*
C2. South Indian dry deciduous forest, throughout Peninsular India.				
(i) Dharwar and Kod Ranges, Dharwar Division, N. Kanara.	*Acacia catechu, Anogeissus latifolia, Terminalia tomentosa, Soymida febrifuga, Chloroxylon swietenia,* etc.		*Lantana.* III a. Fairly good growth of grass.	
(ii) Bhamburda, near Poona, Bombay.	*Boswellia serrata, Acacia leucophlaea, Bauhinia, Rhus mysorensis,* etc.		III a. *Andropogon annulatus, A. monticola, Panicum, Andropogon contortus,* etc.	*Dichanthium annulatum, Iseilema anthephoroides,* etc.

Table 56 (Contd.)

Sub-type and distribution	I	II	III	IV
(iii) C. Salem division, Madras.	*Shorea talura, Dalbergia latifolia, Terminalia tomentosa, T. chebula, T. paniculata, Pterocarpus marsupium,* etc.	II a. *Dendrocalamus strictus.*	III a. Good deal of grass.	
(iv) Cuddalore, S. Kurnool division, Madras.	*Anogeissus latifolia, Cleistanthus collinus, Terminalia tomentosa, Pterocarpus marsupium, P. santalinus, Hardwickia binata, Tectona grandis.*	II a. *Dendrocalamus strictus.*	III a. Heavy grass growth.	
(v) Anantapur Division, Madras.	*Hardwickia binata, Anogeissus latifolia, Chloroxylon swietenia, Erythroxylon monogynum, Acacia sundra,* etc.			
(vi) S. Cuddapah, Madras.	*Terminalia pallida, Shorea talura, Eugenia alternifolia,* etc.		*Phoenix acaulis,* Heavy grass.	
(vii) Bhandara division, Madhya Pradesh.	*Terminalia tomentosa, Cleistanthus collinus, Lagerstroemia parviflora, Soymida febrifuga, Anogeissus latifolia, Chloroxylon swietenia, Aegle marmelos, Phyllanthus emblica, Acacia catechu,* etc.	II a. *Dendrocalamus strictus.*	*Gardenia lucida, G. turgida, Gymnosporia montana Ixora parviflora, Nyctanthes arbortristis, Woodfordia floribunda,* etc. III a. *Heteropogon contortus, Anthistiria,* etc.	Climbers few, *Zizyphus oenoplia, Acacia pennata, Bauhinia vahlii,*
(viii) Chirodi,	*Terminalia tomentosa, Bauhinia racemosa, Acacia arabica, Acacia catechu,* etc.	II a. *Gymnosporia montana, Zizyphus jujuba, Z. xylopyrus, Morinda tinctoria.*	*Mimosa hamata, Terminalia tomentosa.* III a. *Andropogon contortus.*	
(ix) Anthargauge sample plot, Bhadravati division, Mysore.	*Anogeissus latifolia, Terminalia chebula, Lagerstroemia parviflora, Terminalia crenulata, T. paniculata, T. bellerica,* etc.	*Zizyphus xylopyrus, Randia dumetorum, Bauhinia racemosa, Phyllanthus emblica, Gardenia latifolia,* etc. II a. *Dendrocalamus strictus.*	*Holarrhena, Gardenia turgida, Randia uliginosa, Ixora parviflora, Gardenia gummifera.* III a. complete cover of short grass with some *Aristida.*	*Zizyphus oenoplia, Acacia intsia, Celastrus paniculata.*
C4. Red Sanders forest Kurnool, Chittoor and Nellore division of Madras.				
(i) Bhimgava bhama, S. Cuddapah division.	*Pterocarpus santalinus, Anogeissus latifolia, Hardwickia binata, Terminalia chebula.*	*Chloroxylon swietenia, Randia dumetorum, Dolichandrone, Gardenia latifolia.*	*Grewia* sp.	*Andropogon* spp., *Heteropogon contortus.*

Table 57.

SCHEME OF SUCCESSION OF FOREST COMMUNITIES IN SOUTHERN TROPICAL DRY DECIDUOUS FORESTS

(After Champion).

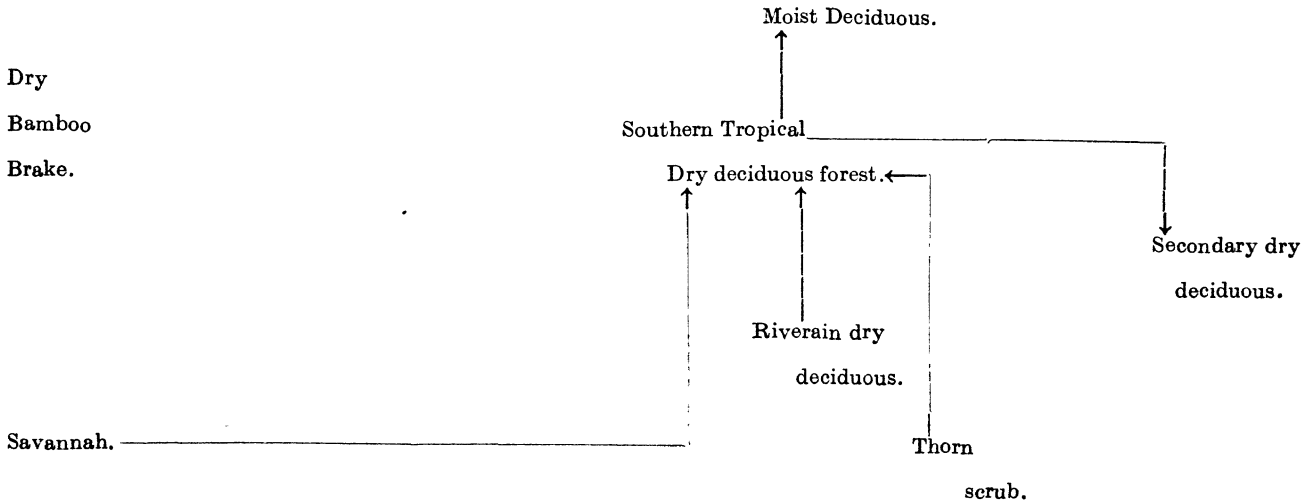


Table 58.

GROUP 4B NORTHERN TROPICAL DRY DECIDUOUS FORESTS.

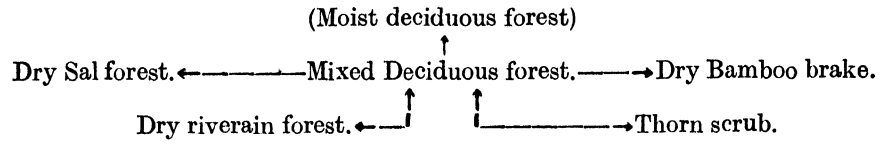
Sub-type and distribution.	I	II	III	IV
C1. Northern dry mixed deciduous forest. Throughout Northern India except in eastern parts which are too moist and in western parts which are too dry.				
(i) Kangra division Punjab.	*Acacia catechu, Anogeissus latifolia, Lannea grandis, Aegle marmelos, Limonia acidissima, Ehretia laevis, Kydia calycina, Ougeinia dalbergioides, Stephegyne parvifolia, Flacourtia ramontchii.*	*Mallotus philippinensis, Nyctanthes arbor-tristis, Cassia fistula.* II a. *Dendrocalamus strictus.*	*Carissa spinarum, Dodonaea viscosa, Woodfordia floribunda, Adhatoda vasica. Zizyphus.*	*Pueraria tuberosa, Bauhinia vahlii, Acacia caesia,* grasses.
(ii) Saharanpur Siwaliks.	*Anogeissus latifolia, Acacia catechu, Buchanania latifolia, Terminalia tomentosa, Bauhinia variegata, Kydia calycina, Shorea robusta, Sterculia pallens, Boswellia serrata.*	*Phyllanthus emblica, Grewia vestita, Ougeinia dalbergioides, Nyctanthes arbor-tristis,* II a. *Dendrocalamus strictus.*	*Woodfordia floribunda, Indigofera pulchella.* III a. *Heteropogon contortus, Ischaemum angustifolium.*	*Bauhinia vahlii.*
(iii) 'Plains forest' Saharanpur division.	*Stereospermum suaveolens, Bombax malabaricum, Erythrina suberosa,* etc.	*Holarrhena antidysenterica. Casearia tomentosa, Ehretia laevis, Miliusa velutina. Mallotus philippinensis.*	*Adhatoda vasica, Helicteres isora.*	
(iv) Sambalpur West division Orissa.	*Terminalia tomentosa. Anogeissus latifolia, Diospyros melanoxylon, Cleistanthus collinus, Adina cordifolia,* etc.	*Chloroxylon swietenia, Phyllanthus emblica, Gardenia latifolia,* II a. *Dendrocalamus strictus.*	*Gardenia.* III a. *Aristida setacea, Andropogon* spp., *Cymbopogon martini.*	

Table 58 (Contd.)

Sub-type and distribution.	I	II	III	IV
(v) Lalitpur, Jhansi division, (U.P.)	*Lannea grandis, Boswellia serrata, Terminalia tomentosa, Diospyros melanoxylon, Anogeissus latifolia*, etc.	II a. *Dendrocalamus strictus.*	*Nyctanthes arbor-tristis, Fluggea microcarpa, Zizyphus jujuba, Carissa spinarum*, etc.	*Heteropogon contortus, Ischaemum laxum, Anthistiria ciliata.*
(vi) Biguri, S. Raipur division, (M.P.)	*Terminalia tomentosa, Anogeissus latifolia. Diospyros melanoxylon, Buchanania latifolia, Terminalia chebula*, etc.	*Phyllanthus emblica, Zizyphus.*	*Phoenix acaulis, Woodfordia floribunda.*	
C2. Dry Sal forests. Usually in the Punjab, in the U.P. both in the Siwalik hills and on the gangetic alluvium, and in the hilly tracts of Orissa and Madhya Pradesh.				
(i) Saharanpur Siwaliks (U.P.)	*Shorea robusta, Anogeissus latifolia, Terminalia tomentosa, Bauhinia variegata, Acacia* spp., *Pinus longifolia.*	*Phyllanthus emblica, Ougeinia dalbergioides, Cassia fistula.* II a. *Dendrocalamus strictus.*	*Woodfordia floribunda, Indigofera pulchella, Colebrookea oppositifolia,* III a. *Ischaemum angustifolium, Heteropogon controtus.*	
(ii) Motipur Bahraich division (U.P.)	*Shorea robusta, Adina cordifolia, Lannea grandis, Diospyros tomentosa, Acacia catechu, Aegle marmelos.*	*Limonia acidissima.*		
(iii) West Sambalpur Orissa.	*Shorea robusta, Terminalia tomentosa, Pterocarpus marsupium, Anogeissus latifolia*, etc.,	*Cleistanthus collinus, Chloroxylon swietenia, Phyllanthus emblica, Cassia fistula*, etc. II a. *Dendrocalamus strictus.*	*Indigofera pulchella.*	
(iv) South Raipur division Madhya Pradesh.	*Shorea robusta, Terminalia tomentosa, Pterocarpus marsupium, Boswellia serrata*, etc.	*Buchanania latifolia, Diospyros melanoxylon, Terminalia chebula, Phyllanthus emblica*, etc.	*Woodfordia floribunda, Indigofera pulchella, Wendlandia* sp., etc.	

Table 59.

SCHEME OF SUCCESSION IN NORTHERN TROPICAL DRY DECIDUOUS FORESTS.



The status of tropical dry deciduous forests is not quite clear. It includes communities which are clearly riverain and edaphic-controlled. Other communities owe their composition and physiognomy to erosion and biotic interference. The thorn scrub is undoubtedly biotic in origin. But since enough work has not been conducted, it has been considered advisable at present to retain the description of Champion.

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10

MONTANE SUB-TROPICAL FORESTS

Sub-tropical forests represent more or less an intermediate zone with characteristic species of both the tropical and temperate forests. Although, there is no marked zonal differentiation of these types a transitional zone with mixed vegetation of both the types is seen. These are divided into Southern, Northern, Pine and dry evergreen types.

Southern Sub-tropical wet hill forests: These are chiefly distributed in south India and are most extensive in the Nilgiri and Palni hills between 3,000 ft. and 5,000 ft. These forests also occur to a fair extent at Mahableshwar, Bhimashankar, Matheran area in Bombay and Pachmarhi in Madhya Pradesh. These types are restricted to hilly districts and are composed of a mixture of wet evergreen and temperate species. The characteristic species are *Eugenia* and *Memecylon*. Melastomaceae and Lauraceae also occur generally.

A summary of floristic data of the type is given in table 60 after Champion.

Sub-tropical forests at Mahabaleshwar. The evergreen forest belt which extends from the south to the north, terminates near Mahableshwar (Photo 81) and in the valleys of the Western Ghats. A few isolated patches are present at Bhimashankar, Matheran, etc. This belt is found extensively at the Mahabaleshwar Plateau and the valleys of the river Koyna, Krishna, etc.

In these forests, many trees attain the heights varying from 5 to 6 metres, and upto 15 metres. The canopy is dense. Under the canopy mostly Cryptogamic flora is seen, while herbs and shrubs are found in openings and on outskirts.

The Mahabaleshwar evergreen forests are mainly a community of *Eugenia jambolana - Memecylon umbellatum* (Photo 82). Here along with the dominant trees *Actinodaphne hookeri* is associated, the other tree species being *Randia dumetorum, Glochidion hohenackeri, Olea dioica, Terminalia chebula,* etc.

In the *Eugenia - Terminalia - Memecylon* community, *Terminalia chebula* is dominant. The other tree species are: *Olea dioica, Bridelia retusa, Mangifera indica, Symplocos beddomei, Canthium umbellatum, Elaeagnus latifolia,* etc.

In the *Eugenia - Memecylon - Randia* community, *Randia dumetorum* is most abundant.

The second storey plants are found on outskirts or in the openings. The most dominant amongst these is *Carvia callosa,* which forms thickets on red clay. The other species are *Allophyllus cobbe, Atylosia lineata, Colebrookea oppositifolia, Crotalaria retusa, Gymnosporia rothiana, Indigofera pulchella, Murraya koenigii, Pavetta indica,* etc. A view of undergrowth in dense part of the forest is shown in photo 83.

Amongst the climbers, the following are common :– *Piper hookeri, Piper trichostachyon, Clematis wightiana, Rosa multiflora, Smilax macrophylla,* etc.

Table 60.

SOUTHERN SUB-TROPICAL WET HILL FORESTS

(After Champion).

Sub-type and distribution.	I	II	III	IV
1. Bombay sub-tropical evergreen forest. Above about 3,000 feet. in the northern part of W. ghats in Bombay.				
(i) Mahableshwar.	*Eugenia jambolana, Actinodaphne hookeri, Canthium umbellatum, Memecylon edule, Flacourtia remontchi, Terminalia chebula, divica Olea cusp data,* Lauraceae.		*Scutia indica, Strobilanthes callosus.*	*Elaeagnus latifolia, Jasminum arborescens.*
(ii) Matheran Plateau, Kolaba division, Bombay.	*Memecylon edule, Eugenia heyneana, E. jambolana, Sideroxylon tomentosum, Glycosmis pentaphylla, Ixora parviflora, Randia dumetorum,* etc.	II a. Bamboo (rare)	*Woodfordia floribunda, Strobilanthes callosus, Pavetta indica, Lasiosiphon eriocephalus,* etc.	Climbers prominant.
2. Central Indian sub-tropical evergreen forest.				
(i) Parasnath, Chhota Nagpur, Bihar.	*Pterospermum acerifolium.*	*Phoenix* sp.	*Osbeckia* sp. *Berberis asiatica, Indigofera.* III a. *Kalanchoe, Begonia* spp. Coarse grass	*Clematis nutans.*

The regeneration of *Terminalia chebula, Eugenia jambolana, Memecylon umbellatum, Randia dumetorum, Actinodaphne hookeri, Artocarpus hirsuta* is common.

Amongst the ground flora, grasses like *Apluda varia, Arundinella spicata,* etc. are common while the herbs *Leucas stelligera, Impatiens balsamina, Blepharis asperrima, Achyranthes aspera, Cheilanthus farinosa, Cynoglossum denticulatum, Rungia parviflora,* etc. are common.

The ferns are of a common occurrence in these forests. The chief amongst them are *Pteris aquilina, Pteris quadriaurita., Pleopeltis linearis, Nephrodium cicutarium.*

These are found mostly under shade. Mosses cover branches and hang in tassels about almost 1/3rd metre long.

Sub-tropical forests of Bhimashankar The Bhimashankar-Junnar area forests constitute a patch of evergreen belt continuing from the south upwards (Photo 84). These were studied by Puri and Vasvada (1957) recently.

In these forests, many trees reach the height of about 30–35 meters. The canopy is dense and under the shade of the trees the undergrowth is meagre. Under the canopy mostly ferns are seen while shrubs and herbs grow on the outskirts, or in openings. Orchids do not grow profusely on the trees where the growth is dense.

These forests are mostly a community of *Eugenia jambolana*— (Photo 85) *Memecylon umbellatum* (Photo 86), with *Magnifera indica* Linn. as a secondary tree. The other common tree species are *Mallotus philippinensis., Actinodaphne hookeri, Atalantia racemosa, Cassia fistula, Embelia robusta, Ficus arnottiana Randia dumetorum, Sideroxylon tomentosum, Symplocos beddomei, Elaeagnus latifolia* etc. Species like *Canthium umbellatum, Bridelia retusa, Ficus religiosa, Ficus glomerata, Pittosporum floribundum,* etc. are found sprinkled here and there. The forests at Mahableshwar (Puri and Mahajan, 1957) are also similar to this area.

The second storey plants are found either on outskirts of the forest or in openings. The most dominant amongst the shrubs is *Carvia callosa* (Photos 87, 88), which forms thickets and grows so profusely that it becomes almost difficult to penetrate through its growth. The other species are *Acacia concinna., Grewia laevigata, Celastrus paniculata, Gymnosporia rothiana. Leea sambucina, Murraya koenigii, Pavetta indica, Callicarpa lanata. Celastrus* and *Gymnosporia, Leea* and *Murraya* are found to be quite common.

The climbing plants are not many. Some of the commonest plants are *Cyclea burmanni, Gnetum scandens, Piper trichostachyon., Smilax macrophylla* and *Vitis elongata.* Of these *Piper trichostachyon* is the commonest and is found everywhere.

In these forests regeneration of species like *Eugenia jambolana, Memecylon umbellatum, Mallotus philippinensis, Mangifera indica, Murraya koenigii* is going on without interference.

Amongst the ground flora, the commonest species are *Curcuma pseudomontana* (Photo 89), *Gerardinia zeylanica. Cynoglossum denticulatum* (Photo 90), *Heracleum concanense, Impatiens balsamina, Pimpinella heyneana, Plumbago zeylanica., Solanum indicum,* etc. Of these, except *Cynoglossum* almost all are found growing on the edge of the forest.

The ferns are either epiphytic (Photo 91) or terrestrial. Of the epiphytic species *Pleopeltis linearis* is the commonest; while *Aspidium* sp. is prominant of the terrestrial ferns. These are mostly found under shade. Mosses cover the branches completely and hang in tassels about 6" – 8" in length. Epiphytic orchids are also common in these forests.

Sub-tropical forests of Coorg: Rangaswami (1941) mentioned that some of the eastern deciduous forests of Coorg which range between 2,600 ft. to 4,077. ft and where fellings were not heavy contain teak in gregarious patches with an admixture of *Terminalia tomentosa, Pterocarpus marsupium, Lagerstroemia lanceolata, Anogeissus latifolia, Kydia calycina, Stereospermum* sp., *Schleichera trijuga, Stephegyne parvifolia, Saccopetalum tomentosum, Dalbergia paniculata, Garuga pinnata,* etc. *Lantana* and *Curcuma* form the main undergrowth throughout the area and some of the woody shrubs are *Desmodium pulchellum, Helicteris isora* and *Cipadessa fruticosa.*

Sub-tropical evergreen forests of Central India. 1. Parasnath hills - The tree vegetation comprises of *Pterospermum acerifolium* in which a number of shrubs are present.

While describing the flora of Behar and the mountain Parasnath, Anderson (1863) mentioned that from 4,000 feet to the summit, a few species representatives of the sub-tropical vegetation are found. These species are *Clematis gouriana, C. nutans, Thalictrum glyphocarpum, Berberis asiatica, Geranium nepalense, Pygeum lucidum, Rubia cordifolia, Buchnera hispida, Habenaria plantaginea, H. commelinifolia.* At about 4,000 feet three species of *Aralia* appear, but they are confined to the cool, dark ravines.

2. **Bailadila range in Bastar State.** Mooney (1942) described the following types of vegetation at different sites in the Bailadila Range of the Bastar State.

Lepidagathis - Anaphalis - Coleus associes occurring between 3,000 and 4,200 feet on the upper slopes and crest of the range, which is rocky open and windswept. The few trees and shrubs that survive are *Emblica officinalis, Rhus paniculata, Glochidion velutinum, Ochna squarrosa, Terminalia* sp., *Xylia xylocarpa, Breynia patens, Pogostemon plectranthoides,* etc. Some of the more characteristic undershrubs and herbs are *Anaphalis adnata, Coleus forskohlii, Conyza stricta, Buettneria herbacea, Euphorbia elegans, Leucas montana, Micromeria biflora, Phaseolus sublobatus, Vicoa* sp., *Swertia angustifolia,* etc.

Dillenia - Phoenix humilis - Pteridium aquilinum associes found on the grassy slopes of the central valleys between 3,000 and 3,700 feet. *Phoenix humilis* is the extremely characteristic species.

Tree vegetation is not abundant and comprises of *Emblica officinalis, Glochidion velutinum, Terminalia* sp., *Rhus paniculata, Dillenia pentagyna, Kydia calycina, Linociera intermedia,* etc. Among the shrubs the most typical are *Cajanus indicus, Crotalaria umbellata, Desmodium* sp., *Flemingia* sp., *Osbeckia chinensis, Tephrosia tinctoria,* etc. The characteristic ground flora species are *Arisaema tortuosum, Commelina obliqua, Conyza* sp., *Cyanotis* sp., *Evolvulus alsinoides, Habenaria diphylla, Justicia* sp., *Leucas montana,, Rungia parviflora, Swertia angustifolia,* etc. There is a great variety of grasses in the community.

Gymnosporia - Glycosmis - Ochna associes are found in small copses and thickets on slopes in central valleys. The only plants attaining tree size are *Dillenia pentagyna, Kydia calycina, Sterculia villosa* and *Terminalia* sp. Among the shrubs the conspicuous are *Alstonia venenatus, Gymnosporia* sp., *Glycosmis cochinchinensis, Ochna squarrosa,* etc.

Memecylon - Strobilanthes association occurring in moist glens between about 3,400 and 3,700 feet. The vegetation is homogenous and the typical tree species are *Eurya japonica, Gymnosporia bailadilana, Memecylon edule, M. madgolense,* and *Glycosmis cochinchinensis. Strobilathes heyneanus* often forms an extensive gregarious society. Ground flora is

generally sparse and the main species are *Adenostemma viscosa, Achyranthes bidentata* and *Ophiorrhiza fasciculata.*

Crallia - Calamus - Cyathea association forms a narrow fringing belt of forest in the northern valley and closed forest in the southern valley. The more characteristic species in this community are *Albizzia* sp., *Antidesma* sp., *Argostemma* sp., *Carallia integerrima, Clematis* sp., *Calamus* sp., *Embelia ribes, Glochidion* sp., *Litsaea* sp. *Machilus macrantha, Memecylon* sp., *Ophiorrohiza fasciculata, O. hirsutula, Pittosporum floribundum, Strobilanthes* sp., *Symplocos spicata, Wendlandia glabrata,* etc. Several ferns also occur in this association.

3. **Kalahandi State.** In the flora of Kalahandi State, Mooney (1941) mentioned that ravines between 2,500 and 3,500 feet are covered over by certain characteristic species, such as *Actinodaphne angustifolia, Ardisia* sp., *Barleria strigosa, Calamus* sp., *Clematis* sp., *Clerodendron infortunatum, Dicliptera bupleuroides, Elaeocarpus robustus, Ficus hispida, F. macrophylla, Leea* sp., *Machilus macrantha, Mallotus philippinensis, Michelia champaca, Pavetta indica, Pittosporum floribundum, Rubus* sp., *Strobilanthes* sp., *Thunbergia fragrans,* etc. Ferns are often very abundant in these ravines.

The most characteristic species of the upper slopes (3,000 - 3,500 ft.) are *Acacia canescens, Bauhinia variegata, B. vahlii, Aegle marmelos, Colebrookia oppositifolia, Dalbergia volubilis, Emblica officinalis, Grewia* sp., *Helectris isora, Mallotus philippinensis, Pittosporum floribundum, Rungia parviflora, Vernonia divergens, Woodfordia fruticosa, Zizyphus xylopyrus* and *Z. rugosa,* etc. Ferns are scarce.

A few of the more typical species of the hill tops, which range between 3,500 to 4,000 feet are *Bauhinia retusa, Careya arborea, Dillenia pentagyna, Ehretia laevis, Elaeodendron glaucum, Emblica officinalis, Flemingia congesta, Grewia tilaefolia, Gardenia* sp., *Pterospermum marsupium, Rubia cordifolia, Shorea robusta, Terminalia* sp., *Woodfordia fruticosa, Xylia xylocarpa, Zizyphus rugosa,* etc. Among the grasses *Arundinella setosa, Cymbopogon martini* and *Themeda triandra* are very abundant.

Northern sub-tropical wet hill forests. These are chiefly distributed in the East Himalayas on lower slopes and Assam hills nearly between 3,000 and 6,000 ft. These are formed mostly of evergreen species which are dominant. There also occur some deciduous trees. Growth of the trees depends upon the various conditions of soil and site. These may attain a height of 150 ft. under favourable conditions but usually between 70–100 ft. The canopy is not much dense and the middle storey is composed of medium sized trees. The undergrowth consists of shrubs and grass is not present. Bamboo may or may not be present. Epiphytes include shrubs and orchids, which may be numerous. Various climbers also occur in large number. Oaks and chestnuts prevail in this type and form an important part of the crop. *Alnus, Prunus, Betula* are also often seen. Another characteristic species of this type is *Schima.*

A summary of floristic data of the type is given in table 61 after Champion.

Sub-tropical forests of the Eastern Himalayas occur between 3,000 and 6,000 feet. The great majority of the trees are evergreen with *Castanopsis indica, Schima wallichii,* and *Engelhardtia* being the commonest species. Epiphytes are not so common as in the tropical zone. Cowan (1926) gives the following associations, consociations, etc. in these forests.

Table 61.

NORTHERN SUB-TROPICAL WET HILL FORESTS

(After Champion).

Sub-type and distribution	I	II	III
C1. Bengal sub-tropical hill forest. The lower slopes of the Himalayas in N. Bengal, the adjoining parts of Nepal and doubtless through Bhutan and the Niri, Abor and Mishmi hills of N. Assam.			
(i) Kalimpong division.	(i) *Castanopsis-Schima* forest.	*Boehmeria rugulosa*, *Ficus cunia*, etc.	
	(ii) *Schima-Castanopsis-Phoebe* forest.	*Eurya* sp., *Macaranga* spp., etc.	
	(iii) *Engelhardtia-Castanopsis-Schima-Betula* forest.	IIa. *Dendrocalamus sikkimensis.*	*Aechmanthera tomentosa*, *Lastrea*, *Maesa*, etc.
	(iv) *Ostodes paniculata* association.		

Associations

1. *Castanopsis - Schima* Hylium 2. *Schima - Castanopsis - Phoebe* Hylium (3) *Engelhardtia - Castanopsis - Schima - Betula* Hylium and (4) *Ostodes* Hylium.

Consociations

Alnus nepalensis D. Don. *Betula cylindrostachys* Wall.

Societies

Aechmanthera tomentosa Nees. *Lastrea dissecta* Forst.
Dichroa febrifuga Lour.
Dendrocalamus sikkimensis Gamble. *Neillia thyrsiflora* D. Don.
Plectocomia himalayana Griff.
Eurya japonica Thunb. *Reinwardtia trigyna* Planch.
Helicia erratica Hk. f. *Rhus semialata* Murr.

Middle hill forests of the Kalimpong forest division. Between the elevations of 2,500 and 4,000 feet the commonest species are *Castanopsis tribuloides, C. indica, Schima wallichii* and *Phoebe hainesiana.*

Between 4,000 and 5,500 feet, *Castanopsis tribuloides, Engelhardtia spicata, Betula alnoides, Cylindrostachys* and *Alnus nepalensis* are plentiful. In localities with a heavy rainfall the principal species are *Ostodes paniculatus, Machilus gammieana, Schima wallichii, Phoebe hainesiana, Beilschmiedia sikkimensis,* etc. Much of the area contains small trees such as *Eurya japonica, Symplocos theaefolia,* etc. but the undergrowth proper is mainly herbaceous, containing a large proportion of *Rubus* sp., *Viburnum* sp., *Strobilanthes* sp., ferns and bamboos.

Darjeeling Hills forests. In the lower hill forests of the Darjeeling division ranging between 3,000 to 5,000 feet the principal species are *Alnus nepalensis, Phoebe* spp., *Bucklandia populnea, Engelhardtia* spp, *Cedrela febrifuga, Quercus, Castanopsis* spp., and *Schima wallichii.* The undergrowth is not usually heavy and consists of numerous herbaceaus and shrubby species.

Aka Hills forests in Assam. Bor (1938) described the following montane subtropical formations in the vegetation of the Aka hills, Assam.

Phoebe-Beilschmiedia-Engelhardtia formation. This is a high evergreen forest in which Lauraceous species predominate and very few dominants are buttressed. The underwood and undergrowth are also evergreen.

(i) *Phoebe - Beilschmiedia - Engelhardtia* hylium lies on the outer slopes of Piri in an area of high rainfall. The association is a high forest with a closed canopy. The dominants are *Phoebe paniculata, Phoebe attenuata, Beilschmiedia roxburghiana, Drimycarpus racemosus, Castanopsis tribuloides, Engelhardtia spicata, Nyssa sessiliflora, Schima wallichii,* etc. The second storey consists of *Hemicyclia venusta, Talauma hodgsoni, Helicia erratica, Cinnamomum obtusifolium, Sarcosperma arboreum, Jambosa kurzii, Gynocardia odorata,* etc. Among the shrubs are *Daphne involucrata, Popowia hookeri, Coffea khasiana, Glycosmis disciformis, Buliospermum corymbiferum, Strobilanthes* sp., etc, In the ground layer are found *Sonerila maculata, Ainsliaea pteropoda, Ophiorrhiza* spp,. *Impatiens* spp., *Chirita punila, Chirita urticaefolia,* etc.

Consociations are:—

Phoebe paniculata. *Phoebe attenuata.*
Castanopsis tribuloides. *Engelhardtia spicata.*
Quercus fenestrata.

Societies are:—

Eugenia kurzii.
Garcinia paniculata.
Arundinaria griffithiana.
Gynocardia odorata.
Pandanus furcatus.
Capparis multiflora
Elatostema spp.,
Baliospermum corymbiferum.
Impatiens stenantha.
I. jurpia.
I. radiata.
Hemicyclia venusta.
Dendrocalamus ptellaris.
Helicia erratica.
Calophyllum polyanthum.
Dichroa febrifuga.
Lastraea dissecta.
Popowia hookeri.
Ainsliaea pteropoda.
Aneilema thomsoni.
Cyanotis cristata.
Calamus flagellum.
Plectocomia himalayana.

(ii) *Populus-Alnus* hylis. is found in the Dunup Ko valley and Pankim La valley near Shergya. In this, the dominant trees are *Populus ciliata* and *Alnus nitida.* Associates with these are *Fraxinus floribunda, Schima khasiana, Prunus nepalensis, Albizzia julibrissin, Machilus edulis,* etc. Small trees and shrubs includes *Pentapanax leschenaultii, Photinia notonina, Corylopsis himalayana, Pittosporum floribundum,* etc.

Consocies are:—

Populus ciliata
Alnus nepalensis.
Pinus excelsa.

Socies are:—

Rhododendron arboreum.
Deutzia corymbosa.
Strobilanthes sp.
Ardisia membranacea.
Girardinia heterophylla.
Capillipedium assimile.
Lomaria glauca.
Pogonatherum paniceum.
Andromeda elliptica.
Rubus lineatus.
Barleria cristata.
Urtica parvifolia.
Valeriana hardwickii.
Woodwardia radicans.
Onychium japonicum.

Sub-tropical pine forests. These are chiefly distributed in Western and Central Himalayas between 3,000 and 6,000 feet. Pine forest of *Pinus khasya* occurs in the Khasi, Naga and Manipur hills at similar altitudes. This type consists of a typical pure association of pine which may be influenced by the periodic fires that take place. The canopy is composed of all pine, generally *Pinus roxburghii* and there may not occur any other tree species. Underwood is absent and shrubs are few. *Quercus* and other broad leaved species come in when the community develops further. With the rising altitude pine is seen on the warmer and drier ridges and trees of evergreen species increase in number. Soil cover is usually grassy and a number of herbs that flower in the rainy season are met with. Bamboos and climbers are not present.

A summary of floristic date of the type from a few localities is given in table 62.

Mussoorie pine forests. In the Mussoorie Himalayas small patches of *Pinus roxburghii* occur in Badraj and Banog blocks on quartzite and there is a larger patch of this community in Koeti Kimoin block, compartment 3 on a quartzite slope. These patches of chir have very little woody undergrowth except sometimes a little small scattered *Quercus incana*; the ground being typically grassy (Puri, 1957).

At Landour chir pine only occupies the lower slopes upto an altitude of 6,700 feet and then on the spurs and on slopes with a southerly aspect. At its upper limits it mingles with the oak. Elsewhere it is typically pure chir forest with little shrubby undergrowth.

Table 62.

SUB-TROPICAL PINE FOREST

(After Champion).

Sub-type and distribution.	I	II	III
C1. Himalayan sub-tropical forest. Himalayan pine from Bhutan westwards, from 3,000' to 6,000'.			
(i) Garkhet, W. Almora division, U.P., 4500'.	*Pinus roxburghii.*	*Ficus roxburghii, Eugenia jambolana, Engelhardtia colebrookeana, Terminalia chebula.*	*Indigofera pulchella, Inula cappa, Plectranthus ternifolius. Glochidion velutinum* etc., III a. *Andropogon contortus, A. micranthus, Pollinia hirtifolia,* etc.
(ii) Maarpali, W. Almora division. U.P. 5,000 feet.	*Pinus roxburghii.*	*Ficus roxburghii, Eugenia jambolana, Engelhardtia colebrookeana, Pieris ovalifolia, Quercus incana, Rhododendron arboreum, Symplocos crataegoides, Myrica nagi.*	*Indigofera dosua, Flemingia, Lespedeza sericea, Rubus ellipticus, Viburnum coriaceum,* etc. III a. *Teucrium quadrifarium, Pedicularis carinosa, Anaphalis araneosa, Pouzolzia hirta,* etc. III b. *Andropogon contortus, A. micranthus, Arundinella brasiliensis, Pollinia hirtifolia,* etc.
(iii) Kaligad, W. Almora division U.P. 6,000	*Pinus roxburghii.*	*Quercus incana, Pieris ovalifolia, Rhododendron arboreum, Pyrus pashia, Myrica rubra, Crataegus crenulata, Symplocos crataegoides, Coriaria nepalensis.*	*Indigofera dosua, Myrsine africana, Inula cappa, Leptodermis lanceolata, Berberis lycium* etc. III a. *Plectranthus strictus, Anaphalis* sp., *Galium* sp., etc. III b. *Pollinia mollis, Arundinella brasiliensis, Agrostis alba, Andropogon micranthus, A. contortus,* etc.
(iv) Kangra, Punjab 3,000-3,500 feet.	*Pinus roxburghii.*	*Pyrus pashia, Quercus incana, Rhododendron arboreum, Pieris ovalifolia, Mallotus philippinensis, Albizzia stipulata.*	*Carissa spinarum, Dodonaea viscosa, Woodfordia floribunda, Indigofera* spp., *Rhamnus triqueter, Casearia tomentosa.*
C2. Assam Pine forest. Khasi and Naga hills of Assam and Manipur.			
(i) Khasi hills.	*Pinus Khasya.*	*Quercus griffithii, Q. fenestrata, Acer oblongum, Magnolia compbelli, Lindera latifolia, Prunus acuminata, P. nepalensis, Schima wallichii,* etc.	*Rubus lasiocarpus, R. rubra, R. paniculatus, R. moluccancus, Viburnum foetidum, V. coriaceum, Myrsine semiserrata,* etc.

Natural regeneration of chir is almost entirely absent except on the quartzite or in disturbed areas.

Chir pine forests of Kangra, Hoshiarpur and Mandi. *Pinus roxburghii* occurs on quartzite, sandstone and conglomerates in the area. It also occurs on schists in the Himalayas where *Quercus incana* community has been destroyed. Chir pine is characteristic of dry newly disturbed soils. In a recent study (Mohan and Puri, 1956) the following types have been recognized from the above areas:—

1. Chir - *Carissa* - grass type with *Terminala chebula, Lannea grandis, Albizzia stipulata, Cedrela toona. Eugenia jambolana* and *Phyllanthus emblica* sometimes present.

2. Chir - *Carissa* - *Indigofera* - grass type. In places with better thickness of alluvium plants of *Bombax, Mallotus, Machilus, Grewia, Ficus, Cedrela, Albizzia, Pieris* and *Engelhardtia* are present. Among the bushes *Berberis, Rubus,* and *Asparagus* are found.

3. Chirpine - *Quercus incana* type with *Berberis, Cotoneaster, Myrsine* and grass as undergrowth.

4. Chir - *Acacia* - grass type with *Mallotus, Odina, Bombax, Aegle. Limonia, Zizyphus, Carissa* and *Murraya* generally present.

5. Mixed chir pine community with *Wendlandia, Mallotus, Phyllanthus, Rhamnus* and shrubs of *Dodonaea, Carissa, Woodfordia* and *Prinsepia,* etc.

6. Open chir pine community mixed with *Mimosa, Carissa, Flacourtia,* grass and here and there plants of *Phyllanthus, Diospyros.* Regeneration of chir is also present here and there.

These six communities are sub-division of Mohan's (1933) three following management types.

(i) *Acacia* - *Zizyphus* type.

(ii) *Carissa* - *Dodonaea* type.

The presence of *Dodonaea* in this type is almost invariably due to the thinness and poverty of the soil caused by fires.

(iii) *Berberis* - *Myrsine* type. The little *Carissa* that may be met in this type is the result of overgrazing and/or light fire.

Chir pine community of Garhwal Himalayas. In the Garhwal Himalayas Osmaston described *Shorea-Anogeissus* - *Pinus* formation which is restricted to the moist zone and ranges upto the height of about 6,500 feet. The rainfall is less than the temperate zone. Temperature is higher throughout the year which makes the soil drier. Fire takes place almost annually. Humus is not found as a distinct layer from the soil.

The vegetation of this formation is xerophytic rather than mesophytic.

Dudgeon and Kenoyer (1925) recognize from Tehri-Garhwal Himalayas the following communities in the moonsoon forests.

(i) *Shorea robusta* forests at 1,000 to 2,500 ft. These are climatic climax.

(ii) Upper Monsoon forests at 2,000 to 5,000 ft. dominated by *Bauhinias.*

(iii) *Pinus roxburghii* at 3,500 to 6,500 ft. These are edaphic climax.

Pinus Khasya forests of Assam. In the Shillong plateau Assam, *Pinus khashya* covers large areas of Khasi Hills, Naga Hills, Manipur, Lushai Hills and also of Shan states, Upper Burma.

The upper limit of *Pinus khasya* is the top of Shillong Peak, 6,400 ft. It does well between 4,000 and 4,500 feet. The seed germinates freely on well aerated soil.

On the slopes of Saramethi, Assam, Burmese border, at an altitude of 5,000 feet, are to be found very large specimens of *P. khasya* growing in evergreen forest.

The pine forests are extremely pure (photo 99); following are the chief associates of the pine:—

Quercus fenestrata, Ilex excelsa, Myrica nagi, Daphniphyllum himalayense, Rhus semialata, Camellia japonica, Cinnamomum impressinervium, Machilus odoratissima, Euonymus grandiflorous, Lindera pulcherrima, Myrsine semiserrata, Phyllanthus glaucus, Prunus puddum, Pentapanax subcordatum, Ternstroemia japonica, Chloranthus brachystachys, Toddalia aculeata, Inula cappa, etc. All these species are of evergreen forest which is the result of fire protection.

Sub-tropical dry evergreen forests. The type occurs in the foot hill zone of Himalayas in the Punjab, Kashmir and adjoining areas. Coventry (1929) has studied the vegetation of the Punjab and distinguished the following type.

(i) Phulai forests (*Acacia modesta*).

(ii) Brushwood forests of Sanatha (*Dodonaea viscosa*).

(iii) Mixed forests of numerous hard-wood species (associate formations).

(iv) Olive or kao forests (*Olea cuspidata*).

The first two types are pioneer establishing themselves on open, exposed mineral soil. The climax according to him are the Olive forests, the mixed forests forming the intermediate stages between the two extreme types. The types are mainly occurring in Punjab, Pakistan. Their present state is due to the intense biotic factor of grazing and fire.

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11

EDAPHIC FORESTS OF INDIA

Edaphic controlled forest communities are well represented in this country. The main soil factor for the development of vegetation in India is the moisture content though minerals and plant foods, like nitrogen and phosphorus are also important. The edaphic types whose existence is due to the presence of water are riparian, riverain, mangroves, swamps, etc.

In the Himalayan regions of sedimentary rocks the availability of water in the habitat is greatly influenced by the structure of the formation which also determines configuration, aspect, etc. The nature of the underlying rock and soil, therefore, determines a number of edaphic types.

The composition of the soil assumes greater importance for the development of vegetation in the plains area also and a number of edaphic types are recognised according to types of soils.

The main edaphic types are described below:—

Riverain forests of India: Riverain forests form distinct communities in main climatic types, viz., tropical, sub-tropical and temperate forest formations. These are edaphic-controlled seral stages preserved in their present condition, more or less premanenlty, by their peculiar habitats. Main types of riverain forests are described below:—

(A) PLAINS OF THE GANGES AND BRAHMAPUTRA

(i) **Moist tropical.**

1. **Moist riparian forest consisting of** *Lagerstroemia* and *Terminalia* is distributed along all the larger rivers on new alluvium. Soil is typically sandy; it may be silty but is rarely clayey. It is normally well drained and liable to erosion and flooding. The trees are usually sub-evergreen but evergreen or deciduous types are also present. The type is maintained by constant erosion and redeposition of soil by river action. It differs from other riverain forests in being the pioneer stage, occupying well drained sites.

2. **Gangetic tropical moist deciduous riverain forests** are chiefly distributed in the moister parts of the Gangetic plain, mainly the sub-Himalayan tract of Uttar Pradesh and Bihar. The community is a mixed high forest in which the constituent species may occur in small groups, but rarely form a pure crop of any extent. This type occurs on the higher and more stable alluvial terraces where the soil is porous, with a high water level. In this type grass is sparse or absent in the moister parts where the vegetation cover is dense and shrubs and ferns predominate. There are a few climbers and bamboos occurring locally.

3. **Upper Assam moist deciduous Riverain forest** is distributed in Assam and S. Bengal along the larger streams, mainly on alluvial flats, where the soil is poorly drained and often clayey (Photo 92). Inspite of a high rainfall the type seems to be dependant on subsoil water. In this

type deciduous species predominate and evergreen species are common in the second storey. *Lagerstroemia flos-reginae* is the characteristic species of this type. Photos 93 & 94 show some riverain communities in U.P. and Bengal.

Rowntree (1954) has described a belt of forests occurring along the banks of the larger rivers in the Brahmaputra valley, consisting of pioneer tree species which had replaced them. The following associes, consocies and socies have been recognised:—

Bombax - Albizzia associes is an open type of forest in which the predominant species is *Salmalia malabarica*. There are consocies of:

Albizzia procera. *Salmalia malabarica.*
Duabanga sonneratioides. *Sterculia villosa.*

and socies of:

Ageratum conyzoides. *Coffea bengalensis.*
Curcuma sp. *Imperata cylindrica.*
Leea sp. *Saccharum* sp.

Acacia - Dalbergia associes occurs on the banks of rivers where the water usually goes undergrowth during the dry season. The consocies are:

Acacia catechu. *Albizzia procera.*
Salmalia malabarica. *Dalbergia sissoo.*
Sterculia villosa.

and socies are:

Coffea bengalensis. *Eupatorium odoratum.*
Imperata cylindrica. *Microstegium ciliatum.*
Saccharum sp.

Duabanga - Pterospermum - Terminalia associes is most common in Upper Assam along the banks of rivers all over the valley on well drained new alluvium. It has the Consocies of:

Salmalia malabarica. *Duabanga sonneratioides.*
Pterospermum acerifolium. *Terminalia myriocarpa.*
Laportea crenulata. *Talauma hodgsoni.*
Calamus tenuis. *Impatiens laevigata.*
Strobilanthes coloratus.

Terminalia - Phoebe associes covers large areas of comparatively low land consisting of recent alluvium and is not confined to the river banks. It has the Consocies of:

Ailanthus grandis. *Amoora wallichii.*
Canarium sp. *Daubanga sonneratioides.*
Dysoxylum hamiltonii. *Phoebe* sp.
Terminalia myriocarpa.

and socies of:

Meliosma simplicifolia. *Mesua ferrea.*
Mesua sp. *Pseudostachyum polymorphum.*
Talauma hodgsoni. *Vatica lanceaefolia.*
Alpinia allughas. *Calamus* sp.
Clerodendron nutans. *Clinogyne dichotoma.*
Ferns. *Laportea crenulata.*
Phrynium sp. *Pinanga gracilis.*

4. **Northern tropical semi-evergreen riverain** forest is particularly distributed in the riverain plains of Upper Assam where the soil varies from sandy loam to clay. The forest is generally similar to the climax tropical semi-evergreen.

5. **Cane brakes** are distributed throughout the evergreen and semi-evergreen climaxes and locally in moist deciduous forest on permanantly wet and usually finely clayey soil, very rich in humus. The cane brake forms an impenetrable thorny thicket sometimes with a few tall trees standing over it (Photo 95). The stems are typically trailing and may be 200 ft. or more long, but some species are more or less erect.

6. **Northern moist bamboo brakes** are distributed locally throughout the northern moist deciduous forests, generally confined to stream sides, hollows and shady slopes. The brakes of N. Bengal and Assam are formed by *Dendrocalamus hamiltonii* but locally gregarious *Dendrocalamus strictus* is also met with. Bamboo brakes also occur in other states (Photo 96 & 97).

7. **Northern (Assam) tropical secondary evergreen forest** is distributed in the plains of Upper Assam on alluvial loamy soils. It is a high forest of mixed species of *Tetrameles nudiflora, Stereospermum chelonoides, Terminalia myriocarpa, Terminalia citrina,* etc.

(ii) **Dry tropical.**

8. **Khair-sissu forest** is distributed along all the larger rivers of N. India on new sandy or gravelly alluvium in the Punjab, Uttar Pradesh, Bihar, Bengal and Assam. Photo 98 shows the community in the Dun valley. The upper soil may be porous, hot and dry during summer but it has an ample water supply at a moderate depth. The soil may be washed away at anytime and is therefore unstable. The type is a deciduous forest in which *Dalbergia sissoo* predominates. *Acacia catechu* is usually present but is often relatively inconspicuous in the mixture and it also does not grow as tall as *Dalbergia.* There is usually fairly complete but light canopy which is usually 60 - 80 feet high. There is more or less a definite understorey composed of young trees and a dense shrubby undergrowth in the older woods. Pure *Acacia catechu* associes are also common on boulder beds in which *Adhatoda vasica* is almost the only other species present.

This community is one of the commnest in India and the following description from Cowan (1929) of the *Khair-sissu* associes from Kalimpong may be usefully given. *Dalbergia - Acacia Hylis* and the *Albizzia Hylis* occupy dry beds of the principal rivers, the Tista, the Lish and the Chel in Kalimpong. *Dalbergia sissoo* and *Acacia catechu* are the first trees to come on river beds. The undergrowth consists of sprawling shrubs, *Croton caudatus* being the comonest. There are also several scandent *Acacias,* various species of *Capparis, Derris* spp. *Zizyphus apetala,* several species of *Glochidion, Munronia wallichii,* etc. A number of trees such as *Premna mucronata, Trema orientalis, Bridelia* spp., *Callicarpa arborea* and *Anthocephalus indicus* also grow simultaneously. Most of these are short-lived and gradually a few more permanent trees manage to push their way through the entaglement. Some of these are *Amoora wallichii, Duabanga sonneratioides, Michelia champaca,* and *Acrocarpus fraxinifolius* on loamy clay and *Sterculia villosa, Tertrameles nudiflora* and groups of *Duabanga sonneratioides* on stony ground. The pioneer community thus changes to a mixed forest.

9. **Aegle forests** are distributed in the dry deciduous and drier parts of the moist deciduous forests of the Gangetic plains, being well represented on typically stiff dry clayey alluvial soils in Gonda and Bahraich divison of Uttar Pradesh, and Palamau division in Bihar. *Aegle marmelos* predominates often forming nearly pure associes in open dry deciduous forest.

A summary of the floristic composition of the types is given in table 63 after Champion.

Table 63
EDAPHIC FOREST TYPES
(Re-arranged for Champion)

Sub-type and distribution	I	II	III	IV
1. Moist riparain forest. Along all the large rivers banks on the alluvium. (i) Upper Assam.	*Lagerstroemia flos-reginae, Terminalia myriocarpa.*	*Salix tetrasperma.*	Heavy grass.	
2. Gangetic tropical moist deciduous riverain forest. Throughout the moister parts of the Gangetic plain in the Sub-Himalayan tract in U.P. (i) Gaula block. Haldwani division (U.P.).	*Bombax malabaricum, Adina cordifolia, Lagerstroemia parviflora, Terminalia belerica, Lannea grandis, Hymenodictyon excelsum, Garuga pinnata, Gmelina arborea.*	*Cassia fistula, Randia longispina, Zizyphus jujuba, Mallotus philippinensis, Phyllanthus emblica', Ehretia acuminata, Holarrhena antidysenterica.* II a. *Dendrocalamus strictus.*	*Adhatoda vasica, Helicteres isora, Pogostemon plectranthoides, Callicarpa macrophylla, Murraya koenigii, Glycosmis pentaphylla.* III a. *Andropogon muricatus, Saccharum munja, S. narenga.*	*Vallaris heynei, Cryptolepis buchanani.*
3. Upper Assam moist deciduous riverain forest. Assam & S. Bengal mainly on the alluvial flats along the larger streams. (i) Upper Assam.	*Lagerstroemia flos-reginae, Terminalia myriocarpa, T. chebula, Dillenia indica.*			
4. Northern tropical semi-evergreen riverain forest. Riverain plains of Upper Assam. (i) Rengna R., Sibsagar division.	*Terminalia myriocarpa, Phoebe hainesiana, Lagerstroemia flos-reginae, Duabanga sonneratioides, Tetrameles nudiflora,* etc.	*Taraktogenos kurzii, Gynocardia odorata.*		
5. Cane brakes. Throughout the evergreen and semi-evergreen climaxes and locally in moist deciduous forest.	*Calamus* spp.	A few palms such as *Licuala* and *Zalacca.*		
6. Northern moist Bamboo brakes. Locally throughout the northern moist deciduous forest.				

Table 63 (Contd.)

Sub-type and distribution.	I	II	III	IV
(i) U.P. (ii) Orissa. (iii) Assam. (iv) Bangal.	*Dendrocalamus strictus, Bambusa arundinacea, Dendrocalamus strictus, Oxytenanthera monostigma, Dendrocalamus hamiltonii, Melocanna bambusoides, Bambusa tulda.*			
7. Northern (Assam) tropical secondary semi-evergreen forest. (Plains of U. Assam).				
(i) Hollongapur R.F. Sibsagar division.	*Tetrameles nudiflora, Stereospermum, chelonoides, Terminalia myriocarpa, Dipterocarpus pilosus,* etc.	*Macaranga* spp., *Melia azedarach, Olea dioica, Mesua ferrea, Amoora wallichii, Vatica.* II a. *Pseudostachyum polymorphum.*		
8. Aegle forests. In the dry deciduous and the drier part of the moist deciduous tracts of the Gangetic plain, being well represented in Gonda and Bahraich division of U.P. and in Palamau division in Bihar.				
(i) Motipur and Chakia, Bahraich division, (U.P.)	*Aegle marmelos, Diospyros tomentosa, Zizyphus xylopyrus, Acacia catechu, Adina cordifolia, Lannea grandis, Shorea robusta.*			
9. *Khair-Sissu* forest. All along the large rivers of N. India on new sandy or gravelly alluvium, in the Punjab, U.P., Bihar, Bengal and Assam.				
(i) Punjab.	*Dalbergia sissoo, Populus euphratica.*	*Tamarix dioica, Acacia farnesiana.*	*Saccharum spontaneum, S. munja.*	*Saccharum munja, Aristida cyanatha, Triraphis madagascariensis. Saccaharum spontaneum,* etc.
(ii) Ganges islands, Lansdowne division, Uttar Pradesh.	*Dalbergia sissoo, Acacia catechu.*	*Holoptelea integrifolia, Zizyphus jujuba, Ehretia laevis.*	*Adhatoda vasica, Murraya koenigii, Helicteres isora, Calotropis procera.*	
(iii) Sarda islands Haldwani division, U.P.	*Dalbergia sissoo, Acacia catechu.*	*Holoptelea integrifolia, Breynia.*	*Adhatoda vasica, Pogostemon plectranthoides.*	
(iv) Teesta River, Bengal	*Dalbergia sissoo, Acacia catechu, Albizzia procera.*	*Premna* spp.	*Saccharum arundinaceum, Erianthus elephantinus.*	

(B) PENINSULAR INDIA

(i) Moist tropical.

1. **Southern tropical moist deciduous riverain forest** is of limited occurrence on low lying level tracts in S. India on mostly clayey and usually alluvial soil, which is of good depth and often more or less water-logged. The type is very similar to the climax moist deciduous type. *Terminalia tomentosa* and *Lagerstroemias* are very generally found in this type. It seems very probable that these forests are seral in nature, but they may represent a number of stable sub-climaxes.

In the wet evergreen forests of the western ghats there are a number of communities described by Kadambi on thin alluvium bordering perennial streams and other bodies of water. These are:—

(1) *Elaeocarpus tuberculatus* community.
(2) *Lophopetalum wightianum* community.
(3) *Vateria indica - Elaeocarpus tuberculatus* community.
(4) *Vateria indica* community.
(5) *Calophyllum wightianum* community.
(6) *Poeciloneuron indicum* community.
(7) *Mastixia arborea* community.

Elaeocarpus tuberculatus community is shown in Photo 99. These communities have masses of epiphytic orchids shown in photo 100 and interesting ground flora species mong which *Arisaema* (Photo 101) is present.

In water logged and poorly drained localities, which are the result of the presence of laterite or other hard rocks near the surface, a community formed of *Careya arborea, Butea frondosa, Zizyphus, Gardenia* spp., *Buchanania latifolia, Randia uliginosa, Dillenia indica, Wendlandia notoniana* and *Phoenix humilis* is present.

Sometimes communitis of ground flora like *Polygonum* (Photo 102) and *Echinops* (Photo 103) occur on riverain alluvium.

2. **Southern wet bamboo brakes** are distributed throughout the tropical evergreen tracts of S. India along streams or on badly drained hollows. The brakes are often very dense and bamboos tend to be of the smaller culmed types (Photo 104).

3. **Southern moist bamboo brakes** distributed locally throughout the semi-evergreen and moist deciduous types along stream sides and shady slopes. The community is more or less a continuous forest of one or two species of tall clumped bamboos, occasionaly with *Terminalias* and other trees (Photo 105).

Kanara bamboo forests: In the deciduous forests of Kanara almost pure patches of Bamboo occur. The commonest species are *Bambusa arundinacea, Dendrocalamus strictus* and *Oxytenanthera monostigma. Bambusa arundinacea* is very common in most bamboo forests (photo 106, 107).

At Maoling near Dandelli, *Dendrocalamus strictus* is more common; however, at Kurli, *Bambusa arundinacea* is more common. *Dendrocalamus* is much less frequent.

There are not many tall trees in bamboo forests. Small trees and shrubs of *Grewia, Lagerstroemia, Adina, Emblica, Butea, Mitragyna, Eugenia, Dalbergia, Flacourtia* and *Zizyphus* are present. The ground flora is poor; few grasses and hardy herbs alone grow at some places.

(ii) Dry tropical.

4. **Southern dry tropical riverain forest** is chiefly distributed in narrow strips along the hilly sections of larger streams. It occurs on a

light sandy soil which often overlies a more or less impervious rock and usually retains adequate water supplies. Due to radiation from the exposed rock and sandy soil the air temperature is fairly high. The type consists of an irregular overwood and trees are often of large size, forming patches and strips with varying amounts of smaller trees and shrubby undergrowth.

5. **Inundation babul forest** is chiefly distributed along the larger streams in Bombay and Central India. For good development of the forest actual flooding for about 6 weeks or so is necessary. The type is formed by practically pure crops of *Acacia arabica* (Photo 108), with local *Populus euphratica* (Photo 109). Canopy is fairly complete and is 40-50 ft. high. The species of the climax type represented by *Prosopis spicigera* appear as the level is raised and the soil gets drier. Grassy undergrowth is typically dense.

A summary of floristic data of the riverain forests of the Peninsular India is given in table 64.

(C) ANDAMANS.

1. **Southern tropical semi-evergreen riverain forest** is distributed in the main valleys of Andamans on sufficiently old, immature, alluvial soil, with a good subsoil water supply and well drained conditions. The forest has a luxuriant growth with many giant trees of both deciduous and evergreen species, often intimately mixed (Photo 110). It has been described by Chengapa (1944) as the densest forest in the Andamans.

The floristic composition of the type is given in table 65.

(D) HIMALAYAS.

(i) Moist Temperate riverain forest.

1. **Alder woods** are chiefly distributed along the banks of larger streams, sometimes extending up to ravines and moist unstable hill sides along the Himalayan range, being best developed in the north-west. They occupy newly formed shingle beds and fine alluvium, with the roots often exposed in water and in swampy ground. This type is limited to sites with permanent water supply and has a wide altitudinal range. The forest is more or less deciduous nearly pure, with trees of 60 to 100 feet high. An underwood may or may not be present. *Alnus nitida* or *A. nepalensis* is the characteristic species of this type.

2. **Temperate Hippophae scrub** is distributed on gravels along the inner Himalayan streams from about 7,000 ft. up to about 10,500 ft. It is more or less a pure thicket of 10–20 ft. high *Hippophae salicifolia*, with some undergrowth of *Salix* spp., *Myricaria* spp., and occasionally *Populus ciliata* at lower elevations. Grass and herbs, such as *Thymus serpyllum* are also present.

3. **Moist temperate deciduous forest** is distributed throughout the moist temperate belt, between 6,000–9,000 ft. on deep, moist newly formed soils, particularly on northerly aspects in hollows and depressions and along hill streams. It is a deciduous 60–100 ft. high forest formed of mixed species. *Aesculus, Acer, Juglans, Ulmus, Betula,* etc., (Photo 111) are the main trees and the undergrowth is usually thin.

A brief summary of the floristic data of the types is given in table 66 after champion.

Succession in riverain habitats: The succession of vegetation in the Indus valley was described by Aitchison as early as 1865. He states

Table 64.

RIVERAIN FORESTS OF THE PENINSULAR INDIA

(Re-arranged from Champion)

Sub-type and distribution	I	II	III	IV
1. Southern tropical moist deciduous riverain forest on low lying level tracts in South India.	*Terminalia tomentosa* and *Lagerstroemia* spp.			
2. Southern wet Bamboo brakes. Throughout the tropical evergreen tracts of S. India.	*Albizzia stipulata*, etc.	*Ochlandra travancorica.*		
3. Southern Moist Bamboo Brakes. Locally throughout the semi-evergreen and moist deciduous types.				
(i) Kuriarki, Cochin.	*Terminalia crenulata.*	*Bambusa arundinacea.*	*Clerodendron infortunatum.*	
4. Southern dry tropical riverain forest. Narrow strips along the hilly section of the larger streams in the dry deciduous types.				
(i) Wainganga warda river junction, S. Chanda, C.P.	*Terminalia arjuna* (a), *Anogeissus acuminata* (f), *Stephegyne parvifolia* (o).	*Pongamia glabra* (a), *Barringtonia acutangularis* (o), *Alangium lamarckii* (a),	*Helicteres isora*, very little grass.	*Derris scandens* (o), climbers very few.
5. Inundation bbul forest. Along the larger streams in Bombay and Central India.		*Bauhinia malabarica* (f), *Streblus asper* (f), *Mallotus philippinensis* (f), etc.		
(i) Dond, Poona division, Bombay.	*Acacia arabica, Azadirachta indica, Ailanthus excelsa.*	*Pongamia glabra, Zizyphus jujuba.*		

Table 65.

RIVERAIN FORESTS OF ANDAMANS.

Sub-types and distribution.	I	II	III	IV
Southern tropical semi-evergreen riverain forest.				
(i) Andamans.	*Dipterocarpus alatus, D. pilosus, Sterculia alata, S. campanulata, Terminalia bialata, T. procera, Albizzia stipulata, A. lebbek, Calophyllum spectabile, Bombax insigne, Artocarpus lakoocha, A. chaplasha, Pterocarpus dalbergioides.*	*Lagerstroemia hypoleuca, Dillenia pentagyna, Dracontomelum mangiferum, Pometia pinnata, Myristica irya, Pisonia excelsa, Litsaea penamonja, Xanthophyllum andamanicum*, etc. Ususally no bamboos, *Oxytenanthera* sp. *Licuala peltata, Caryota mitisa, Areca triandra.*	*Saprosma ternatum, Maesa andamanica, Micromelum pubescens, Clerodendron infortunatum. Clinogyne grandis.*	*Dinochloa andamanica, Thamtergia laurifolia, Buettneria andamanensis. Combretum ex tensum, Daemonorops, Calamus.*

Table 66.

RIVERAIN FORESTS OF THE HIMALAYAS.

(Moist temperate riverain types).

Sub-type and distribution	I	II	III	IV
1S/1 Alder woods. Along the banks of the larger streams, best developed in North West.				
(i) Beas valley, Kulu, Punjab.	*Alnus nitida.*	*Crataegus crenulata.*		
(ii) Kumaon and Garhwal.	*Alnus nepalensis. Populus ciliata.*			
(iii) Bengal.	*Alnus nepalensis. Trema orientalis.*			
1S/2 Temperate *Hippophae* scrub. On gravel along inner Himalayan streams from, 7,500′ upto about about 10,500.				
(i) Sunderdhunga valley, Kumaon, 9,500′.	*Hippophae salicifolia* (8Ft) *Salix elegans* (o).	*Thymus serphyllum* (b). *Epilobium* sp. (f).		
2. Moist temperate deciduous forest. On suitable sites throughout the moist temperate zone except the lower parts.				
(i) Dwali, W. Almora division, U.P.	*Aesculus indica* (a), *Acer caesium* (a), *A. pictum* (f), *Carpinus viminea* (f), *Ulmus wallichiana* (f), *Betula alnoides* (o). *Juglans regia.* (o).	*Corylus colurna* (f), *Cornus macrophylla* (f), *Rhus punjabensis* (lf), *Taxus baccata* (o), *Prunus undulata* (o), etc. *Arundinaria spathiflora* (lo), *A. falconeri* (lf).	*Viburnum foetens, Rubus repens, Berberis* spp., *Spiraea sorbifolia.* III a. *Paeonia emodi* (la), *Impatiens* spp., *Strobilanthes wallichii, Aconitum* sp. *Lilium giganteum.*	*Vitis semicordata, Clematis connata, Rubus lanatus.*
(ii) Sutlej valley Punjab.	*Acer caesium, A. pictum, A. villosum. Aesculus indica, Betula alnoides, Carpinus* sp., *Celtis australis, Fraxinus micrantha, Ulmus* spp., *Abies pindrow., Juglans regia. Pyrus lanata.*	*Cornus* spp., *Corylus colurna, Euonymus tingens, Pieris ovalifolia, Rhododendron arboreum, Rhus* sp., *Taxus baccata, Arundinaria* spp.	*Berberis petiolaris, Cotoneaster* spp., *Doutzia corymbosa. Jasminum humile. Ribes, Sarcococca,* etc. III a. *Aconitum, Impatiens, Polygonatum, Spiraea* spp., etc.	*Hedera helix. Vitis semicordata, V. lanata.*

that on falling the river in September, gradually an island type area comes out where seeds of *Saccharum spontaneum,* from other islands, fall and germinate. In one or two months they spring up and their leaves now aid in catching seeds of *Tamarix* and *Saccharum munja* which are flying about in wind. These seeds lie dormant until the next year. By September *Saccharum spontaneum* comes in full growth and blossoms. Now *Tamarix* and *Saccharum munja* are favoured by the habitat conditions and grow to such an extent that they completely suppress *Saccharum spontaneum.* When next year again the river is flooded, many seeds which float in water are entangled on to the islands and there develops a jungle. A community of *Saccharum, Cyperus* and *Tamarix* is shown in Photo 112.

The most common riverain type found throughout India is *Khair-Sissoo.* From the Dehra Dun valley Puri (1950) has described the following successional trend:

(i) On boulder beds occur *Acacia catechu-Tamarix* with little or no *Adhatoda vasica.* It does not progress any further.

(ii) Sandy coarse gravel carry *Tamarix.* Depending upon the moisture content of the soil this community may develop to an almost pure *Tamarix* type. The undergrowth may be formed of *Calotropis,* etc.

(iii) Shingle islands bear *Acacia catechu - Dalbergia sissoo* community and if some gravel collects on this habitat *Holoptelea, Trewia,* etc. enter this community.

(iv) Gravels bear *Holoptelea - Trewia - Salmalia* community with *Limonia, Aegle, Eugenia jambolana,* etc. This is the highest development of vegetation on alluvial sites in most places. The successional relationship is shown in Photo 113–116.

From the Himalayas Mohan and Puri (1955) have described *Dalbergia sissoo* community between Nirath and Rampur at an altitude of 3,000 feet in the Sutlej valley. It develops into a mixed community with *Mallotus, Adhatoda, Ficus* and bamboos as understorey. *Plectranthus rugosus, Arisaema* sp., *Commelina* and some grasses form undergrowth.

From the temperate regions of the outer Himalayas in Kulu, Puri (1950) described a number of communities occurring on alluvial and flood plain deposits. On deposits derived from quartzite a pioneer community of chir pine which progresses to blue pine in some cases, is present (Photo 117).

On more fertile soil derived from schists and/or phyllite, Chir pine→ blue pine→blue pine-deodar→deodar communities occur (Photo 118). At higher altitudes, blue pine→ *Picea smithiana* are found. On fresh alluvium, the pioneer community is a mixed broad leaved forest of *Alnus nitida - Populus ciliata - Ulmus wallichiana - Cornus macrophylla* etc. This community may remain in a seral stage or may progress to a conifer community with varying amounts of broad leaved species, depending upon the nature of the substratum. At higher elevations the forest succession is from *Populus - Alnus - Juglans - Prunus - Pinus→Pinus-Picea→*pure *Picea* community.

In the middle and the inner Himalayas, where valleys are formed of granite and the alluvial deposit fringing rivers is small, *Plectranthus rugosus* is almost the only pioneer species. In wider portions of the Sutlej valley, *Artemisia vulgaris, A. maritima, Daphne oleoides, Spiraea sorbifolia* are the principal species among which *Pinus gerardiana* gains a permanent foot hold.

MANGROVE FORESTS OF INDIA

The mangroves or deltoid forests of India occur on the sea-coast in the sheltered places against strong waves and winds. They occupy

mainly the deltas of chief river systems, i.e. the Ganges, Brahmaputra and Indus. The alluvial deposits are within the tidal inundation. Water logging, salinity, high humidity and such other factors are common on most of the mangrove formations of India. The mangrove vegetation has a few species, which mainly occur gregariously. These are used mainly for fuel and fodder.

The best known classification of the mangrove forests of India is given by Champion and the following description is given according to this.

(i) **Beach forests** are distributed locally in Andamans, Sunderbans along sea face in Bengal, in Orissa, Madras, Travancore Cochin and Bombay all round the coast wherever a fair width of sandy beach occurs. Soil is sea sand, with adequate lime from shell fragments, but poor in other mineral contents. Water table is usually at a depth of only a few feet. The temperature is moderate and the rainfall varies with locality from 30" to 200". *Casuarina equisetifolia* is the most characteristic planted species, forming an almost pure fringe forests. Scattered small evergreen trees of *Casuarina* occur with a few deciduous species and these form the dominant canopy. Shrubs are numerous and maritime grasses, such as *Spinifex*, etc. and surface creepers are conspicuous where the undergrowth is light (Photo 119). Tidal species are poorly developed with a dense undergrowth in swampy depressions, usually having saline water. Tall grasses, such as *Phragmites*, occur where the water is fresh. *Borassus* and *Phoenix* are often present behind the recently fixed sand dunes. *Ipomaea biloba* is oten present in extensive patches on sea sand (photo 120). The type seems to be very stable under the existing conditions of the habitat.

In the Barren Islands (Prain, 1893) beach forests developed on the east Bay contain much *Pisonia excelsa*, with far less common *Pisonia alba*. The other trees of the zone are *Terminalia catappa, Calophyllum inophyllum, Thespesia populnea, Gyrocarpus jacquini, Ixora brunnescens, Ficus brevicupis, Ficus callosa*, etc.

Along the edge of the cliff overlooking the west side of Coco Bay some species, not seen elsewhere are present. These are *Entada scandens, Acacia concinna, Grewia* sp., *Tylophora* sp., *Poederia foetida*, and *Dioscorea sativa*.

On the ridges between the gorges *Premna integrifolia, Morinda bracteata, Trema amboinensis, Capparis sepiaria* and *Acacia concinna* are commonly present. *Callicarpa arborea* is very common on Barren islands. *Amoora rohituka, Apodytes andamanica, Semecarpus heterophylla, Myristica glabra* are met with in the gorge leading from Anchorage Bay to the summit of the peak.

In the Coco group of Islands Prain (1891) found the first line of beach forest containing *Terminalia, Hernandia, Erythrina, Pongamia, Stephegyne, Thespesia*, and the second line of *Mimusops, Gyrocarpus, Pisonia, Ardisia* and *Cycas*. There occurs a common sea-face jungle fence of *Pandanus, Sophora tomentosa, Caesalpinia bonducella, Tournefortia argentea, Desmodium umbellatum, Premna integrifolia, Clerodendron inerme*, etc.

If the beach is composed of shingle, the trees in the same zone comprise of *Ixora brunnescens, Terminalia catappa, Stephegyne diversifolia, Thespesia populnea, Hernandia peltata, Erythrina indica*, etc.

On sandy parts of the beach there occurs a grove of *Cocos nucifera* within the sea fence. In the coconut zone there is *Gyrocarpus jacquini, Mimusops littoralis*, various species of *Dipterocarpus, Miliusa* sp. and some species of *Meliaceae*.

Further inward, the vegetation is of a mangrove swamp type consisting of *Bruguiera, Ceriops, Rhizophora, Aegiceras* and *Avicennia*. On the ridges, trees are much the same as on the lower ground.

Beach forest of Andamans. Just above the high tide along the coasts of the Andamans beach vegetation develops on sand shingles, forming efficient wind belts on loose sand and within reach of the high tide develop *Ipomaea biloba, Crinum asiaticum, Vigna retusa, Pandanus tectorius,* etc.

Behind this vegetation on firmer soil are present *Morinda citrifolia, Thespesia populnea, Pongamia glabra, Desmodium umbellatum, Gyrocarpus americanus, Erythrina indica, Barringtonia speciosa, Calophyllum inophyllum, Terminalia catappa, Cordia subcordata,* which are generally laden with climbers and shrubs of *Caesalpinia, Mucuna gigantea, Colubrina asiatica,* etc. *Mimusops littoralis* also grows on flat and deep sand deposits.

(ii) **Tidal forests** are distributed in the delta of the Ganges, Brahmaputra carrying the important forests of the Sunderbans. Small patches also occur at the mouths of the Mahanadi, Krishna, Godavari and other rivers, and some in the creeks on the west coast. There is also a little mangrove at the mouth of the Indus. The soil is entirely river borne silt, a very fine mud being loamy where the water is fresh and stiff clay where it is saltish, locally with some overlying sand.

Rhizophoraceae are almost confined to the type on newly deposited mud banks, submerged by the tides daily (Photo 121). There are also found *Heritiera, Carapa, Sonneratia, Avicennia, Excoecaria, Cerbera* and *Cynometra* (Photo 122). *Acanthus* is very common among the shrubs and the fern *Acrostichum aureum* is very typical. *Phoenix paludosa* and *Nipa fruticans* (Photo 123) are present among the palms. Except, *Oryza coarctata,* an early colonist in fresh water deposits, grasses are usually absent.

Champion gives the following four typs of the tidal forests:

1. **Low mangrove forest** is distributed in the river delta along the edge of water ways and the east coast of India with a little on the west coast. It occurs on soft tidal mud submerged by salt water at every tide. The type consists of more or less of a dense forest with trees of very low average height, often only 10–20 feet. There are only a few species which are gregarious and evergreen with leathery leaves. *Ceriops roxburghiana* and *Avicennia* are the characteristic species.

2. **Tree mangrove forest** is distributed in the river delta on the east coast and a little on the westcoast. The ground of this forest is flooded daily by salt water. The type is a closed evergreen forest of moderate height. *Rhizophora conjugata* is the characteristic species and stilt roots are very typical. *Acanthus* among the shrubs and *Nipa* are present as undergrowth.

Sunderbans forests: Sunderbans form the southern part of the Gangetic delta, between Hughli on the west and the Megna on the east, and consists of a number of low-lying swampy islands formed by the principal tributaries of the Ganges. Most of the central and western portions are occupied by extensive forests. The streams of the central and eastern Sunderbans bring down an enormous volume of fresh water and are thus less brackish than those of the western rivers and the character of the vegetation in these divisions of the Sunderbans is thus markedly affected throughout much of the western Sunderbans and southern islands of the central Sunderbans. The vegetation is largely of the mangrove (Rhizophoraceae) type, associated by *Excoecaria agallocha, Phoenix paludosa* and *Aegialitis annulata.* Throughout the rest of the central Sunderbans and in the northern islands of the western Sunderbans the predominant species is *Heritiera minor* (Photo 124) as associated with, *Excoecaria, Amoora cucullata, Carapa* sp., *Avicennia, Cynometra* and

Sonneratia apetala on river banks. The savannahs of the eastern Sunderbans are largely composed of *Phragmites karka,* associated with several other grasses and sedges. Clearing of considerable extent exist throughout the whole of eastern Sunderbans and in central and eastern Sunderbans where they are confined to the northern border of the forests. The forest in such places contains some species like *Aegle marmelos, Diospyros embryopteris, Cassia fistula* that do not occur in the swamp forests, although along embankments and on the banks of the creeks and Khals, a number of species characteristic of the swamp forest still persist.

Prain (1903) found that a number of species were intentionally introduced by man in the flora of Sunderbans, the mode of introduction of some of these is given in table 67.

Table 67.

MODE OF INTRODUCTION OF SUNDRIBAN PLANTS.

(After Prain, 1903).

Habitats.	Number of species introduced. By animate agencies				By Inanimate agencies		
	Man.		Birds.				
	Intentionally.	Inadvertently.	Aquatic	Frugivorous.	Winds.	Rivers.	Tides.
Existing clearings. ...	23	56	29	4	15	19	36
Abandoned settlement.	16	10	5	20	5	—	—
Grassy savannahs. ...	—	—	—	—	4	5	1
Swamp forests. ...	1	—	—	10	32	21	58
Sea face fence. ...	—	—	—	2	3	11	31
Total, eliminating over lapping species in different areas. ...	36	58	30	23	50	41	96

Mangroves of the Bombay Presidency: Blatter (1904) gave a floristic account and biology of the mangrove species of the Bombay Presidency. There are 14 species, viz., *Rhizophora mucronata* and *R. conjugata, Ceriops candolleana, Kandelia rheedii, Bruguiera gymnorhiza, Lumnitzera gymnorhiza, Lumnitzera racemosa, Sonneratia apetala* and *S. acida, Carapa obovata, Aegiceras maj s, Avicennia officianlis, Acanthus ilicifolius* and *Excoecaria agallocha* in these forests.

Rhizophora mucronata is found chiefly near the shallow mouth of rivers forming sometimes tangled thickets by the inter-lacing of its roots (Photo 125). It may sometimes be isolated, but always occurs on the outer border of the mangrove formation towards the open sea, serving to protect the less favoured representatives of the same formation. The tree has got elasticity.

Rhizophora conjugata is also found in the same localities but is not so common.

Bruguiera gymnorhiza is an evergreen, glabrous shrub or tree.

Bruguiera caryophylloides is less common and occurs in the southern parts of the Presidency.

Bruguiera parviflora is found in salt marshes and is not so common.

Ceriops candolleana is a glabrous shrub or small tree, reaching a height of 3 to 6 ft.

Kandelia rheedii is a small tree with terete leafy branches.

Avicennia officinalis grows abundantly in the salt marshes in Bombay, the Konkan and elsewhere. It is a shrub or a dwarf tree.

Sonneratia apetala is rather rare, pretty slender tree, reaching a height of 40 feet.

Sonneratia acida is a small tree reaching a height of 15 ft. It occurs on the Island of Salsette, in Ratnagiri, Vingorla, Hareshvar, Dharamtar, Kanara, etc.

Carapa obovata grows along the muddy sea coast of the Konkan. It is a small glabrous tree.

Lumnitzera racemosa is found in the South Konkan along salt-water creeks and back waters. It is a glabrous shrub or a small tree.

Aegiceras majus is a handsome shrub and grows in salt marshes.

Acanthus ilicifolius has the cylindrical, glabrous stems, rarely exceeding the height of 4 ft. and is scarcely branching.

Excoecaria agallocha is a small tree and bears thick branchlets marked with leaf scars.

These species belong to the xerophilous type of plants having adaptations which help to diminish transpiration. The leaves of mangrove plants have the extraordinarily thickened and cuticularised walls of their epidermal cells, and reduced intercellular spaces in the mesophyll. The other peculiarities are the lengthening of the palisades, depression of the stomata, formation of aqueous tissue and multiplication of the vascular bundles.

Bharucha and Navalkar (1942) and Navalkar (1940) have made interesting studies on the ecology of Bombay Mangroves (Photo 126) and their succession, which are described in the next few pages.

Mangroves forests of Andaman occur on marshes along creeks and sheltered coast line in which the wave action or wind does not disturb much. Their extent is determined by the level of high tide. *Rhizophora mucronata* and *R. conjugata* occur immediately facing the sea (Photo 127). These are extremely gregarious species and predominate in mangrove vegetation of the area. Behind this vegetation where there is some influence of fresh water there occur *Bruguiera gymnorhiza* and *B. parviflora* (Photo 128).

These four species with their stilt root are extremely abundant and form impenetrable thickets. *Avicennia officinalis* is another gregarious species. Other mangrove species which are not so common are *Ceriops candolleana, Kandelia rheedii, Carapa obovata, C. moluccensis, Sonneratia acida* and *S. alba*. Sahni (1957) has recently given a systematic account of species occurring in the Mangrove Forests of the Andaman and Nicobar Islands. The following list of species is compiled from his paper:—

Sterculiaceae	*Heritiera littoralis* Dryand.
Tiliaceae	*Brownlowia lanceolata* Benth.
Meliaceae	*Xylocarpus grabatum* Koenig syn. *Carapa granat* (Koenig) Alston syn. *C. obovata* Bl.
Leguminosae	*Cynometra ramiflora* Linn.
Rhizophoraceae	*Rhizophora mucronata* Lam.
,,	*Ceriops tagal* (Perr.) C. B. Robins syn. *C. candolleana* Arn.
,,	*Bruguiera conjugata* (Linn,) Merr. syn. *B. gymnorhiza* Lam.
,,	*B. parviflora* Wight et Arn.

Combretaceae	*Lumnitzera racemosa* Willd.
,,	*L. littorea* (Jack) Voigt syn. *L. coccinea* Wight et Arn.
Lythraceae	*Sonneratia acida* Linn. f. *S. alba* Sm.
Rubiaceae	*Scyphiphora hydrophyllacea* Gaertn.
Myrsinaceae	*Aegiceras corniculatum* (Linn.) Blanco syn. *A. majus* Gaertn.
Apocynaceae	*Cerbera manghas* Linn.
Acanthaceae	*Acanthus ilicifolius* Linn. *A. ebracteatus* Vahl. *A. volubilis* Wall.
Verbenaceae	*Avicennia officinalis* Linn.
Euphorbiaceae	*Excoecaria agallocha* Linn.
Palmae	*Nipa fruticans* Wurmb. *Phoenix paludosa* Roxb.

Along the outward fringe of the swamp where the spring tide reaches, vegetation is formed by *Nipa fruticans, Licuala spinosa, Barringtonia racemosa, B. speciosa, Heritiera littoralis, Phoenix paludosa*, etc.

3. **Salt water Heritiera forest** is distributed in the big river deltas where the ground is flooded with every tide with brackish water. Due to less silt deposition the soil consists of a stiffer clay with a smaller amount of humus. The forest is fairly dense, rarely over 60 feet in height; the trees do not attain large girths. There are a number of species which tend to occur gregariously. Pneumatophores are found and stilt roots are infrequent.

4. **Fresh-water Heritiera forest** is also distributed in the delta of the Ganges on ground which is flooded for some portion of each day. It is best developed in between the drier banks of streams and central depressions. Water is never very salty and during rains it is either quite fresh or only slightly brackish. There is a good deposit of fresh silt each year. The type is a closed forest over 100 ft. high and is the finest development of the tidal forests. *Heritiera* and *Bruguiera* are the characteristic trees.

Mangroves of Chakaria Sunderbans : In Chakaria Sunderbans the mangrove forests consist mainly of an association of two species namely, *Ceriops roxburghiana* and *Avicennia officinalis*. Within this association groups of *Kandelia rheedii* and *Bruguiera* spp. are also found over a considerable area. *Ceriops roxburghiana* grows as pure forest.

On high land, subject to inundation for shorter period, the principal tree is *Heritiera minor*, which forms a characteristic community. *Excoecaria agallocha* may also be found and clumps of gregarious *Phoenix palludosa* are fairly common. Species characteristic of other communities are absent, except *Avicennia officinalis*, which grows almost everywhere and is sometimes mixed with *Heritiera minor*. On sea front and along larger rivers large trees of *Sonneratia apetala* occupy a strip of about 100 feet width. The edges of the creeks and smaller streams, where the banks are usually perpendicular, are characterised by *Rhizophora mucronata*, mixed with *Avicennia* or *Aegiceras majus* or *Sonneratia*. Occasionally, *Carapa moluccensis* and *Findlaysonia obovata*, the later growing at the water edge, are also found. Besides the species already mentioned the only trees occurring actually on the muddy flats are *Carapa obovata, Avicennia alba* and *Sonneratia griffithii*.

Tropical valley fresh water swamp forests: are distributed in certain tracts of Assam, Bengal, Madras and Uttar Pradesh which are under water for a fairly long period during the rains. Typical examples are met with in depressions which are probably old river beds but some are met with in well watered plains districts. Soils are rich in humus and aeration is usually poor. Rainfall exceeds 50", and the water table is usually not more than a few feet from the surface. The type consists of evergreen trees of medium height, generally 30-60 ft. which often form pure open crops. Thick undergrowth of evergreen species may or may not be present. Climber are few. Due to human interference the luxuriance of the type varies greatly from a very open crop of low trees with grass to a dense closed canopy. Photo 129 shows a Swampy Vegetation in the Nilgiris.

Swamp forest of Mothronwala: In the Dehra Dun District at Mothronwala clay beds of the Siwaliks Series outcrop in great thickness. The rainfall is about 100". The water which goes underground in the valley oozes out here. These oozed waters form small streams which drain off in the Suswa. *Quercus incana* with *Hedera helix, Ficus scandens,* etc. occur in this habitat.

Lower down in the ravine are species that usually occur in marshy places or at higher elevations. The chief of these being *Cocculus laurifolius, Acronychia laurifolia, Olea glandulifera, Cyclostemon assamicus, Phoebe lanceolata, Machilus odoratissima, M. gamblei, Litsea lanuginosa, Celtis australis, Toddalia aculeata, Glycosmis pentaphylla.*

In river beds and along the streams there occurs a forest of *Bischofia javanica, Cudrania javanensis, Salix tetrasperma, Acer oblongum, Glochidion lanceolarium, Ficus glaberrima, Citrus medica, Elaeagnus latifolia, Trachelospermum fragrans, Callicarpa macrophylla,* etc., interrupted only by cane brakes of *Calamus tenuis,* where the current is perceptible. Clumps of *Typha elephantina* and *Typha laxmanni* occur where the water is stagnant. The water edge is lined with various kinds of weeds, chief among them being ferns, sedges and *Typha.*

Another swamp in this valley is at Nakrunda, formed similarly and with a similar type of vegetation.

There is still another swamp near Khairi at an altitude of about 1,200 ft. The vegetation here consists of *Diospyros embryopteris, Putranjiva roxburghii, Holoptelea integrifolia, Ficus bengalensis, Ficus glomerata,* etc., with a dense undergrowth of *Murraya exotica, Murraya koenigii, Adhatoda vasica* and *Glycosmis pentaphylla.* Inside the swamps, which are open and sunny, there occur the usual cane brakes in which, wild plantain, *Pterospermum acerifolium, Bauhinia vahlii,* and occasionally sal and *Alsionia scholaris* are inextricably mixed. A fresh water swamp forest with cane brakes and *Eugenia* from Pilibhit is shown in Photo 130.

Swamp forest of the Brahmaputra valley: The *Cephalanthus - Glochidion* associes described by Rowntree (1954) from the Brahmaputra valley is found in swampy places where it appears to thrive in the deepest parts of depressions. The tree vegetation mainly consists of *Cephalanthus occidentalis, Glochidion hirsutum* and *Barringtonia acutangula.* The shrubs and ground layer species are *Alkinia* sp., *Canna indica, Clinogyne dichotoma, Hymenachne pseudo-interrupta, Leersia hexandra, Melastoma malabathricum, Phragmites karka* and *Saccolepis interrupta.*

A summary of floristic data of the mangrove types described is given in table 68 after Champion.

Physiology of mangroves plants: Cooper and Pasha (1935) studied Osmotic and suction pressures of *Acanthus ilicifolius, Avicennia officinalis* and *Sonneratia apetala* growing on the coast around Bombay.

Table 68.

MOIST TROPICAL MANGROVE FORESTS OF INDIA

(After Champion).

Sub-type and distribution.	I	II	III	IV
1S/1. Beach forest. All round the coast, wherever a fair width of sandy beach occurs. Andamans, Bengal, Orissa, Madras, Travancore Cochin and Bombay.				
(i) Andamans.	*Mimusops littoralis.*	*Pongamia glabra, Morinda citrifolia, Erythrina indica, Terminalia catappa,* etc.	*Thespesia populnea, Hibiscus tiliaceus, Crinum asiaticum, Vigna retusa.*	*Mucuna gigantea Colubrina asiatica. Caesalpinia bonducella, Ipomea* spp.
(ii) Sunderbans, Bengal.	*Hibiscus tiliaceus, Thespesia populnea, Erythrina indica, Ixora parviflora, Vitex negundo, V. trifolia, Trewia nudiflora, Dolichandrone rheedii, Tamarix gallica.*		*Acanthus ilicifolius, Crotalaria* spp., *Oryza coarctata, Saccharum spontaneum.*	*Caesalpinia bonducella, Derris scandens, Dalbergia, Vitis trifolia. Clerodendron inerme, Ipomea* spp.
1S/2. Tidal forests.				
1S/2(a). Low mangrove forest. Mostly east coast and here and there in W. coast in river delta.				
(i) Sunderbans, Bengal.	*Ceriops roxburghiana, Avicennia alba, Aegialitis rotundifolia, Excoecaria agallocha.*	*Acanthus ilicifolius.*	Local patches of grass.	
1S/2 (b). Tree mangrove forest, in the river deltas on the east coast.				
(i) Sunderbans, Bengal.	*Rhizophora conjugata, Kandelia rheedii, Avicennia alba, Bruguiera gymnorhiza, Carapa moluccensis, Ceriops candolleana,* etc.		*Nipa, Acanthus.*	

Table 68 (Contd.)

Sub-type and distribution.	I	II	III	IV
1S/2 (c). Salt water *Heritiera* forest, in big river deltas.				
(i) Sunderbans, Bengal.	*Heritiera minor, Excoecaria agallocha, Ceriops roxburghiana,* etc.	*Carapa moluccensis, Bruguiera gymnorhiza, Avicennia officinalis,* etc.	*Nipa* relatively uncommon.	
1S/2 (d), Freshwater *Heritiera* forest, in the large deltas of Ganges.				
(i) Sunderbans, Bengal.	*Heritiera minor, Carapa moluccensis, Bruguiera gymnorhiza, Sonneratia apetala, Avicennia officinalis, Sonneratia acida.*	*Excoecaria agallocha, Cynometra ramiflora,* (dry soils) *Amoora cuculiata,* (wet soils), *Ceriops roxburghiana, Phoenix paludosa* (high land).	*Acanthus ilicifolius, Hibiscus, Pandanus, Acrostichum aureum, Nipa.*	*Derris* sp.
1S/3. Delta freshwater Swamp forest.				
1S/4. Tropical valley freshwater swamp forest, Assam, Bengal, U.P. and Madras.				
(i) Gudalur, Nilgiri Wyanaad, Madras.	*Eugenia* spp., *Mallotus alba.*		*Pandanus* sp.	
(ii) Golatappar Dehra Dun, (U.P.)	*Ficus glomerata, Trewia nudiflora, Eugenia jambolana, Pterospermum acerifolium, Cedrela toona, Bischofia javanica.*	*Diospyros embryopteris, Putranjiva roxburghii, Phoebe lanceolata, Machilus gamblei, Salix tetrasperma.*	*Acronychia laurifolia, Ardisia solanacea, Clerodendron infortunatum, Desmodium, Adhatoda vasica.*	*Calamus tenuis.* Ferns, no grass.

They found that the osmotic and suction pressures of the mangrove species rise from the roots towards the leaves. The osmotic pressure of mangrove plants is very high as compared to other plants, while the osmotic pressure of the water is nearly 25 atmospheres. Since the osmotic pressure of roots and leaves of mangrove species are much higher than that of the sea water, plants do not experience any great difficulty in the absorption of water. Although, the osmotic pressure of the sea water remains more or less uniform there is a rise of osmotic pressure in mangrove plants as the dry season sets in. The halophytes transpire more vigorously than the mesophytes and as the humidity of the air decreases they lose more water, at the same time showing an increase in absorption of water. The plants absorb salts in sea water which increases osmotic pressure of the cell sap. The increase in osmotic pressure from July to October increases the absorption of water, which is so necessary for their life.

Osmotic pressure was determined by Sen Gupta (1947) in two species of jute. The osmotic values were found to be high when plants were 1–2 months old. Then there was a fall in the osmotic pressure and again a rise, the variations were, however, not related with rainfall during the period of study. The variations in osmotic pressure were found to be related with the stage of growth, high during the period of active vegetative growth, and showing a fall previous to flowering.

Navalkar (1940) has made detailed studies on mangrove habitat and vegetation. He compared his own data on osmotic pressure with that of Sen Gupta from India and of Walter from east Africa.

Table 69.

OSMOTIC PRESSURE OF DIFFERENT MANGROVE PLANTS

	Walter.	Navalkar.	Sen Gupta
Sonneratia alba.	31.45 atms.	...	...
Sonneratia apetala.	...	45.465 atms.	14.99 atms.
Rhizophora mucronata.	31. 6 atms.	33.788 atms.	32.13 ,,
Ceriops candolleana.	32.45 ,,	29.438 ,,	26.65 ,,
Avicennia marina.	48. 5 ,,	...	...
Avicennia alba.	...	38.607 ,,	41.29 ,,
Avicennia officinalis.	...	...	41.93 ,,
Acanthus ilicifolius.	...	33.258 ,,	24.92 ,,
Bruguiera gymnorhiza.	30. 3 ,,	32.234 ,,	27.90 ,,
Sesuvium portulacastrum.	...	25. 38 ,,	26.66 ,,

From these studies Navalkar concluded that osmotic pressure of the mangrove cell sap (*Avicennia alba*) varies directly with **(1)** tide **(2)** temperature and **(3)** inversally with the humidity and the rainfall.

Physiological anatomy of *Rhizophora mucronata, Ceriops candolleana, Bruguiera caryophylloides, Sonneratia apetala, Aegiceras majus, Acanthus ilicifolius, Avicennia officinalis* and *Avicennia alba* was worked out by Mullan (1932).

Geographical distribution of mangrove plants: Geographical distribution of mangrove vegetation attracted attention of Indian Botanists quite early. In their study of the flora of the Indus delta, Blatter, McCann and Sabnis (1928) gave detailed geographical distribution of mangrove plants. A summary of their data is given in table 70.

Table 70.

GEOGRAPHICAL DISTRIBUTION OF MANGROVES PLANTS OF THE INDUS DELTA

(After Blatter, McCann and Sabnis, 1928).

Family.	Species.	Indus delta.	W. Coast.	E. Coast.	Sunderibans.	Chittagong.	Burma.	Andamans.
Rhizophoraceae.	*Rhizophora mucronata.*	X	X	X	X	X	X	X
	Rhizophora conjugata.	X	X	X	—	X	X	X
	Ceriops candolleana.	X	X	—	X	—	—	X
	Ceriops roxburghiana.	X	X	X	X	X	X	—
	Kandelia rheedii.	—	X	X	X	X	X	X
	Bruguiera gymnorhiza.	X	X	X	X	X	X	X
	Bruguiera eriopetala.	—	X	X	—	—	—	—
	Bruguiera caryophylloides.	—	X	X	—	—	X	—
	Bruguiera parviflora.	—	—	—	—	—	X	—
Meliaceae.	*Carapa obovata.*	—	X	X	X	X	X	X
	Carapa moluccensis.	—	—	—	X	—	—	X
Leguminosae.	*Cynometra ramiflora.*	—	X	X	X	X	X	X
Combretaceae.	*Lumnitzera racemosa.*	—	X	X	X	X	X	X
	Lumnitzera coccinea.	—	—	—	—	—	X	X
Lythraceae.	*Sonneratia acida.*	X	X	X	X	X	X	X
	Sonneratia apetala.	—	—	X	X	X	X	—
	Sonneratia alba.	—	X	—	—	—	—	X
	Sonneratia griffithii.	—	—	—	—	—	X	—
Rubiaceae.	*Scyphiphora hydrophyllacea.*	—	—	X	—	—	—	X
Myrsinaceae.	*Aegiceras majus.*	X	X	X	X	X	X	X
Acanthaceae.	*Acanthus ilicifolius.*	—	X	X	X	X	X	—
Verbenaceae.	*Avicennia officinalis.*	X	X	X	X	X	X	X
	Avicennia alba.	—	—	X	—	—	—	—
	Avicennia agallocha.	—	—	X	—	—	—	—
	Avicennia marina.	—	—	X	—	—	—	—
Euphorbiaceae.	*Excoecaria agallocha.*	—	X	X	X	X	X	X
Palmae.	*Nipa fruticans.*	—	—	X	X	X	X	X
	Phoenix paludosa.	—	—	X	X	X	X	X
	Total ...	8	17	22	17	16	20	18

They compared in table 71 the number of plants present in the mangrove vegetation of the Indus delta and Sundribans.

Table 71.

NUMBER OF MANGROVE PLANTS COMMON BETWEEN INDUS DELTA AND SUNDRIBANS DELTA.

Region.	Families	Genera.	Species.	Ratio.
Indus delta.	61	184	279	1:3:4.5
Sundribans.	72	230	304	1:3.1:4.2

Region.	Dicotyledons.		Monocotyledons.		Ratio of	
	Genera.	Species.	Genera.	Species.	Genera.	Species.
Indus delta. ...	139	211	44	67	3.1:1	3.1:1
Sundribans. ...	168	220	62	84	2.7:1	2 6:1

Succession of forest communities in mangrove forests: Navalkar (1951) found that in mangrove vegetation succession is governed by disintegration of rock, soil salinity, soil humidity and biotic factors. He recognized the following seven stages in the succession which are given in table 72.

Table 72.

SUCCESSION OF VEGETATION IN THE MANGROVE SWAMPS OF BOMBAY SALSETTE

(After Navalkar).

Soil.	Anthropozoic influence.	Stage of Succession.
Blackish or grayish of clay and salt. Always inundated and swampy, lying between low and high tide marks.		1. *Avicennia alba* Association (Optimum Stage)
		2. *Avicennia alba* and *Acanthus ilicifolius* Stage.
High level of ground water mingles with creek water. Areas where sweet water mingles with creek water.	Cutting and burning.	2(a) *Ceriops candolleana* and *Acanthus ilicifolius* Stage.
Greater distance from shore and weathered rocks.	Increase in biotic factor.	3. *Avicennia alba* Stage.
Still greater distance from the shore.		4. *Sesuvium portulacastrum* Stage.
Increase in height above the sea level and decreasing salinity.		5. *Sesuvium portulacastrum* and *Aeluropus repens* Stage.
Still increase in height above the sea level and decreasing salinity.		6. *Aeluropus repens* and *Paspalum vaginatum* Stage.
Increasing aridity and very little salinity.		7. *Clerodendron inerme* Stage.

Recently Puri and Jain (1957) have studied mangrove vegetation of the Western Coast and have recognised a number of plant communities, that are really edaphic or bio-edaphic in nature.

12

TERRESTRIAL EDAPHIC FOREST COMMUNITIES

The terrestrial edaphic types of forests occur in different parts of the country. The various communities are intimately related to the soil conditions. The chief features of soil that markedly influence the growth, development and succession of forest communities are its origin, physical conditions, chemical and biological characteristics. A good discussion of this topic has been given by Misra and Puri (1954) in their book on Indian Manual of Plant Ecology; and earlier Puri (1948) has discussed this topic in some detail from various parts of India. The subject of edaphic types is still very much undeveloped, therefore in this chapter few examples will be given. The examples given by Champion will also be taken in, although, they may not give exact relationship between forest soil and forest communities. The following six examples from the plains of the Ganges and Brahmaputra and four from Peninsular India, one from Andamans and four from Himalayas are given after Champion. Other examples under various headings are given from authors' own studies and only brief descriptions of these are given here. The following six edaphic types of the deciduous forests are mainly from the zone of *Shorea robusta* which forms diverse communities of plants in its entire belt of distribution. A good deal of work has been done on the ecology of *sal*, however, an exact status of various *sal* communities in different parts of the country has not been clearly defined. In some places *sal* may be a climatic climax, at others, it may only form an edaphic, or even bio-edaphic community, which, although seral in character may have been preserved in its present state by the various methods of forest management. Therefore, the entire *sal* communities in the view of the author should be viewed as bio-edaphic or edaphic tyes. This is the view, with which Champion has expressed an agreement but on account of the lack of complete data more justice cannot be done to this important question here.

EDAPHIC TYPES OF THE PLAINS OF THE GANGES AND BRAHMAPUTRA.

1. **N. Indian moist deciduous forest** scattered in the hilly tracts in the moist *sal* type and more locally in plains. The site occupied by the type appears to cover the whole range of moisture conditions under which *sal* occurs but is more extensive in the poorer and drier parts. This is a closed forest of medium to good height, having a number of intimately mixed dominant species and a good many second storey trees including some evergreens. There is usually a shrubby undergrowth and climbers are heavy.

2. **North Indian moist Terminalia forest** is distributed throughout the *sal* region on heavy clayey soils, usually in valleys and hollows. The soil is moisture retentive and the growth of *Terminalia tomentosa* is usually good. This is typically a closed forest of good height with a lower storey of smaller trees and a shrubby undergrowth.

3. **E. Himalayan moist deciduous forest** is distributed along the foot of the Himalayas in Bengal and Assam. The soil is very well

drained and porous. There is high rainfall with a short dry season. The forest is tall and closed, in which species are usually well mixed with an abundance of underwood and shrubby undergrowth, without grass.

4. **E. Sub-Himalayan wet mixed forest** is distributed in the heavy rainfall tracts of N. Bengal and the adjoining parts of E. Assam and Bhutan. At present it is confined to the moister soils of the terai belt and lower parts of the Bhabar but is rapidly extending with protection. The soil is an old Tertiary alluvium of varying thickness but mostly heavy and moisture retaining. The type is a dense evergreen forest with or without scattered tall, deciduous, or evergreen trees.

5. **Wet plains sal forest** is distributed in the plains, Terai and lower Bhabar portions of the east sub-Himalayan tract in Bengal and West Assam. The soil is an old alluvium, coarse with gravel and boulders in the Bhabar, becoming finer and heavier in the Terai, where it may be dark with humus, but is often red on the old Gangetic alluvium. The type occurs exclusively on flat ground, though in the Bhabar it is well drained both by the general slope of the surface and by a very porous subsoil.

6. **Secondary moist bamboo brakes** are distributed mainly in the hill tracts of Assam and S. Bengal, upto an altitude of about 2,500 ft. The habitat is usually fairly steep hill slopes, particularly on hotter aspects. It is a continuous bamboo forest with scattered trees over it and usually dominating in sheltered hollows, and other favourable sites.

A summary of the floristic composition of the types is given in table 73.

7. **Moist deciduous sal forest on Siwalik clay**: The strata of the Siwalik clay are interbedded with the conglomerate and at some places they outcrop on the surface where a good quality moist deciduous *Sal* forest comes into being (Photo 131). The *Sal* on the clay is more or less pure but may have *Terminalia tomentosa* and *Eugenia jambolana* and in the undergrowth, the evergreen second storey of *Mallotus, Litsaea, Machilus* is ound. The ground flora is very little but has got *Adiantum,* occurring commonly. The regeneration of this type of *Sal* is adequate, though other species are also regenerating.

8. **Sal forest on dip slope of Siwalik clay**: On the dip slope of Siwalik clay *Sal* forest develops into a mixed community in which evergreen constituents predominate. In such situations there is preponderance in the undergrowth of ferns and cane (Photo 132). In the second storey *Bischofia javanica* and *Putranjiva* occur. This type of community occurs throughout the Siwalik and even in low rainfall areas in the valleys. In high rainfall areas in the eastern parts of Siwalik this community is much more predominant.

9. **Sal forest on conglomerate:** On the conglomerate especially on the escarpments the *Sal* forest has got deciduous species, such as *Anogeissus latifolia, Sterculia, Bauhinia, Terminalia belerica,* etc. The second storey species have *Nyctanthes arbor-tristis, Ehretia, Holarrhena* and the undergrowth is predominantly grassy. The habitat of this community is generally dry and sometimes the conglomerate has a higher amount of calcium carbonate. In some places the proportion of *Sal* in the forest is extremely low and a pure or almost pure deciduous forest is the result (Photo 133).

10. **Sal forests on red clayey soils in Central India:** A good quality *sal* forest is present on deep red clayey soil in the States of Madhya Pradesh, Bihar and Orissa, (Photo 134). The *sal* trees grow to first quality but trees are scattered with other species such as *Terminalia tomentosa, Anogeissus latifolia,* etc. In such forests where alluvial deposits from the

Table 73.

EDAPHIC TYPES OF THE PLAINS OF THE GANGES AND BRAHMAPUTRA

(Re-arranged from Champion).

Sub-type and distribution.	I	II	III	IV
1. N. Indian (climax) moist deciduous forests. Scattered freely through the hilly tracts characterised by moist *sal* type.				
(i) Hill working circle. Haldwani Division, U.P.	*Albizzia procera, Adina cordifolia, Terminalia tomentosa, T. belerica, Cedrela toona, Garuga pinnata.*	*Mallotus philippinensis, Ougeinia dalbergioides, Phyllanthus emblica.* II a. *Dendrocalamus strictus. Schleichera trijuga, Eugenia jambolana.*	*Adhatoda vasica, Clerodendron infortunatum, Colebrookea oppositifolia.*	*Bauhinia vahlii.*
(ii) Sarande division, Singhbhum, Bihar and Orissa.	*Adina cordifolia, Pterocarpus marsupium, Terminalia tomentosa, T. belerica, Mangifera indica.*		*Clerodendron infortunatum, Flemingia* spp., *Desmodium* spp.	*Bauhinia vahlii.*
(iii) Madhya Pradesh.	*Pterocarpus marsupium, Terminalia belerica, Adina cordifolia, Stereospermum suaveolens, Albizzia odoratissima, Anogeissus latifolia.*	*Ougeinia dalbergioides, Casearia graveolens, Cleistanthus collinus.*	*Helicteres isora, Flemingia, Desmodium, Embelia, Strobilanthes* spp.	*Bauhinia vahlii.*
2. North Indian moist *Terminalia* forest. Throughout the *sal* region on heavy or wet soils.				
(i) Singhbhum, Bihar.	*Terminalia tomentosa, T. belerica, T. arjuna. Shorea robusta, Bombax malabaricum, Sterculia villosa.*	*Mallotus philippinensis.*	*Clerodendron infortunatum, Flemingia* spp., *Ardisia solanacea.*	
(ii) Sitanadi, S. Raipur division, Madhya Pradesh.	*Terminalia tomentosa, T. belerica, T. arjuna, Stephegyne parvifolia, Adina cordifolia, Pterocarpus marsupium, Schleichera trijuga, Eugenia jambolana, Garuga pinnata, Dalbergia paniculata.*	*Ougeinia dalbergioides, Eugenia jambolana, Cleistanthus collinus.*	Shrub growth without grass	*Bauhinia vahlii. Butea superba.*
3. E. Himalayan moist deciduous forest. East of Himalayas in Bengal and Assam.				
(i) U. Bhabar tract, N. Bengal.	*Lagerstroemia parviflora, Terminalia belerica, Sterculia villosa, Bombax malabaricum, Schima wallichii.*	*Careya arborea, Bauhinia purpurea, Amoora* spp.		

(ii) Buxa division.	*Terminalia belerica, Sterculia villosa, Amoora rohituka, Stereospermum chelonoides, Cedrela toona, Shorea robusta, Lagerstroemia parviflora*, etc.	*Litsaea polyantha, Premna integrifolia, Mallotus philippinensis, Wrightia tomentosa, Machilus* sp., *Callicarpa arborea*, etc.			
4. E. Sub-Himalayan Wet mixed forest. In the heavy rainfall tract of N. Bengal and the adjoining parts of E. Assam and Bhutan.					
(i) Jalpaiguri, Bengal.	*Michelia montana, Turpinia pomifera, Jambosa praecox, Machilus* spp., *Elaeocarpus* spp., etc.	*Aporosa dioica, Symplocos* spp., *Meliosma pinnata*, etc.	Canes and other monocotyledons, *Leea crispa*.	Climbers moderately heavy including cane.	
(ii) Buxa division.	*Michelia champaca, Shorea robusta, Amoora wallichii, Premna bengalensis, Schima wallichii*, etc.	*Actinodaphne obovata, Meliosma simplicifolia, Machilus villosa*, etc.	*Leea crispa, ferns*, etc,	*Calamus* spp., *Acacia pennata, Milletia auriculata, Vitis* sp.	
(iii) Kurseong division . N. Bengal.	*Schima wallichii, Machilus villosa, Syzygium jambolanum, Ternstroemia japonica, Podocarpus neriifolia, Lophopetalum fimbriatum, Michelia oblonga*, etc.	*Ilex, Aporosa dioica, Acronychia laurifolia, Amoora rohituka, Magnolia pterocarpa, Mastixia pentandra*, etc.	Canes, *Coffea bengalensis, Clerodendron infortunatum, Piper* spp., ferns, etc.		
5. Wet plains *sal* forests. The plains Tarai and L. Bhabar portions of the Sub-Himalayan tract in Bengal and W. Assam.					
(i) Gorumara, Jalpaiguri division.	*Shorea robusta, Terminalia belerica, T. tomentosa, Dillenia pentagyna.*	*Aporosa roxburghii, Amoora* sp. *Macaranga*, Lauraceae, *Meliosma simplicifolia.*	*Leea* sp. (f), *Alpinia* spp. (a) Ferns (a) No grass.		
6. Secondary moist bamboo brakes. S. Bengal and Assam brakes particularly in the hill tracts upto 2,500 ft. or more.		No bamboos.	*Imperata* with burning.		
(i) Inoni, Cox's Bazar, S. Bengal.	*Albizzia stipulata, Grewia* spp., *Mangifera longipes, Heynea trijuga, Dipterocarpus alatus, Amoora* sp.				
(ii) Upper Assam.	—	*Dendrocalamus hamiltonii.*	—		

rivers get mixed with the clayey soil, Bamboo comes in the *sal* community forming the mixed *sal* - bamboo - *Terminalia* community. This latter type of forest is clearly the result of the alluvial deposits and may form a different type altogether. The forest is in general adeciduous one.

(B) EDAPHIC TYPES OF THE PENINSULAR INDIA

In the Peninsular India, Deccan trap forms the dominant edaphic habitat in the upper portion. The trap is distinguished into basalt, amygdaloid, ferruginous clay and ashy beds. In the lower portion of the crystalline rocks, laterite is a distinct edaphic type. There are also some patches of sedimentary rocks, although, metamorphic rocks predominate in this region. Unfortunately there are very little data on the relationship of forest communities and edaphic conditions in this region.

(1) **Western laterite semi-evergreen forest** occurs on lateritic soils in various parts of India and is particularly characterised by the prevalence of *Xylia xylocarpa*. *Xylia* is of wide distribution and is often common in the moist mixed forests and in secondary seres to evergreen or semi-evergreen climaxes.

(2) **Secondary evergreen Dipterocarp forest** is distributed on the coastal plains below the western ghats. The soil is stiff, red, often lateritic, on fairly level country intersected by a net work of eroded depressions. The forest is nearly pure of evergreen *Dipterocarps*, which are of relatively poor development but have an even and dense canopy. There is no definite middle storey but an undergrowth of evergreen shrubs is present.

(3) **Coastal sal forest** is of limited occurrence in Orissa and Ganjam on soils of high humidity. *Shorea robusta* is mixed with miscellaneous species and the undergrowth includes more and varied evergreen small trees and shrubs. Generally, bamboos are many and climbers are heavy.

(4) **Southern tropical secondary moist deciduous forest** is distributed along the whole length of the western ghats very usually on hilly grounds. The soil is often shallow, and stony, through past exposure and erosion the lateritic outcrops being frequently met with. The forest is usually with a few or no big trees. There are more of the soft, quick growing species.

A summary of the floristic composition of the types is given in table 74.

(5) **Teak Community on the Basalt.** The basaltic soils all over the Peninsular India bear a pure or almost pure community of teak. The other associates in places are *Anogeissus latifolia* and *Santalum album*. A number of communities of this type have been studied by Puri and Vasavada (1957) from Poona District and by Jain and Karmarkar (1956) from the Thana District. In the Thana District the forests are a little more moist than in the Poona District and have got in addition to *Anogeissus* some *Bauhinia* and *Adina cordifolia*. The second storey species which may sometimes be associated in the upper layer are *Bridelia, Dillenia pentagyna, Boswellia serrata*. In the shrub layer *Randia dumetorum, Wrightia tinctoria, Wendlandia exserta* and sometimes *Salmalia malabarica, Stephegyne parvifo'ia*, etc. may be present. The usual climbers are *Vitis* species and *Ipomaea*. The grasses form a distinct feature of this community (Photo 135), the chief being *Cymbopogon martinii, Heteropogon contortus, Arundinella tenella, Andropogon* species, *Apluda varia, Themeda* species, etc. The regeneration of teak in this community is present, though in most cases teak is coppiced.

Table 74.

EDAPHIC TYPES OF THE PENINSULAR INDIA

(Compiled from Champion).

Sub-type and distribution.	I	II	III	IV
1. Western laterite semi-evergreen forest. Occurs on lateritic soils in various parts of India.	Prevelence of *Xylia xylocarpa* is characteristic.			
2. Secondary evergreen *Dipterocarp* forest. On the coastal plain below the W. ghats.				
(i) Pilarkhan, N. Mangalore division.	*Hopea parviflora, H. wightiana, Vateria indica, Diospyros microphylla*, etc.	*Aporosa lindleyana, Olea dioica.* No bamboos.	*Memecylon* sp., *Eugenia caryophyllcea*, Rubiaceae and Acanthaceae.	*Calycopteris.*
3. Coastal *sal* forest of limited occurrence in Orissa notably in Angul and Puri Division.	*Shorea robusta, Dillenia pentagyna, Terminalia, Bridelia retusa, Adina cordifolia.*	*Eugenia jambolana, Bursera serrata, Polyalthia cerasoides, Cycas circinalis, Bambusa arundinacea, Dendrocalamus strictus, Oxytenanthera*, etc.	*Ardisia humilis, Leea* sp., *Macaranga peltat a, Strobilanthes* spp., III a. *Thysanolaena, Imperata, Panicum* spp.	*Bauhinia vahlii, Butea superba, Zizyphus oenoplia.*
4. Southern tropical secondary moist deciduous forest. The whole of western ghats.				
(i) Parappa, S. Kanara District.	*Terminalia paniculata, Bombax malabaricum, Mangifera indica, Dalbergia latifolia, Adina, Lagerstroemia lanceolata*, etc.	*Olea dioica, Holarrhena, Careya arborea, Phyllanthus emblica, Limonia acidissima, Saccopetalum, Mallotus philippinensis, Strychnos* sp., etc.	*Clerodendron infortunatum, Helicteres, Glycosmis.*	*Calycopteris, Acacia intsia.*

(6) **Evergreen forests on ferruginous clay** : The ferruginous clay bears an edaphic community of *Eugenia-Memecylon-Actinodaphne*. Such evergreen communities have recently been studied by Puri and Vasavada (1957) from Bhimashankar and Puri and Mahajan (1957) from Mahabaleshwar. These communities have already been described elsewhere in the chapter on evergreen forests. It may, however, be stated that these communities owe their presence to the ferruginous clay.

(7) **Acacia catechu community on amygdaloid :** Large areas of amygdaloid are present in the Deccan and where the rock outcrops on the surface it forms a murrum type of soil which is generally dry and bears scrubby community in which *Acacia catechu* predominates. Puri and Jain (1957) have recently studied deciduous scrub vegetation from the Poona District. The other tree species along with *Acacia catechu* are *Boswellia serrata* and *Grewia tiliaefolia*. Teak is also present at some places, but it is heavily lopped and mal-formed. Among the shrubs, *Flacourtia ramontchii, Grewia pilosa* and *Schrebera swietenioides* are prominent. *Elaeodendron glaucum* is also present. *Lagerstroemia, Terminalia tomentosa* and *Acacia arabica* are present here and there. *Gymnosporia montana* and *Zizyphus xylopyrus* also occur in some places. Climbers are *Rivea hypocrateriformis* and *Vitis woodrowii*.

The undergrowth is grassy, with *Apluda aristata* being the most common grass. Other grasses are *Chloris incompleta, Cymbopogon martinii, Chrysopogon montanus, Heteropogon contortus,* and *Sehima sulcatum*. Among the grasses, a number of dicotylendonous plants such as *Barleria gibsoni, Lavendula bipinnata, Lagascea mollis, Rungia elegans* and *Xanthium strumarium* are present.

Acacia catechu—Palms community, with *Acacia arabica* also occurs at some of the slopes on murrum soil on Amygdaloid hills. In such communities, *Terminalia tomentosa* and shrubs of *Woodfordia fruticosa* are quite common. Among the second storey species, *Carissa congesta, Gardenia turgida, Zizyphus jujuba,* and *Securinnega leucopyrus* are present scattered at distant places. The most common grass here also is *Apluda aristata*. Other common associates in the grasses are: *Heteropogon contortus, Cymbopogon martinii,* and *Pseudanthistiria heteroclita*. Other less common grasses on this slope are *Andropogon pumilus, Arundinella tuberculata, Chrysopogon montanus, Setaria intermedia* and *Setaria pallidifusca*.

(C) EDAPHIC TYPES OF THE ANDAMANS.

1. **Andamans moist deciduous forest** is distributed throughout the Andaman islands, covering nearly half of the total area, on coarse grained, hard sandstone, with bands of shale and conglomerate. The soil is often shallow, sandy or clayey loam of light yellowish colour. The top storey of the forest which is about 125 ft. or more in height is somewhat irregular and beneath this there is a definite second storey. There is also a fairly complete shrubby undergrowth, which includes bamboos.

A summary of the floristic composition of the type is given in table 75.

(D) EDAPHIC TYPES OF THE HIMALAYAS.

1. **Cypress forest** is distributed in the N. W. Himalayas in the middle oak zone on dry sites, very usually on rocky limestone ground. (Photo 136). The type is more frequent in a dry temperate climate and being very sensitive to fire is limited to steep ground. This is a very open forest of scattered trees, 20–50 ft. high, branchy to the base with xerophytic shrubs and without grasses. It is locally better developed with a second storey of oaks and other evergreens.

2. **Dry temperate deciduous forest** is distributed in the dry zone behind the Himalayan axis but its development is not so good. Pure woods 50–60 ft. high of *Corylus colurna* between 8,000 and 9,000 ft. in North Garhwal have been mentioned under this type.

3. **Temperate Bamboo brakes** are distributed throughout the moist temperate forests of the Himalayas and are dense, almost impenetrable brakes of one or more species of *Arundinaria* and often no other large woody plants.

4. **High level blue pine forest** is the seral type occurring near the timber line in the Punjab and Kashmir, particularly in the inner drier tracts. Regeneration of blue pine occurs only where the progression is thrown back by new snow or earth slides; otherwise fire gradually displaces it. Good examples of this type are available in the Parbatti valley, Kulu, on moraines and on all aspects on other types of soil.

A summary of the floristic composition of the types is given in table 76.

5. **Chir Pine on Siwalik Conglomerate:** This community develops in the Siwalik when capping of the clay is lost by erosion and the underlying conglomerate comes on the surface. The Chir Pine is of a fairly good quality and its development is very good (Photo 137). Occasionally, some other species like *Anogeissus, Terminalia* , etc. may form a mixture with the Chir Pine but usually the community is pure. The undergrowth in this community is grassy with the common *Sabai* grass becoming quite dominant. The type is developed on steep and percipitous slopes which are a common feature in the Siwaliks.

6. **Chir Pine on the Siwalik Sandstones:** The community of *Pinus roxburghii* develops on sandstone rock of the lower Siwaliks in the Kangra valley at many places. This Chir Pine is ultimately succeeded by *Quercus incana* community and very often *Quercus* trees over-top Chir Pine. The regeneration of Chir Pine is then badly affected and ultimately the community is replaced by the Oaks. However, due to biotic interference such as fire and grazing and the demand for resin, the chir Pine community is allowed to stay on in many places and this seral edaphic type is becoming more or less prominent. Due to grazing and other factors the ground flora is mainly grassy with here and there shrubs of *Berberis.* An account of this is already given by Mohan and Puri (1956).

7. **Chir Pine community in the Middle and Inner Himalayas:** This is developed on quartzite formation in the various Himalayan valleys at elevations from 4,000' to 9,000' (Photo 138). The Chir Pine community is scattered and has got in the second storey at places *Euphorbia, Acacia,* etc. In slightly moist places a good deal of ground flora may develop but usually the quartzite Chir Pine has got a very scanty undergrowth. Similar Chir Pine community may develop on dry lime-stone and a number of cases of both these types often tend to develop into a *Quercus incana* community. However, pure edaphic Chir Pine communities on quartzite are very noticeable.

8. **Silver Fir community on Moraines:** *Abies webbiana* forms a pure community on glacial moraines and in some cases in Kashmir Himalayas such communities are found at as low an altitude as 6,000' in the valleys. Usually this community occurs above an altitude of 9,000'. On account of the peculiar habitat conditions provided by glacial moraines Silver Fir community remains more or less in a permanent condition, regenerating abundantly. However, on disturbance a certain amount of *Pinus excelsa* also comes in and may form a mixed Blue Pine - Silver Fir community. Sometimes when the seepage water from the glaciers above

Table 75.

EDAPHIC TYPES OF THE ANDAMANS.

Sub-type and distribution.	I	II	III	IV
2. (Andaman moist deciduous forest. Throughout Andaman Islands.	*Pterocarpus dalbergioides, Terminalia bialata, T. manii, T. procera, Canarium euphyllum,* etc.	*Lannea grandis, Adenanthera pavonina, Dillenia pentagyna, Diospyros marmorata,* etc. II a. *Oxytenanthera nigrociliata, Bambusa schizostachyoides.*	*Murraya exotica, Atalantia monophylla, Limonia alata. Canthium gracilipes, Ixora grandiflora. Alsodeia bengalensis, Mallotus acuminatus,* etc.	*Ventilago madraspatana, Delima sarmentosa, Buettneria andamanensis, Acacia pennata, Entada scandens, Calamus* spp.

Table 76.

EDAPHIC TYPES OF THE HIMALAYAS.

Sub-type and distribution.	I	II	III
1. Cyperus forest. On dry sites very usually on rocky limestone ground in the N.W. Himalayas in the middle Oak zone.			
(i) Naini Tal, 7,500'.	*Cupressus torulosa* (a).	*Quercus dilatata* (a).	*Abelia triflora.*
(ii) N. Garhwal.	*Cupressus torulosa, Quercus dilatata.*		II a. *Arundinaria falconeri* (lf) I. *A. jaunsarensis.*
2. Dry temperate deciduous forest. Dry zone in the Himalayan temperate deciduous forest.			
(i) N. Garhwal, 8-9,000 ft.	*Corylus colurna* pure.		
3. Temperate, bamboo brakes. Throughout the moist temperate forests of Himalaya.	Dense, almost impenetrable brakes of one or more species of *Arundinaria.*	—	A herbaceous flora.
4. High level blue pine forest. Near Timber line in the Punjab and Kashmir.	*Pinus excelsa.*		

coming into the moraines ceases and the soil conditions become dry the Silver Fir community may develop into a Birch community, examples of which are also found in the Himalayas. It seems, however, doubtful whether this Birch community is a real climatic climax of the glacial moraines.

9. **Deodar Communities in the Himalayas:** Deodar forms pure extensive forest communities on flood plain deposits along the various Himalayan rivers (Photo 139). The altitude of the Deodar communities may vary from 4,000' to 10,000' above sea level and the community occurs both in the zone of high rainfall as well as in the zone of low rainfall in the inner Himalayas. The Deodar community along the Sutlej valley in the Bashahar Himalayas is developed at an altitude of 9,000' to 10,000' and, although, this has been very greatly disturbed and destroyed, huge trees of Deodar are still present in it. The peculiar edaphic conditions provided by the flood plain deposits of the last Ice Age seem to be particularly suited to the development of new Deodar communities.

Besides on flood plain deposits Deodar forms mixed communities on granite and sometimes on Phyllites which are rich in calcium. These communities are variously mixed with other conifers such as Blue Pine, and Spruce. They also have a good admixture of deciduous broad leaved species charactristic of such habitats.

10. **Blue Pine communities on the Karewas of Kashmir:** The Karewas of Kashmir are the old lake deposits, a few thousand feet in thickness and are occurring in the Kashmir valley now in the form of small mounds. These are colonised by *Pinus excelsa*, and this community seems to be particularly suited for the soil conditions provided by these deposits. The Blue Pine is variously mixed with other broad leaved species and sometimes Spruce may be present but Deodar is particularly absent from such habitats.

11. **Forest communities on Dip and Scarp slopes in the Himalayas:** The strata of the rocks in the Himalayas are inclined towards north and north-east, forming huge precipitous escarpments on the south and south-west and gentle dip slopes on the north and north-east. The edaphic conditions on the escarpments are generally not favourable for the growth of luxuriant vegetation or for the development of a mesophyllous community. On the dip slope, however, due to the seepage of water through the strata of the rocks the soil is more moist and comparatively fertile than on the escarpments. These, therefore, bear mesophyllous and mixed communities whose requirements for soil minerals and plant food are heavier. On the similar type of rock Chir Pine and Blue Pine communities develop on escarpments, while Deodar and Spruce and Silver Fir occur on the dip slope. When Oaks and conifers occur together, Oaks form dominant climax communities on escarpment, whereas conifers especially Deodar and Silver Fir form extensive gregarious patches on the dip slope. This relationship is also governed by the composition of the rock. Quartzite is comparatively much poorer in calcium content whereas granite has the maximum calcium from amongst the Himalayan rocks. Schists are somewhere intermediate. Thus, Chir Pine is the dominant feature on escarpments of quartzite and it may occur in mixture with Blue Pine on the dip slope. In the case of schists, Chir Pine and Blue Pine may form mixed communities on the escarpment but Deodar is usually the dominant community on the dip slope. On granite, Chir Pine may not be occurring at all and while the escarpment may have some Blue Pine the dip slope is almost always occupied by luxuriant growth of Deodar. These relationships have been discussed by Puri (1950) from the Himalayas and have been variously extended both to glaciated and non-glaciated parts of these mountains.

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13

BIOTIC FORESTS OF INDIA

Since the times immemorial man and his domesticated animals have acted on vegetation of the country in various ways. Forest clearing for agriculture, pasturing and habitation have been the chief features of man's contact with natural vegetation. There are large areas scattered throughout the country which have been so maltreated in this way that it is not possible even to recognise their natural vegetation. The secondary successions, that started as a result of biotic interference not only owe their origin directly to man but their very preservation in their present state is by biotic control. A reference has already been made in Chapter 3 about the historical nature of some of the Indian forests and a fuller account was given by Misra and Puri (1954) in their book.

The biotic forests are of the following types:—

Dry evergreen forests: The dry evergreen forest of Champion which, is restricted in distribution to the Carnatic coast and the east coast district from Tinnevelly northwards to Nellore in the Madras presidency is clearly a degraded form of an evergreen high forest brought into being by the biota. This is characterised by trees, with thick evergreen coriaceous leaves, between 30–40 ft. high, forming a complete canopy. The forest is a mixed one with a number of spiny and shrubby species in the second storey. Bamboos are mostly absent and grass may be present. These forests owe their origin to biotic factor and are preserved in the present state as a result of selective felling, lopping, fire, etc. The preponderance of the thorny and unplatable species is due to grazing, browsing, etc.

Dry evergreen forest of Sriharikota Island: The dry evergreen type of forest is also found at numerous places both on the east and west coasts. It was studied by Puri (1954) from Sriharikota island on the Western coast above Madras. This forest was developed in the island on sandy soil and had a community of plants dominated by *Calotropis gigantea, Memecylon edule, Maba buxifolia, Strychnos nux-vomica, Feronia elephantum, Garcinia spicata, Ochna squarrosa, Glycosmis pentaphylla, Pavetta indica,* etc.

The ground flora in this type of vegetation is hardly anything. However, patches of *Spinifex squarrosus* (Photo 140) are present here and there.

In slightly moist and clayey soils, a community of *Eugenia jambolana, Albizzia amara, Ficus bengalensis* and *Garcinia spicata* is present. Some grasses and even a fern *Adiantum* sp. are sometimes found in this type of vegetation.

This vegetation is considered to be useless and is being felled to take up the area under *Casuarina* plantations. Extensive plantations of this exotics are being laid both along the eastern coast as well as in the western coast for fuel.

N. Indian tropical secondary moist deciduous forest is distributed in the regions of high rainfall corresponding to semi-evergreen and occasionally evergreen forest in Bengal, Assam and Orissa. The forest is

under varying conditions on abandoned cultivation. It resembles the climax type and has very rarely old trees in it.

Champion has given example of this type of forest from Dhuanali in Orissa. But this type of forest grows throughout the northern India and should be considered as a relict vegetation of a once evergreen type of forest. Most of the trees in this forest have been felled but on account of religious feelings *Ficus bengalensis* and *Mangifera indica* have been left here and there. Other trees which occur among such a forest to-day are *Terminalia chebula, Moringa tinctoria, Zizyphus* species, etc. In such types of vegetation palms have come up naturally and form a conspicuous feature of the landscape. Photo 141 shows a community of *Phoenix* trees growing on dry, sandy, gravelly soil, at Sakalaspur-Hassan road in the Mysore State. There are numerous examples of *Phoenix* communities that are relict vegetation and they can be put under Champion's secondary moist deciduous forest type.

Floristic composition of the types described by Champion are given in Table 77.

These forests are considered to be useless from the economic point of view and are being felled at many places for raising plantations of *Casuarina, Anacardium* and other species. The type is a highly degraded form of evergreen forests and its total destruction and replacement by exotic species may not be wholly desirable.

Thorn forests of India are dominated by *Acacias* and other trees with thorns and *Euphorbias*. They are usually in areas of low rainfall or rocky soils, and always where the pressure of the biotic factor had been very intense since centuries. These are degraded from the tropical dry deciduous types, in the preservation of which biotic factors play a more important role than climate and soil. Champion divides these into southern and northern forms, though, there is not much difference in the two forms floristically or in physiognomy.

Southern thorn forests are distributed in parts of Madhya Pradesh, Bombay, Madras, Mysore in areas of low rainfall on dry lateritic, basaltic, granitic rocks and poor soils. The forest is characterised by species of *Acacia* with an open growth. The crowns of trees are spreading but do not meet. Trees usually have a height of 20–30 ft. Second storey is very poorly developed, consisting of spiny and xerophytic species. Shrubs of similar nature are present. The soil is usually bare and some grassy growth may appear during the short monsoon. The few climbers that are present have xerophytic features. Such forest types are clearly the result of biotic features of browsing by sheep, goat, camel, etc.

A summary of floristic data of this type of forest is given in table 78 after Champion.

Thorn forests of Dhond: The thorn forests at Dhond are typical of the Bombay State. They are truly biotic forests that have been brought into existence by felling, grazing and lopping. They were extensively studied recently by Puri and Jain (1957). At Dhond proper they are formed of *Acacia arabica, Capparis decidua* and *Capparis zeylanica* forming a closed forest. *Zizyphus jujuba* and *Cassia auriculata* are shrubs. In the ground flora are present *Eclipta alba, Setaria intermedia, Paspalidium flavidum* and *Digitaria marginata*. In heavily grazed areas patches of *Corchorus* and *Xanthium* are present.

The area produces a fairly good grassland and a small plot of land adjoining the forest which has been closed by the Forest Department has got a better development of vegetation. In this closed area the following

Table 77.

TROPICAL DRY EVERGREEN FOREST.

(Described by Champion from the given localities and now arranged under Biotic Forests).

Sub-type and distribution.	I	II	III	IV
Restricted to the Carnatic coast from Tinnevelly northwards to Nellore in Madras.				
(i) General.	*Mimusops hexandra, M. elengi, Diospyros ebenum, Strychnos nux-vomica, Eugenia* spp.		*Memecylon edule.*	
(ii) Nagavera IV, S. Cuddapah, Madras.	*Mimusops hexandra, Canthium didymum, Zizyphus xylopyrus, Acacia leucophlaea, Randia dumetorum, Buchanania angustifolia, Strychnos nux-vomica, S. potatorum, Sapindus emarginatus, Diospyros chloroxylon,* etc.	*Carissa carandas, Flacourtia sepiaria, Maba buxifolia, Grewia* spp., *Dodonaea viscosa, Gymnosporia* spp., *Ixora parviflora, Webera* sp.	*Strobilanthes* sp. III a. Grass light.	*Derris scandens, Asparagus* sp., *Acacia intsia, Pterolobium indicum, Zizyphus oenoplia, Combretum* sp. Climbers abundant.
2S/6(b). N. Indian Tropical secondary moist deciduous forests, Bengal, Assam and Orissa.				
(i) Dhuanali, etc. Puri division, Orissa.	*Mangifera indica, Anthocephalus cadamba, Alstonia scholaris, Dillenia pentagyna, Schleichera trijuga, Terminalia tomentosa,* etc.	*Miliusa velutina, Glochidion lanceolarium, Careya arborea, Zizyphus xylopyrus, Bambusa arundinacea,* etc.	*Glycosmis pentaphylla, Psychotria adenophylla, Maba buxifolia,* etc.	*Combretum decandrum, Bauhinia vahlii.*

Table 78.

SOUTHERN THORN FOREST.

(Champion considered these as climax types but these are now included by the author under biotic types.).

Sub-type and distribution.	I	II	III	IV
1. Southern Cutch Thorn forest. In Central India throughout the dry peninsulartract tothe lee of the W. ghats, except on south coastal tracts.				
(i) Panapakam, Chitoor division, Madras.	*Albizzia amara, Acacia sundra, Azadirachta indica, Cassia fistula, Albizzia odoratissima, Randia dumetorum, Anogeissus latifolia,* etc.		*Carissa carandas, Canthium didymum, Strychnos* sp., *Dodonaea viscosa, Cassia auriculata,* III a. *Aristida, Heteropogon contortus.*	*Zizyphus* spp.
(ii) C. Salem, Madras.	*Chloroxylon swietenia, Albizzia amara, Acacia sundra, A. ferruginea, Azadirachta indica, Canthium didymum, Erythroxylon monogynum, Zizyphus jujuba, Z. xylopyrus,* etc.			
(iii) Lontak, Amraoti division, Berar.	*Acacia leucophlaea, A. arabica, Balanites roxburghii, Cordia myxa.*	*Dichrostachys cinerea, Phoenix humilis, Gymnosporia* sp., *Zizyphus jujuba.*	*Mimosa hamata, Calotropis procera, Heteropogon contortus.*	*Pergularia extensa. Cardiospermum. Zizyphus oenoplia, Lantana.*
(iv) Dharwar-Bijawar division, S. Bombay.	*Acacia catechu, A. leucophlaea, A. arabica, Aegle marmelos, Chloroxylon swietenia,* etc.	*Carissa* spp., *Cassia auriculata, Dodonaea viscosa, Opuntia.*		
(v) Dhond, Poona, division, C. Bombay.	*Acacia arabica, A. latronum, Capparis spinella, C. horrida.*	*Mimosa hamata, Cassia auriculata.*	*Aristida, A. funiculata, Andropogon contortus.*	
Carnatic umbrella thorn forest. Madura and Tinnevelly districts in S. Madras.	*Acacia planifrons, Albizzia amara.*	*Acacia latronum, Dichrostachys cinerea, Chloroxylon swietenia.*	—	
Southern Euphorbia semi-desert scrub scattered throughout the type usually on the shallowest and poorest sites. (i) krishnagiri Madras.	*Euphorbia tirucalli, Capparis* sp.	*Dodonaea viscosa, Cassia auriculata.*		

plants attain a height of 0.1 meter to 0.5 meter: *Justicia quinqueangularis, Rungia elegans, Acalypha malabarica, Tridax procumbens, Phyllanthus maderaspatensis, Commelina forskalii, Brachiaria isachne, Sporobolus* species, *Eclipta alba, Flaveria contrayerba.*

The following are the prostrate or decumbent: *Merremia emarginata, Phaseolus trilobus, Rhynchosia minima, Aristida funiculata, Brachiaria isachne, Ruellia patula, Indigofera linifolia, Alternanthera echinatus, Indigofera cordifolia.*

There are about 10 species of grasses of which *Brachiaria isachne* is the most abundant. Other common grasses are: *Urochloa helopus, Aristida adscensionis, Aristida funiculata, Tripogon jacquemontii, Nazia racemosa* and *Sporobolus diander.*

Thorn forests of Walhe and Trap hills near Khadakwasla: These forests, also studied by Puri and Jain (1957), consist of *Acacia arabica, Acacia catechu* with heavily lopped, coppiced and malformed trees of teak, *Terminalia tomentosa,* etc. The spiny shrubs are *Carissa congesta, Gardenia turgida, Zizyphus* species; and grasses are a dominant feature of this vegetation especially developed on the flat portion of the hills. *Lantana camara* has invaded this area and is growing rapidly. In some of the places where no vegetation occurs *Lantana* forms dense plant communities. The growth of grasses on the top is very dense, most of the species growing upto 2 to 3 meters height. *Apluda aristata* and *Cymbopogon martini* are the tallest and the commonest grasses. *Heteropogon contortus, Sehima sulcatum* and *Themeda quadrivalvis* are the associated species in these grasslands.

The vegetation of Walhe is very greatly degraded and only very few trees or shrubs are found. The outcrops of rock are conspicuous among which small patches of *Aristida funiculata, Melanocenchrus jacquemontii,* and *Commelina forskalii* are the most common plants. The only shrub found here and there which has escaped grazing is *Cassia auriculata. Indigofera cordifolia* and *Tridax procumbens* are present between the boulders and rocks. Other commonest herbs present in this area are *Zornia diphylla, Glossocardia linearifolia, Evolvulus alsinoides, Boerhaavia diffusa* and grasses such as *Heteropogon contortus, Andropogon pumilus* and *Chrysopogon montanus.*

Thorn forests of Khandesh: Thorn forests are scattered all over the Satpudas in Khandesh. They are developed on the trap hills in areas which are very badly grazed and lopping of trees is regularly practised. All stages of degradation of the thorn forests were studied by Puri and Mahajan (1958). In the Laling Kurans, which are situated near Dhulia, a poorly developed community in which *Acacia catechu, Mimosa hamata* predominate, is present. *Euphorbia nivulia* clumps are extremely abundant (Photo 142) and *Dichrostachys cinerea* is prevalent. *Flacourtia latifolia* and *Zizyphus rotundifolia* are other shrubby spiny species. The following grasses were abundant in the undergrowth: *Andropogon annulatus, Andropogon pumilus, Aristida funiculata, Aristida setacea, Apluda aristata, Eleusine aegyptiaca, Heteropogon contortus, Cymbopogon martini, Eragrostis amabilis, Pennisetum* sp., *Sporobolus* sp., *Arthraxon* sp., *Chrysopogon* sp., etc.

Next to the grasses in abundance are the Legumes belonging to the species of *Indigofera cordifolia, Cassia tora, Alysicarpus, Desmodium. Tridax procumbens* and *Eclipta erecta* are common species in the open rocky places and in grasses.

In the moist places, masses of *Chlorophytum* with conspicuous white flowers are present (photo 143). There are several species of *Chlorophytum,* viz., *C. tuberosum, C. attenuatum, C. laxum and C. undulatum.* Another plant worth mentioning in this area is *Cleome viscosa* which shows a tremendous range of morphological variations.

Semi-desert vegetation of the Anamalai Hills: Fischer (1921) has described the flora of the Anamalai hills in the Coimbatore district. The semi-desert type occurs in the low eastern region in the Amravati valley between an altitude of 900–1,500 ft. He describes it as follows:—

This type is characterised by such plants as:— *Cocculus pendulus, Polycarpaea corymbosa, Portulaca wightiana* (among rocks), *Pavonia procumbens, Commiphora berryi, Pyrenacanthus volubilis, Vitis quadrangularis, Rothia trifoliata, Crotalaria medicaginea, Indigofera marginulata, Pterolobium indicum, Acacia latronum, Acacia planifrons, Dichrostachys cinerea, Vahlia viscosa,* and abundance of *Opuntia dillenii, Gisekia pharnaceoides, Coffea wightiana, Sphaeranthus amaranthoides, Mimusops hexandra, Salvadora persica, Heliotropium zeylanicum, Solanum trilobatum, Barleria noctiflora, Geniosporum prostratum, Euphorbia dracunculoides, Euphorbia antiquorum, Hemicyclia sepiaria,* etc.

A forest of *Acacia sundra* in Mangalore, Madras is shown in Photo 144. It is typical of a southern thorn forest.

Northern Thorn forests: The northern thorn forests are distributed in the deserts of Rajasthan, Saurashtra, and desert like areas in the Punjab, Cutch and Uttar Pradesh. These forests like their southern counterparts are biotic-controlled but are much poorer in species than those. The main species are *Acacias* but they are less predominant and are mixed with *Euphorbias,* forming large clumps. The regeneration of the dominant species is mostly by root sucker and they tend to occur in clumps. *Prosopis, Capparis, Salvadora, Gardenia,* etc. are some of the characteristic species. Climbers, though more numerous than the southern forms, are also adapted to xerophytic and the biotic conditions. As a matter of fact the xerophytism in the vegetation is largely brought about by the adverse biotic factor. The dwarfness in some of the plants is also due to this. There is hardly any ground flora excepting a thin grassy growth during rains. The chief floristic features are given in table 79.

Euphorbia Scrubs: *Euphorbia* scrubs occur in many parts of India including Bombay, Deccan, Rajasthan, Cutch, Khandesh, etc. These form large clumps and may either be occurring more or less pure, or with a number of other species, e.g., *Acacia, Carissa, Capparis, Prosopis, Gymnosporia, Grewia,* etc. The undergrowth of the ground is always grassy and numerous climbers are always found on the *Euphorbia* clumps. Photos 145 to 149 give different types of *Euphorbia* clumps from different regions of the country. Although, these clumps are occurring on different types of rocks and soils and in different conditions of climate, the uniform environmental condition for all these is biotic interference, which is intense grazing and cutting away of all other types of vegetation.

Scrubby Vegetation of Kathiawar: In Kathiawar there are three chief places famous for their vegetation viz., Gir, Ginnar, and Barda. Barda mountain chain is equally distributed in states of Jamnagar and Porbandar. The four highest peaks in Porbandar are Malik, the Kalo, the Sath Bagadi, and the Ghelansar, which are volcanic in origin. The vegetation in the entire area has been so greatly disturbed that there are hardly any places with a natural covering of plants.

The scrubby vegetation is characterised by *Cocculus villosus, Polycarpaea corymbosa, Bergia odorata, Grewia villosa, Zizyphus rotundifolia, Mimosa hamata, Justicia heterocarpa, Panicum flavidum,* etc. The chief grasses are *Schima nervosum, Chrysopogon polyphyllus, Digitaria pennata, Sporobolus virginicus,* etc.

Climbing plants are well represented. The characteristic species are of the families Convolvulaceae, Leguminosae, Asclepiadaceae, etc.

Table 79.

NORTHERN THORN FORESTS.

(Considered by Champion as climax types and included here under biotic forests).

Sub-type and distribution.	I	II	III	IV
Northern desert thorn forest. Rajputana. Northern *Acacia* scrub forest. Northern India wherever rainfall is between 20" & 40".	*Euphorbia* sp., *Acacia* sp., *Prosopis spicigera, Salvadora oleoides.*	*Capparis aphylla, Gardenia turgida,* etc.		
(i) Fisher Forest Etawah.	*Prosopis spicigera, Balanites roxburghii, Salvadora oleoides, A. arabica.*	*Capparis aphylla, Zizyphus jujuba, Acacia leucophlaea.*	*Carissa spinarum, Adhatoda vasica.* III a. *Aristida adscensionis, Andropogon contortus, A. foveolatus, Chloris virgata,* etc.	
(ii) Palamau division, Bihar.	*Acacia catechu, Stereospermum suaveolens, Boswellia serrata.*	*Gardenia turgida.*	*Woodfordia floribunda. Carissa paucinervia.* III a. *Pennisetum setosum.*	
Northern *Euphorbia* scrub. Rajputana.	*Euphorbia* sp., *Capparis aphylla,* etc.	*Prosopis spicigera,* etc.		

Sand dunes bear *Bergia odorata, Corchorus antichorus, Calotropis procera, Asparagus dumosus, Aerva javanica, Euphorbia hypericifolia,* etc. Sandy soil is clothed with *Polycarpaea spicata, Indigofera cordifolia, Cassia obtusa, Cucumis trigonus, Eclipta erecta, Aerva lanata,* etc.

Scrubby vegetation of Dwarka: Borgesen (1929) has studied vegetation along the West coast of India at Dwarka. He found the following plants on dry flats:

Euphorbia neriifolia.
Capparis galeata.
Senra incana.
Lycium europaeum.
Atriplex stocksii.
Lepidagathis trinervis.
Taverniera nummularia.
Indigofera pauciflora.
Suaeda nudiflora.
Statice stocksii.
Corchorus antichorus.
Cucumis prophetarum.
Linaria ramosissima.
Boerhaavia repens.
Fagonia arabica.
Cocculus microphyllus.
Ipomoea biloba.
Cressa cretica.
Heleochloa dura.
Sporobolus arabicus.
Cyperus conglomeratus.
Justicia simplex.
Launaea glomerata.
Polycarpaea corymbosa.
Portulaca quadrifida.
Pulicaria vulgaris.
Eragrostis ciliaris.

This vegetation seems to show similarity to the Canarian vegetation from the dry flats and hills and to the Mediterranean region not only as to the physiognomy but also to the composition of the flora on the whole. It is also well known that the eastern limit of the Mediterranean flora reaches the dry region in the north of India.

Scrubby vegetation of Bet Dwarka: Bet Dwarka is an island about a mile off the Saurashtra coast on the west of Okha.

The vegetation of this area was recently studied by Puri and Vasavada (1957). It is scrubby composed mainly of a community of *Acacia leucophlaea - Acacia arabica - Grewia populifolia. Salvadora persica, Prosopis spicigera, Euphorbia tirucalli* are also present here and there.

Amongst the second storey plants are *Euphorbia neriifolia* Dalz., *Flacourtia latifolia* Cooke, *Grewia tiliaefolia* Vahl., *Capparis aphylla* L., *Gymnosporia montana* Benth., etc.

The common climbers are *Gymnema sylvestre, Asparagus racemosus,* and *Ephedra,* members of the family *Cucurbitaceae* etc. Amongst the spreading plants *Ipomaea biloba* Forsk. and species of *Solanum* are common.

The ground flora consists of many herbs, the chief amongst these being *Solanum nigrum* L., *Fagonia cretica* L., *Sonchus arvensis, Aloe vera, Vicoa, Barleria prionitis, Boerhaavia* sp., *Hibiscus* sp., etc.

Since the island is raised from the surface of the sea, the vegetation is both of the coastal and inland types.

The vegetation at Dwarka is slightly different since the locality is on the sea level. In inland there are almost no trees. The common shrubs are *Euphorbia neriifolia* Dalz. and *Capparis aphylla* Linn.

The ground flora are mainly made up of *Fagonia cretica* L., *Arthrocnemum indicum, Cynodon dactylon* Pers., etc.

Arthrocnemum indicum is seen forming pure communities on the saline soil of the shore (Photo 150) and *Fagonia* is likewise common (Photo 151).

Here and there a branched palm - *Hyphaene thebaica* Mart. is found growing.

Thorny scrub Jungle of Cutch: The thorny scrub jungle is the commonest type of vegetation in Kutch (Photo 152).

In areas protected from heavy grazing and lopping, shrubs of *Acacia senegal, Acacia leucophlaea, Balsamodendron mukul, Capparis* sp., *Balanites roxburghii, Grewia populifolia, Euphorbia nivulia* and *Premna integrifolia,* are common (Photo 153). The growth is quite dense and the number of climbers is good. *Tragia, Rivea, Tinospora, Vitis,* and *Peristrophe* commonly grow. *Apluda* is the most abundant grass.

In some rocky tracts where soil is shallow and poor, *Cassia-Butea* community is frequently met with. In Saline tracts, *Salvadora* and *Tamarix* grow most frequently and this is one of the commonest types in areas nearer the coast.

Scrub vegetation of N. India: Scrub forests of N. India are degraded forms of different types of forests. Champion classifies these into the following types:—

1. **Dry deciduous scrub:** mainly distributed in the Punjab, locally in Uttar Pradesh, Bihar and Orissa. It consists of about 10–20 ft. high shrubby growth which may also include some tree species reduced to similar conditions, usually many stemmed from the base. Some bamboo may also be present. Many shrubs like *Holarrhena, Dodonaea,* being distasteful to cattle occur in this type. Thin grass occurs throughout. The stunted condition of vegetation and the low broken soil cover is due to maltreatment, usually directly or indirectly, connected with grazing, etc.

2. **Lower blue pine forest** is distributed in the whole length of the Himalayas, generally in the Punjab at all elevations from 6,000 ft. to about 12,000 ft. The type overlaps the whole coniferous belt except the lower chir pine and sometimes the top of the fir and extending well into the dry zone. It tends to occupy relatively xerophytic sites which may have been so due to various causes, such as eroded land, landslips, avalanche paths, abandoned cultivation, burns, over-felled, or over-grazed areas, etc. Although, fire is destructive to the bluepine itself, it is an important factor which tends to maintain the type in its present status. These forests are more or less even-aged, with strongly predominating blue pine. Usually they have very little undergrowth. There is a good deal of scrub growth of *Berberis, Indigofera,* etc. on the southern slopes, especially when the area is open. The associated species including all the conifers and many broad-leaved evergreen and deciduous trees vary greatly due to the great range of altitude occupied by the type.

3. **Oak scrub** is distributed in the lowest portion of the temperate belt, particularly in the outer ranges and on southern aspects of the Himalayas. Its distribution is that of the Ban-oak type with local extensions into the middle oak zone. Soil is usually badly eroded and often completely stripped. The oak is reduced to low stunted unsound trees, of coppice origin due to intense lopping for fodder and litter removal, combined with a continuous grazing and fuel and pole felling. With the oak there are *Rhododendron arboreum* and *Pieris ovalifolia* and bushes of *Berberis* sp., *Crataegus, Prinsepia* and sometimes *Spiraea, Indigofera, Wikstroemia,* etc. Short grass with some *Pteridium aquilinum* on deeper pockets cover the soil, where it is not completely exposed by trampling.

4. **Secondary temperate scrub** is distributed throughout the temperate forest on the site of abandoned shifting cultivation, on burnt areas, especially on southern aspects, on excessively grazed and lopped areas near villages and on similar sites. The type is an extensive scrub cover which is irregular and often dense with a few species predominating. Bushes of *Berberis, Prinsepia, Indigofera, Cotoneaster,* etc. form the characteristic soil cover of this type.

5. **Thach park land** is distributed throughout the upper, the middle and the uppermost of the lower oak forests of the Himalayas. The type is derived from the temperate deciduous forest by grazing, lopping, and burning which destroys all its undergrowth except for patches of inedible species, and replaces the shrubby ground cover by a close grassy turf. The type is an open park like land with scattered large, mis-shapen and often moribund trees. There are often also browsed clumps of *Berberis, Lonicera, Arundinaria, Cotoneaster* or patches of inedible shrub such as *Viburnum foetens* and herbs such as *Iris* and *Osmunda.*

The floristic data of the types are given in table 80 after Champion.

Scrub Vegetation of the Himalayas: For the last several centuries the Himalayas have been subjected to shifting cultivtion and one recognises at many places conifer forests which are developed on terraced fields that have been abandoned by one reason or the other. These communities which are mostly formed of *Pinus excelsa,* are secondary and show at some places seedlings and saplings of oaks; but their succession to oak climax is prevented by continued grazing in the area and oaks being cut, fodder species are eaten up and are not allowed to grow into big forest. Similarly, deodar and chir-pine communities occur in the Himalayas, the origin of which is biotic. Some blue-pine or deodar communities are relicts since they show among them large sized trees of *Rhododendron,, Pieris* and such other species which constitute oak associates in climax conditions.

Puri (1950) has studied these from Kulu Himalayas and recently Mohan and Puri (1955) from the Bashahar Himalayas, and Puri and Maini (1957) from the Chakrata Himalayas have studied these types. The following descriptions of some of the important communities from the Bashahar Himalayas is given from the above paper of Mohan and Puri:—

Open Pasture: In a part of the forest, which has been cleared for cultivation in the past but has since been abandoned, a pasture community has developed. In this, a large number of seedlings and saplings of *Pinus excelsa* are present at places where grazing is not intense. In the grassy undergrowth the following species are recorded:

Anemone rivularis, Achillea spp., *Brunella* sp., *Cynoglossum* sp., *Geranium* sp., *Galium* sp., *Medicago* sp., *Mellilotus* sp., *Impatiens* sp., *Indigofera* sp., *Pteridium aquilinum, Potentilla* sp., *Origanum* sp., *Gnaphalium* sp., *Oxalis corniculata, Rumex* sp., *Thymus* sp., *Viola* sp., *Viburnum cotinifolium, Plantago major,* etc. Most of these species are not present in the silver fir communities from which the pasture has been derived.

Pinus excelsa Secondary Community: This Community represents a secondary succession on abandoned cultivated soils which are usually dry and poor. Originally these soils represent scree masses. The blue pine community has at some places trees of spruce, and seedlings of both spruce and pine are present in varying amounts. There are a large variety of shrubs some of which show the intensity of grazing and fire. The undergrowth is mainly grassy with *Pteridium* and *Salvia glutinosa.* Patches of *Iris* are present here and there. In grassy undergrowth *Fragaria, Galium, Geranium, Anemone, Thalictrum, Ainsliaea,* etc. are found in situations with slightly different moisture contents.

At some places in blue pine communities seedlings and saplings of oak have been found, thereby indicating that these are seral stages tending to progress to the climax oak.

Secondary Scrub Community (Dry Type):— In places where *Quercus incana* has been very badly treated and the soil is too rocky and dry for occupation by oaks a scrubby vegetation results. One type was

Table 80.

FLORISTIC FEATURES OF SCRUB VEGETATION OF N. INDIA

(described by Champion under Edaphic types and now included under biotic forest types).

Sub-type and distribution.	I	II	III	IV
Dry deciduous scrub forest.				
Mainly in the Punjab, locally in the U.P., Bihar and Orissa.				
(i) Kangra division, Punjab.	*Nyctanthes arbor-tristis, Dodonaea viscosa, Woodfordia, Carissa spinarum, Flacourtia ramontchii, Lannea grandis, Cassia fistula, Acacia catechu,* etc.			
(ii) Sambalpur W. division, Bihar and Orissa.	*Chloroxylon swietenia, Acacia catechu, Zizyphus xylopyrus, Gardenia gummifera, G. turgida, G. lucida, Boswellia serrata,* etc.			
Lower blue pine forest.				
The whole length of the Himalaya.				
(i) Dharan,, L. Bashahr division.	*Pinus excelsa, Morinda.*	*Picea Juglans regia, Acer caesium.*	*Cotoneaster bacillaris, Rosa macrophylla, Lonicera angustifolia, Desmodium tiliaefolium, Rubus niveus, Berberis lycium, Indigofera gerardiana.*	*Anaphalis* sp.,*Geranium wallichianum, Galium* sp., *Fragaria vesca, Ainsliaea aptera, Valeriana, Carex* sp., *Adiantum,* etc.
(ii) Sapni near Kilba, U. Bashahr division.	*Pinus excelsa.*	Nil.	*Spiraea sorbifolia, Desmodium tiliaefolium, Viburnum cotonifolium, V. nervosum, Berberis* sp., *Rubus niveus,* some seedlings of *Cedrus deodara* and *Taxus baccata.*	*Fragaria vesca, Salvia glutinosa, Ainsliaea aptera, Galium* sp., *Impatiens, Viola patrinii, Carex* sp., *Adiantum venustum, Clematis montana.*

(iii) Udhampur division, Kashmir.	*Pinus excelsa, Cedrus deodara.*	*Quercus incana, Rhus succedanea, Quercus dilatata, Pyrus pashia, Populus ciliata.*	*Sarcococca pruniformis, Prinsepia utilis, Viburnum nervosum, V. cotonifolium, Daphne cannabina, Berberis lycium, Spiraea canescens, Cotoneaster bacillaris,* etc.	*Fragaria, Viola, Geranium wallichii, Adiantum, Hedera helix, Rosa moschata.*	
(iv) Chamba.	*Pinus excelsa.*	*Parrotia jacquemontiana.*			
Oak scrub.					
That of ban-oak type.	Oak reduced to low stunted unsound trees, often of coppice origin.			Short grass.	
Secondary temperate scrub.					
Throughout the temperate forest on the site of abandoned cultivation.					
(i) W. Almora.	*Quercus incana.*	*Berberis lycium, Spiraea canescens, Prinsepia utilis, Indigofera gerardiana, Crataegus crenulata, Pyrus pashia.*			
(ii) Jaunsar.	*Quercus incana.*	*Indigofera gerardiana, Cotoneaster bacillaris, Berberis lycium,* etc.			
(iii) Naini Tal.	*Quercus incana.*	*Plectranthus rugosus, Berberis asiatica, Crataegus crenulata.*			
(iv) Sikkim.	Oak-hemlock.	*Piptanthus nepalensis, Rosa sericea, Berberis,* sp. *Elsholtzia* sp.			
Thach Park-land.					
Throughout upper, middle and upper most of lower oak forests of Himalaya.	*Prunus padus, Acer* spp., *Juglans regia,* etc.	*Berberis, Lonicera, Contoneaster,*	*Arundinaria, Viburnum foetens.*	*Rumex nepalensis, Iris, Osmunda, Cannabis sativa, Boerhaavia, Chenopodium,* etc.	

seen near Sarahan on a rocky soil formed by blocks of granite and quartzite. The scrubby vegetation was dominated by *Desmodium floribundum* with some *Desmodium tiliaefolium, Cotoneaster bacillaris, Leptodermis lanceolata, Deutzia staminea, Buddleia paniculata, Withania coagulans, Plectranthus rugosus*, etc. Here and there in slightly moister situations an odd tree of *Quercus incana, Pyrus pashia, Morus alba*, and shrubs of *Indigofera* were present. In areas where terraced walls of old cultivated fields were recognized shrubs of *Berberis lycium, Rosa macrophylla, Prinsepia utilis* and *Rhamnus virgatus* were found. Here and there seedlings of blue pine were present. This community is no doubt a degenerate *Quercus incana* forest.

Secondary Scrub Community (Moist type): A moist secondary scrub community developed at many places above Sarahan is composed of scattered trees of *Prunus padus, Populus ciliata, Salix wallichiana, Cedrela serrata, Pieris ovalifolia* and rarely *Quercus incana*. Patches of *Iris nepalensis* and Balsam are present in the moist soil and scattered plants of *Aquilegia, Anemone biflora, Geranium wallichianum, Viola canescens* and ferns are present. There is no doubt that such communities are degenerate oak forests and are preserved in their present state by the intense biotic factor.

Degenerate Quercus ilex Scrub: When *Quercus ilex* is heavily felled and the soil is too rocky, a scrub vegetation of *Desmodium floribundum, Plectranthus rugosus, Artemisia* sp. with scattered trees of *Pinus gerardiana* and *Quercus ilex* becomes prominent. This community no doubt represents a secondary succession and its persistence in its present stage is due to the biotic interference.

Savannah vegetation: Savannah are scrubby degraded forests in plains of India. These are generally degraded from the riverain forests and are occurring on old alluvia. These are classified by Champion into the following main types:—

1. **N. Indian upper alluvial Savannah** is distributed throughout the Gangetic plains including the lower Brahmputra valley. The type is an open degraded *sal* forest in which *sal* occurs in groups with scattered *Lagerstroemia parviflora, Lannea grandis, Adina cordifolia* and *Bombax*. The grasses are heavy and include *Anthistiria gigantea, Saccharum narenga, Andropogon nardus*. etc. This type has been included in the moist *sal* type by various authors and is also known as *sal* savannah.

2. **N. Indian lower alluvial Savannah** has a similar distribution as to No. 1. It occurs on the more stable riverain flats where the soil is mainly sandy with local clay patches and is subject to occasional floods with a tendency of water logging during rains and of remaining dry during rest of the year. Loamy soil usually forms a thin surface layer. Frost is not uncommon and fires usually sweep through annually. The type consists of scattered trees of certain fire hardy species, such as *Bombax malabaricum, Adina cordifolia, Lagerstroemia, Lannea grandis*, etc. which are often of quite good height. Grasses are tall and dense and include *Anthistiria, Erianthus, Saccharum*, etc. Patches of shrub growth of fire hardy species, such as *Zizyphus jujuba* also occur.

3. **Dry Savannah** is distributed throughout the dry deciduous forests, in which trees occur singly or in small groups, with a heavy grassy under-growth. The trees are usually crooked, unsound and hollow and have very short boles. The characteristic species of this type is stemless *Phoenix*; and thorny shrubs are common. Certain fire resistant plants also occur. Over exploitation, heavy grazing and usual annual burning are the regular features of this type.

4. **Nilgiri subtropical hill Savannah** is chiefly distributed on the slopes of the Nilgiri and Palni hills of Madras between 3,500 and 5,500 ft. The rainfall is well distributed and is more than about 60 inches. Burning of the forest is done usually annually. The type is an open savannah forest with almost all deciduous scattered trees and fire hardy shrubs and tall coarse grass even 6–10 ft. high. The characteristic species of the type is *Phoenix humilis*.

The floristic composition of all the above savannah types is given in table 81.

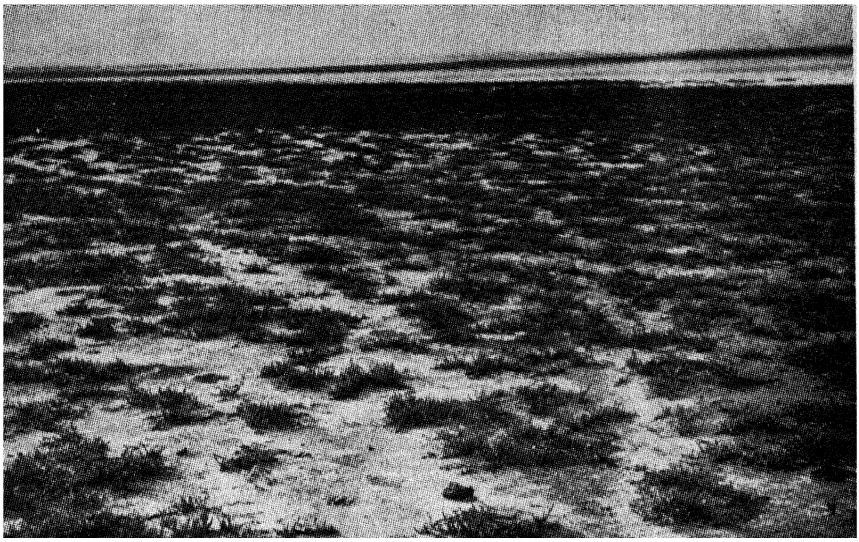
Ecological status of savannah in India: There are no true Savannah types of vegetation in India and the term is certainly a misnomer. Just as there are no true grasslands in India, similarly Savannah are degraded high forest communities in which all sorts of mal-practices exist. These are chiefly grazing, lopping and felling and the areas are open to numerous types of weeds, the seeds of which are spread by grazing animals and are abundant in grasses. At best the Savannahs can be considered as relict communities which may be only biotic or bio-edaphic and not climatic. On account of the persistence of the biotic interference the seedlings of main tree species are destroyed as and when they grow, and the ground gets colonized by shrubby and spiny species which are not generally eaten by cattle. These are mainly *Zizyphus* species and plants like *Holarrhena, Ehretia,* etc. The presence in such communities of big trees of *Shorea robusta, Adina cordifolia* or *Lagerstroemia parviflora* has misled several workers in India to presume that the Savannahs constitute a developing sere. These big trees are in fact remnants of the once high forest occurring in the localities where these are found. Along the main river systems river erosion assists in the formation of Savannah lands by uprooting several trees and by killing much of the vegetation by flooding. Erosion and deposition go side by side and once the area has been heavily eroded it receives some new deposits on which grasses and shrubby plants, whose seeds are transported by water, begin to grow. Photo 154 shows the effect of erosion on a forest which as indicated by the board on the tree was not long ago away from the river bank and now only in the course of a year or two, erosion has converted good high forest into something like Savannah. This area will now gather some sand and humus in the next flood on which different species will begin to grow and the area will be converted into something like Savannah. The afforestation or conversion of such areas into high forest becomes a very great problem since erosion and deposition of soils by water erosion creates very much different soil conditions and the coming in of the same species which were existing in the area before, becomes impossible. It is on account of these features that these types of degraded biotic or bio-edaphic communities have taken the name of Savannah.

Desert vegetation of India: Desert conditions have developed in India, as elsewhere, in areas of low rainfall and very low water table. In map (fig. 50) of the arid regions of the world a large part of north India is shown as an arid tract. It was only after the second world war that the study of desert regions of the world came into prominence. In a recent discussion (Hora, 1952) held in the symposium on Rajputana desert, it was pointed out that no scientific data have so far been adduced, which could point to the spread of the desert and that the Planning Commission's view that the Rajasthan desert is encroaching on 50 square miles of fertile land every year does not hold much scientific ground. As regards the deterioration of the desert conditions there is a considerable historical, archaeological and to a certain extent geological evidence to show that the desert conditions have been deteriorating in the past and that this process instead of being checked has continued more markedly during the recent past.

Table 81.

SAVANNAH FOREST TYPES INCLUDED UNDER THE BIOTIC FORESTS.

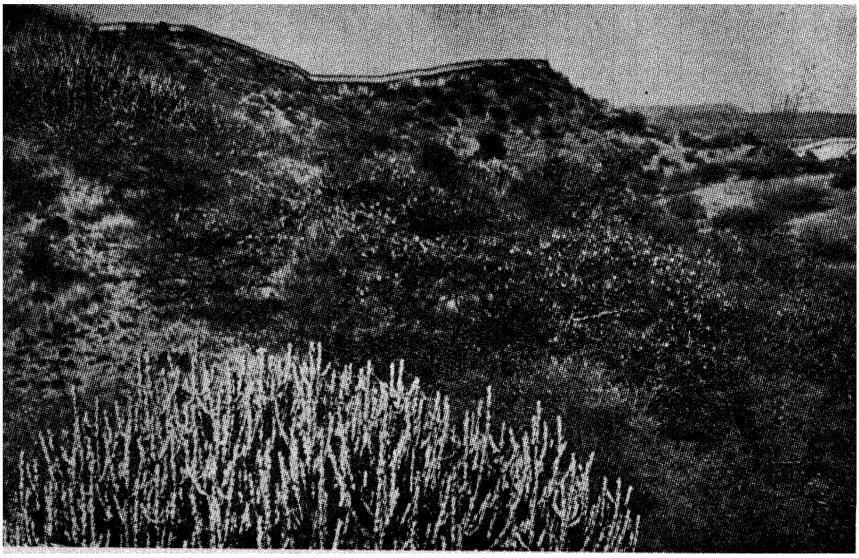
Sub-type and distribution.	I	II	III	IV
(a) North Indian Upper alluvial Savannah forest.				
Throughout the Gangetic plains including L. Brahamputra valley.	*Shorea robusta, Lagerstroemia parviflora, Lannea grandis, Adina cordifolia, Bombax,* etc.	—	—	*Anthistiria gigantea, Saccharum narenga, Andropogon nardus.*
(b) N. Indian Lower alluvial savannah forest.				
Throughout the Gangetic plains including the Brahamputra valley.				
(i) Haldwani (U.P.)	*Bombax malabaricum, Adina cordifolia, Lagerstroemia parviflora, Lannea grandis, Acacia catechu, Holoptelea integrifolia.*	*Cassia fistula, Ehretia laevis, Holarrhena antidysenterica. Zizyphus xylopyrus, Butea frondosa, Bauhinia* spp.	*Zizyphus, jujuba, Helicteres isora, Andropogon muricatus, Saccharum narenga, Anthistiria gigantea, Imperata arundinacea.*	*Vallaris heynei, Cryptolepis buchanani.*
(ii) Bengal Duars.	*Bombax malabaricum, Albizzia procera, Dillenia pentagyna, Terminalia bellerica, Gmelina arborea.*	*Eugenia operculata, Careya arborea, Sterculia villosa, Callicarpa arborea.*	*Zizyphus jujuba.* IIIa. *Saccharum procerum, Erianthus elephantinus, Anthistiria gigantea, Saccharum spontaneum, S. nardus,* etc.	——
Dry Savannah forest.				
Throughout dry deciduous forests.				
(i) *Shorea talura* Savannah, Madras.	*Shorea talura, S. tumbugaia, Pterocarpus santalinus, P. marsupium, Anogeissus latifolia, Diospyros melanoxylon.*	—	*Phoenix humilis.* Dense grass.	
Nilgiri subtropical hill Savannah.				
On the slopes of the Nilgiri and Palni hills of Madras 3,500′ to 5,500′.	*Dalbergia latifolia* (lower levels), *Anogeissus latifolia,* (lower levels).	*Phyllanthus emblica, Wendlandia* spp., *Olea dioica.*	*Phoenix humilis.*	——



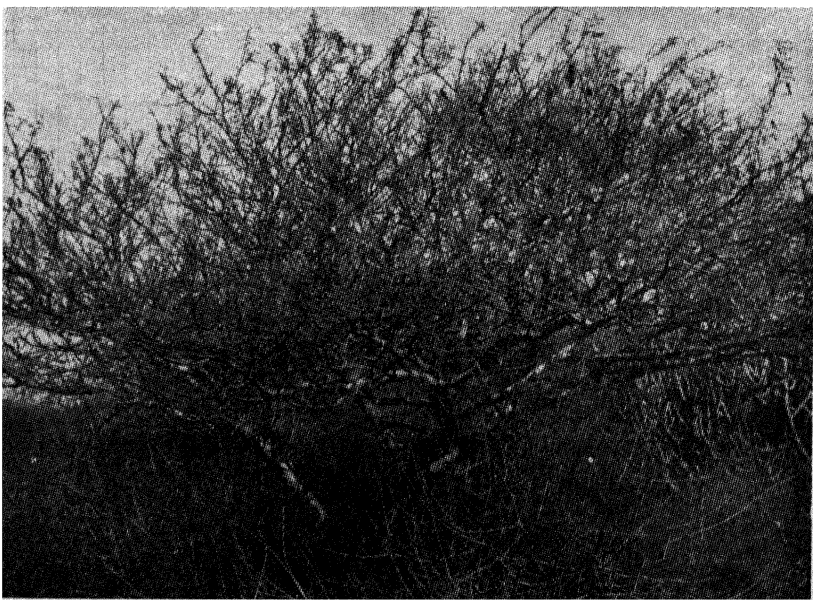
150. Communities of *Orthocnemum indicum* growing on saline soils at Surendarnagar. — G. S. Puri.



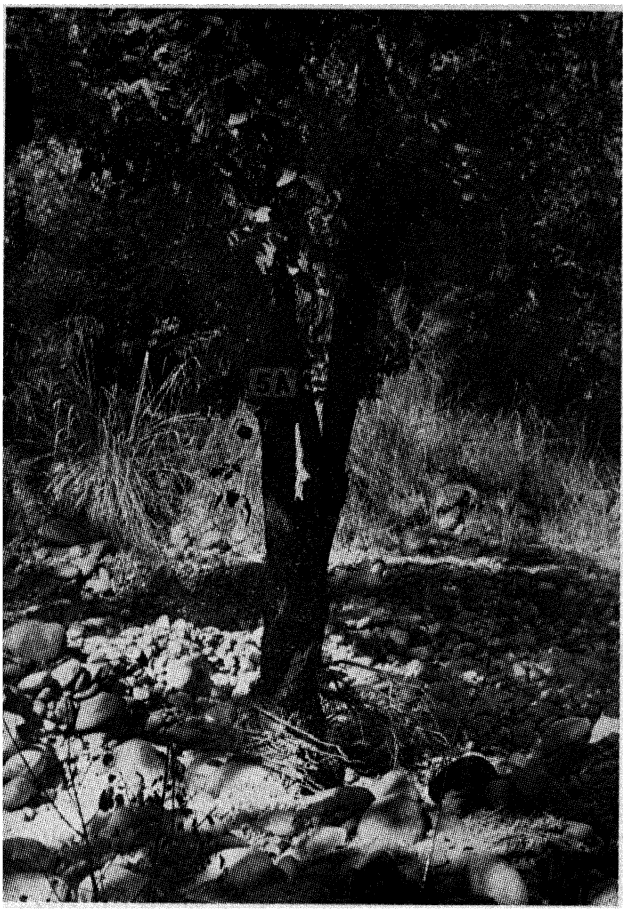
151. A dense community of *Fagonia cretica* on saline soils in Saurashtra. — G. S. Puri.



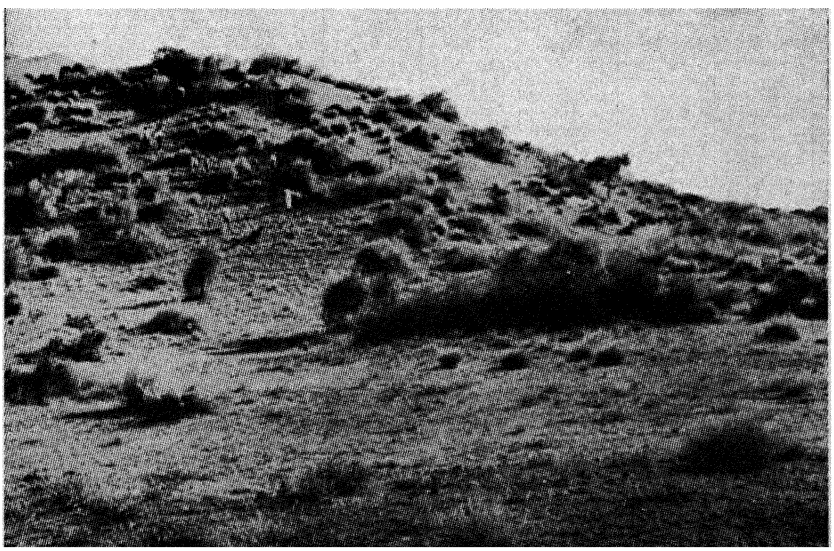
152. Scrub jungle of *Acacias* and *Euphorbias* in Bhujia Hill, Cutch. —Gangurde.



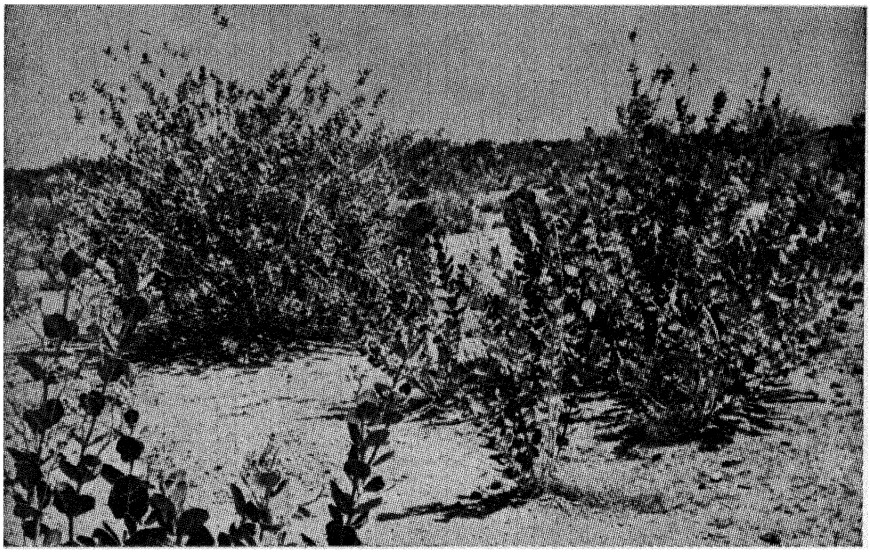
153. Community of *Acacia Senegal—Balsamodendron mukul—Euphorbia* at Mevo Rakhal, Cutch. —Gangurd



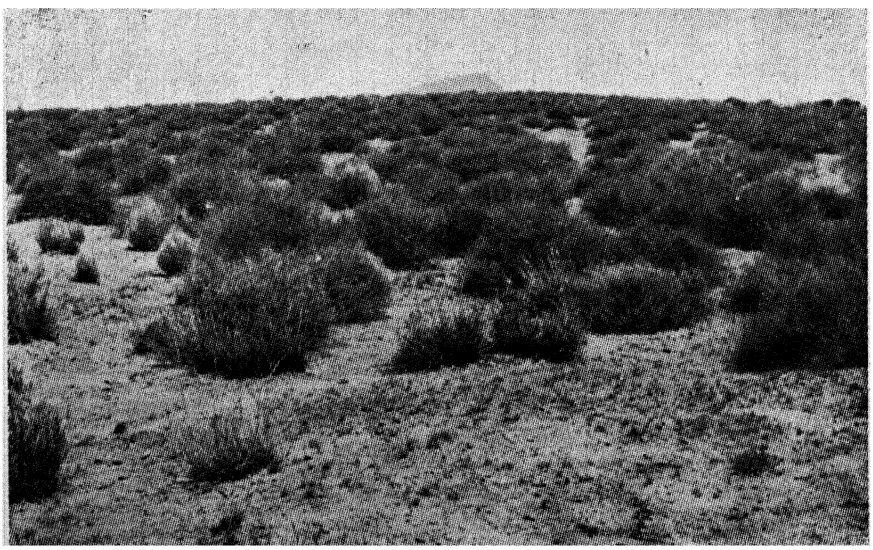
154. Savannah in the making. The effect of water erosion on a high forest of *Sal* in the Dun Valley. Note the growth of grasses and bushes on bouldery habitat —G. S. Puri.



155. A sand dune being colonised by shrubby vegetation of *Aerua*, *Crotalaria*, *Leptadenia*, etc. — Near Barmer —G. S. Puri.



156. A well developed community of *Calotropis gigantea* on sandy soil in Rajasthan — G. S. Puri.



157. Community of *Elionurus* on sandy calcareous soil in Rajasthan — G. S. Puri.

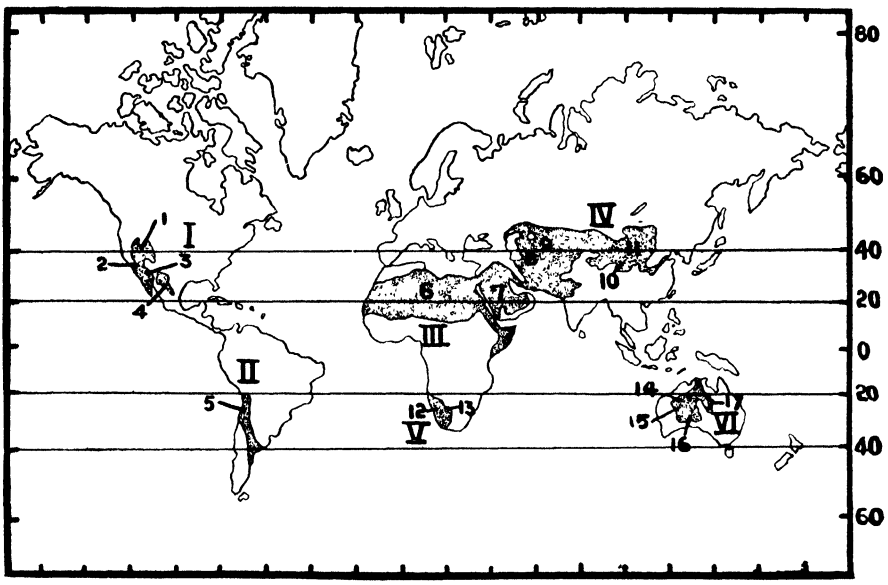


Fig. 50 ARID REGIONS OF THE WORLD
(From African Soils, Vol. I, No. 1.)

There have been marked changes in the physiography of Rajasthan during geologically speaking recent times and there are geological considerations which seem to have contributed materially to the deterioration of the desert conditions in this area, since the close of the last Glacial period in North India. Though, the original cause of desert formation can be traced to geological events, its deterioration since 600 A.D. can definitely be attributed largely to man.

The Origin of the Indian desert: The flora of the Indian desert though apparently therophytic, contains a fairly high percentage of phanerophytes, which are of wide geographical distribution, there being very few plants endemic to desert areas. The plants have affinities with central India, with eastern India and quite a number are common to arid regions of the country. This feature of the flora seems to suggest that the desert is of comparatively recent age which finds support from historical and other known facts about the area also.

Mohanjo-Daro and Harappa are two of the oldest Indian civilizations developed in the area which is in the desert to-day, and in their buildings burnt clay bricks were used, which looking at the present scrubby vegetation is an impossibility, unless the area had a luxuriant tree vegetation in the past. Even as late as the 4th century B.C., at the time of Alexander's invasion this area was forested and Mughals are believed to have hunted tigers in these forests. The deterioration of vegetation in the area is considered to be due to a change of climate, and it is supposed that "the edge of the South-Western monsoon area has shifted eastwards, and that the Indus was formerly within the area of monsoon rains", (Piggott, 1950, p., 136).

It is difficult to prove this shifting of the monsoon area eastwards but there is evidence to show that the Indus and in fact all extra-peninsular rivers have drifted westwards during historical times (Chhibber, 1949).

In 300 B.C., Harappa is believed to have stood on the banks of the confluence of the branches of the Ravi and now the main river is 6 miles away.

Mohanjo Daro stands on what is significantly known in the locality as the island, a narrow strip of land between the main bed of the Indus and the western Nara loop and was subject to flooding until very recent times, when the building of a long embankment prevented a recurrence of floods. At present the river is far from the ruins.

As late as the 11th or 12th century the Sutlej used to flow near Bhawalpur through what is now the dry bed of Hakra or Wandan river. The courses of small rivers between the Sutlej and the Jumna in the eastern Punjab and eastern Nara river in lower Sind are very suggestive and the flood water of the present Sutlej and Indus flows out in the dry bed of the old river showing that the westward drift of these rivers has occurred. The Indus itself has shown great fluctuations in its course in recent times.

This westward drift of extra-peninsular rivers may be due to the slow elevation of the Himalayas and the areas immediately in the vicinity of these mountains (West, 1937; Puri, 1947; 1949). The shifting of a river has been often seen as a result of silting up of its bed by the clearance of forest in the catchment area and upper reaches and the extension of cultivation and irrigation in plains at lower levels.

The forests have definitely been cleared in the past, which combined with secular changes in level may have caused the westerly drift of the Punjab rivers and drying up of the Hakra, thus changing the climate of the area and bringing aridity and desert conditions.

Desert vegetation of Rajputana: The study of desert vegetation has been made by a number of Indian botanists, among whom Blatter (1910, 1920) and Sabnis (1919–21, 1929) have made notable contributions. Recently, Shanti Sarup and his students (1952) have made detailed studies of the Rajasthan desert and recognised a number of ecological zones. More recently, Puri and Vasvada (1957) have studied desert vegetation from a number of places. The description of desert vegetation given here is mainly from their observations. The ecological zones in the desert are the following:—

(1) South and south east of the region near the Aravalli hills but not strictly in the desert.

(2) The semi-arid area, some 1,000 miles across the line parallel to region one, where a number of extreme xerophytes may be found.

(3) The arid region in the extreme north and west of zone one where the vegetation is very poor and there are vast barren areas.

Blatter recognised the following main types of vegetation in the desert of Rajputana.

Sand Communities: The sandy region includes sand dunes, sandy plains and sand hills. The sand dunes being mobile are least covered with plants. The leeward side being steep is much more bare, however, the growth of vegetation on the windward side is more rapid. Photo 155 shows a sand dune in the Barmer region being colonised by shrubs.

Pioneer plants on sand dunes, near Loharki are: *Calotropis procera, Leptadenia spartium, Crotalaria burhia, Indigofera argentea, Aerua pseudo-tomentosa, Citrullus colocynthis, Farsetia jacquemontii, Eleusine* sp., *Panicum turgidum*, etc. Out of these *Calotropis procera* persists and on slightly older dunes pure associations of these species are found. *Indigofera* is one of the typical sand dunes pioneers. Photo 156 shows a well developed community of *Calotropis gigantea.*

Spread out sand on plain country is colonised by *Aerua tomentosa, A. pseudo-tomentosa* and at a later stage *Leptadenia spartium, Panicum*

turgidum come in; *Capparis decidua* also occurs. The next stage of vegetational development on this sort of habitat is characterised by *Crotalaria burhia* which along with *Leptadenia, Aerua pseudo-tomentosa* and *Panicum* forms an association covering several square miles of the area. However, ultimately *Crotalaria* prevails. These plants form big tufts and species between tufts are *Convolvulus* sp., *Polygala* spp., *Brewería latifolia.*

On well developed old sand dunes vegetation follows an interesting elevational zonation. Begining with foot of the dune *Aeura* association is dominant for nearly half of the dune. Near the crest, however, it is succeeded by an association of *Panicum turgidum, Pennisetum cenchroides, Indigofera argentea, Rhynchosia arenaria* and Cyperaceae. The top has a pure association of *Calligonum polygonoides.* This plant grows into bush on plain ground and becomes a climber on gravel. *Cyperus arenarius* with stoloniferous roots are extremely useful in binding sands. The common grasses on sand are *Eragrostis tremula, E. ciliaris, Cenchrus catharticus, Pennisetum prieurii* and *P. cenchroides.* Photo 157 shows community of *Elionurus* on sandy calcareous soils.

On well developed sandy plains occur *Capparis decidua* and Compositae and *Crotalaria.* On low dunes *Capparis* with *Zizyphus rotundifolia, Panicum* and *Calligonum* are present. *Zizyphus* is more common on gravelly soils.

Towards west of Bikamker dunes have no *Calligonum,* but are covered over by *Lycium barbarum, Sericostoma pauciflorum, Blepharis sindica, Farsetia jacquemontii, Boerhaavia diffusa* and *Aristida funiculata* and other grasses.

On sandy plains locally *Clerodendron phlomoidis, Mimosa hamata, Lycium barbarum,* etc., occur.

On drier sandy ridges on loose sand, tufted grasses, particularly *Andropogon iwarancusa* and *Elionurus hirsutus* are found. In plains *Acacia senegal, Grewia populifolia,* and *Zizyphus rotundifolia* commonly occur (Photo 158). Further, *Capparis decidua* with Cucurbitaceous plants becomes common (*photo* 159).

On sandy dried up river beds at Barmer occur *Cadaba indica, Salvadora oleoides,* with *Euphorbia neriifolia, Commiphora* spp., and *Panicum antidotale.*

Gravel Communities: Most of the gravel in the desert is formed by sorting action of wind, which carries away sand to form dunes and leaves behind larger pebbles that form gravel (Photo 160). The Loharki gravel plain studied by the author is deficient in water and organic matter and colonisation of this by plants is a very slow process. A gravel association at Bap to Jaisalmer is composed of *Cleome papillosa, Boerhaavia diffusa, Fagonia cretica, Aristida mutabilis, Eleusine aristata,* etc.

Typical gravel plants have stiff, more or less woody branches lying flat on the ground, examplified by *Tribulus terrestris, T. alatus, Indigofera linifolia, I. trigonelloides, I. enneaphylla,* etc.

Gravelly plants of bushy habit are: *Fagonia cretica* (also on sand), *Cleome papillosa, Brewería latifolia* (also on sand and rocks), *Sericostoma pauciflorum, Heliotropium* spp., *Salvia aegyptiaca,* etc. (Photo 161). *Calotropis procera* is common on sand and gravel.

A great majority of the trees and shrubs of the region belong to gravel formation, e.g., *Zizyphus rotundifolia* forms quite a forest in places, and is accompanied by *Salvadora oleoides, Prosopis spicigera, Gymnosporia montana, Capparis decidua,* etc. (Photo 162).

Grasses on gravelly soil are *Eleusine aristata, E. flagellifera,* etc.

On gravelly paths and plains, vegetation generally becomes more shrubby.

Rock Communities: The rock formation in the area is classified into three main types:

(a) The Kailana-Jodhpur-Mandor Plateau, consisting of Vindhyan sandstone which is overlying Malani lavas. It is 200 feet high and Jodhpur is located on this.

The commonest plant of this is *Euphorbia neriifolia,* besides which *Lepidagathis trinervis, Monsonia senegalensis, Indigofera cordifolia* (very common), *Orygia decumbens,* etc., are found. *Anogeissus pendula, Grewia populifolia* and other small trees and shrubs are also present. Parts of these areas are now closed, as a result of which a good amount of herbaceous vegetation has come up (Photo 163) in contrast to unfenced areas (Photo 164).

(b) Jaisalmer plateau and outliers. On the scarp of the plateau there occurs hard grained dark brown limestone of Jurassic age overlying sandstone (Photo 165). Jaisalmer town is built entirely of this limestone. Photo 166 shows a fort built on limestone in this area. The characteristic plants here are *Barleria acanthoides, Pappophorum aucheri, Grewia populifolia, Viola stocksii, Calotropis gigantea,* etc.

(c) Barmer hills are chiefly volcanic and have narrow fringe of sandstone at the foot of the hills. The following plants are very abundant covering the whole hillside: *Solanum albecaule, Mimosa hamata, Boerhaavia verticillata, Capparis decidua, Achyranthes aspera, Barleria acanthoides, B. prionitis, B. hochstetteri, Farsetia machantha, Salsola foetida, Pupalia* spp., etc. A view of Barmer Hills is shown in Photo 167.

Besides the above characteristic plants on the three types of hills, the following plants are common throughout: *Pegolettia senegalensis, Bouchea marrubiifolia, Heliotropium* spp., *Convolvulus* spp., *Gracilea royleana, Elionurus royleanus, Tragus racemosus, Leptipes senegalensis,* etc.

Along foot of the hill among pebbles at Kotda Hill the following occur: *Eleusine aristata, E. aegyptiaca, Aristida funiculata, A. hirtigluma, Gracilea royleana, Crotalaria ovalifolia.*

In rocky depressions occur *Salvadora, Acacia senegal, Capparis* spp., *Grewia populifolia, G. villosa, Blepharis sindica,* etc. *Salvadora* trees sometimes attain huge dimensions. Photo 168 shows a large tree near Barmer, under which groups of *Cistanche tubulosa* are growing.

Higher up on the rock are found *Fagonia cretica, Farsetia jacquemontii, Anticharis linearis, Cleome* spp., *Tribulus, Polygala erioptera, Aristida hystricula,* etc.

Near the top, occur *Barleria acanthoides, Lindenbergia urticaefolia, Eleusine flagellifera, Euphorbia neriifolia,* etc.

Besides this natural vegetation the following species are cultivated in gardens and near towns: *Prosopis spicigera, Ficus bengalensis, F. religiosa, Zizyphus jujuba, Azadirachta indica, Poinciana elata, Mangifera indica,* etc.

Desert vegetation of Ajmer - Jaipur Region: The vegetation of this part of the country is allied to the Rajasthan Desert and due to intense biotic pressure the hillsides all over the area are covered over by scrubby vegetation with *Euphorbia.* The vegetation about Nila Sevadi area which consists of rocky hillsides formed of Sandstone was recently studied and it consists of *Euphorbia, Zizyphus nummularia, Grewia populifolia, Acacia*

leucophlaea, A. senegal with grassy undergrowth, in which *Aristida, Saccharum munja* were common. Photo 169 shows an aspect of this type of vegetation at Ajmer-Marwara.

The high hills e.g. in Panchkund area are covered with *Anogeissus pendula,* which is predominant, associated with *Acacia leucophlaea* and *Stephegyne parvifolia.* The shrubby growth has *Zizyphus, Euphorbia, Grewia,* etc. and grasses may be only *Aristida.* This type of vegetation is represented in Photo 170.

The vegetation round about Jaipur is also of the same type of scrubs, formed of *Zizyphus, Acacia senegal, A. leucophlaea,* in which grassy undergrowth of *Aristida, Heteropogon contortus, Themeda, Cymbopogon,* etc. is present.

The herbs in this area are few, mainly *Aerua lanata, Tridax,* etc. The reason for the above type of vegetation in this area is biotic interference.

Sind desert: The desert in Sind adjoins Rajputana and is closely related to the western deserts. Though, not a part of India now, it is of considerable interest, botanically. The flora of the Indus delta is closely related to that of Sind, but the Rajputana flora has a number of eastern species. The western deserts being much drier than the eastern ones have plants with pronounced xerophytic characters.

The Sind desert is in the middle of the western and eastern deserts. The western plants in Sind are *Physorhynchus, Dipterygium, Reseda, Ochradenus, Althaea, Senra, Taverniera, Alhagi, Inula, Statice, Rhazya, Periploca, Convolvulus sindicus, Linaria, Cometes, Forskahlea, Nannorhops.*

The flora of the Sind desert was divided by Sabnis (1929) into the following broad categories in accordance with the terminology of Schimper:—

1. Halophytic and semi-halophytic.
2. Aquatic and semi-aquatic.
3. Kalar soil.
4. Sand.
5. Gravel.
6. Rock.

(1) *Halophytic* and *semi-halophytic* species are *Ipomoea biloba, Andropogon aucheri, Calotropis procera, Salvadora oleoides, Aerua pseudotomentosa, Convolvulus microphyllus, Tamarix articulata, Fagonia cretica, Launaea chondrilloides, Artiplex stocksii, Suaeda nudiflora, Salsola foetida* and *Halopyrum mucronatum.*

(2) Aquatic and semi-aquatic include *Nymphaea lotus, Hydrilla verticillata, Potamogeton pectinatus* and *Scirpus littoralis.*

The semi-aquatic plants along the banks of the river consist of *Capparis decidua, Portulaca oleracea* and the species of *Tamarix, Bergia, Sida, Abutilon, Zizyphus, Indigofera, Alhagi, Rhynchosia,* Acacia, *Ammannia, Trianthema, Mollugo, Gnaphalium, Eclipta, Launaea, Salvadora, Calotropis, Prosopis* (Photo 171), *Leptadenia, Cressa, Lippia, Amarantus, Aerua, Achyranthes.*

(3) Kalar soil formation has *Capparis, Bergia, Corchorus, Zygophyllum, Zizyphus, Indigofera, Alhagi, Prosopis, Acacia, Cirtullus, Trianthema, Eclipta, Launaea, Salvadora, Rhazya, Calotropis, Leptadenia, Solanum, Aerua, Achyranthes, Euphorbia, Phoenix, Panicum, Erianthus, Desmostachya,* and *Aeluropus.* Also *Capparis decidua, Zizyphus rotundifolia* and species of *Leptadenia* and *Aerua* and *Tamarix* are found (Photo 172).

(4) Sand formations are found both in the plains and in dunes, the vegetation on which consists of *Capparis* and *Zizyphus.* Small groups

of species of *Calotropis, Leptadenia, Crotalaria* and occasionally *Panicum, Eragrostis, Desmostachya* and *Tamarix* are present.

On sandy plains associations of *Tamarix* and *Erianthus*, also *Aerua, Zizyphus, Calotropis*, etc., are found.

On sand dunes the vegetation is typically of *Capparis, Tamarix, Zygophyllum, Crotalaria, Acacia, Salvadora, Rhazya, Pentatropis, Leptadenia, Heliotropium, Lycium, Aerua, Calligonum, Pennisetum, Erianthus* and *Desmostachya* and *Salvadora*, with or without *Euphorbias*. Photo 173 shows a community of plants near Karachi.

At another place sand dunes have an association of the species of *Crotalaria, Capparis, Zizyphus* and occasionally *Aerua, Leptadenia* and *Salvadora*.

Vegetation of sandy plains consists of species of *Dipterygium, Capparis*, etc.

(5) Gravel formation: The plants on the gravel formation are the following·

Tribulus, Sida, Trianthema, Corchorus and *Euphorbia*.

Climbing or twining vegetation consists of species of *Rhynchosia, Convolvulus* and *Ipomaea*.

Plants with bushy habit form a bigger group and consist of species of *Capparis, Bergia, Eclipta, Salsola* and *Inula*.

Among trees, species of *Zizyphus, Prosopis* and *Cordia* are commonly found. The majority of plants belonging to this formation are found between Sehwan and Mirpur khas.

(6) Rock formation: The Laki Range and Ganja are of volcanic origin and have hot springs and sulphur springs. On the Laki range the following are found:

Corchorus, Xanthium, Eclipta, Tephrosia, Striga, Lippia, Pennisetum, Heliotropium, Zygophyllum, Daemia and *Aeluropus*.

Undershrubs and shrubs are represented by species of *Reseda, Pluchea, Tamarix, Alhagi, Aerua, Calotropis* and *Blepharis, Forskahlea, Zizyphus*, and *Salvadora*.

Among trees may be mentioned species of *Moringa, Dalbergia, Prosopis, Cordia, Acacia, Salvadora* (Photo 174).

The flora on the hills has a typical western character.

Ganja hill is composed of limestones and has the following flora: *Ammannia, Cressa, Zygophyllum, Cleome, Launaea, Eclipta, Schweinfurthia, Abutilon, Calotropis, Leptadenia, Lycium, Salvadora* and *Pentatropis*.

Desert vegetation of the Jhelum district: On account of the intense biotic interference desert conditions have spread to the fertile Indo-gangetic basin. In the Indus valley a good account of the vegetation of the Jhelum district, which has been the scene of the battle fields from the Alexander's time, was given in 1865 by Aitchison. He described stunted vegetation of *Acacia modesta, Capparis aphylla, Carissa diffusa, Sageretia brandrethiana, Gymnosporia spinosa, Ehretia aspera, Grewia betulaefolia, Cocculus, Periploca aphylla, Asparagus, Taverniera nummularia, Dodonaea burmaniana, Zizyphus jujuba, Acacia arabica, Adhatoda vasica, Butea frondosa, Tecoma undulata* and *Olea europea*.

The undershrubs and herbs growing in the above jungle are: *Salvia pumila, Boucerosia aucheriana, Solanum gracilipes, Linaria ramosissima, Commelina communis, Commelina bengalensis, Polygala arvensis, Polygala vahliana, Astragalus multiceps, Pupalia lappacea, Dipteracanthus prostratus, Aerua javanica, Ballota limbata, Allium rubellum, Cleome linearis, Abutilon indicum, Sida rhombifolia, Triumfetta angulata*, etc.

There are several grasses, viz., *Cynodon dactylon, Melanocenchris royleana, Pennisetum, Aristida depressa, Eragrostis cynosuroides, Dactyloctenium aegyptium.*

In ravines *Saccharum munja, S. spontaneum* and *Nerium odoratum* are met with.

On rich alluvial soils trees of *Tamarindus indica* with *Syzygium jambolanum, Phyllanthus emblica, Feronia elephantum, Mangifera indica, Phoenix dactylifera* are found.

In the salt plains on tracts incapable of cultivation vegetation of *Tamarix indica, Salvadora oleoides, Prosopis spicigera, Acacia modesta, Capparis aphylla, Suaeda fruticosa, Anabasis multiflora, Farsetia jacquemontii, Saccharum spontaneum* are present.

In the Salt Range, Aitchison and Tierney (1864) found a similar vegetation. *Buxus sempervirens* is present on the summit about 2,000 feet above sea level. *Prosopis spicigera, Dodonaea, Barleria, Astragalus leucocephalus* are found. *Salvadora oleoides* forms a part of the jungle.

Tamarix dioica with *Saccharum* are present on islands and banks of rivers.

Characters of Xerophytic desert plants: Desert vegetation has certain morphological and anatomical features which make the plants survive under adverse conditions imposed by climate, soil and the biotic interference. Some of these are given below after Sabnis (1921):—

(1) **Glandular hairs:**

(a) Club shaped:—

(i) With a stalk cell and with a unicellular head e.g., in Boraginaceae and Labiatae.

(ii) With a stalk cell and a head divided both by horizontal and vertical walls, e.g., in Sterculiaceae, Papilionaceae.

(b) With a stalk cell and with a head irregularly divided, e.g., in Malvaceae.

(c) Capitate:

(i) With a uniseriate stalk and with a unicellular head, e.g., in Geraniaceae.

(ii) With a uniseriate stalk and with a head divided by horizontal and vertical walls, e.g., in Cucurbitaceae and Acanthaceae.

(d) Shaggy hairs:—

(i) With a multicellular stalk and with a multicellular head, e.g., in Capparidaceae and Elatineae.

(e) Depressed spherical salt glands:—

Placed in pits and divided by a single vertical and horizontal wall with two epidermal subsidiary cells at the base, e.g., in Tamariscineae.

(2) **Water storing cells:** Water storing epidermal cells have the inner walls very thin and convexly arched inwards. They are found in some of the species of Capparidaceae, Papilionaceae, and Polygonaceae.

(3) **Secretory organs.** The different types are as follows:—

(a) Oxalate of lime: Found in the species of Violaceae, Malvaceae, Amarantaceae, Polygonaceae, Sterculiaceae, Euphorbiaceae, Rubiaceae, Solanaceae and Acanthaceae.

(b) Calcium carbonate deposits; e.g., in walls of hairs of Cruciferae and Boraginaceae.

(c) Tannin.

(i) In the epidermal cells of Sterculiaceae and Rosaceae.

(ii) In the mesophyll or in the different tissues of the axis, e.g., in Caryophyllaceae, Sapindaceae, Polygonaceae, Cyperaceae.

(4) **Pericyle:**

(a) Presence of stone cells. e.g., in Elatineae, Convolvulaceae, Polygonaceae, Labiatae, Amarantaceae, Compositae, and Commelinaceae.

(b) Presence of bast fibres e.g., in Cruciferae, Acanthaceae, Nyctaginaceae, Euphorbiaceae, Rubiaceae, Solanaceae, Asclepiadaceae, Rhamneae and Papilionaceae.

Vegetation of the Gangetic valley: The vegetation of the Gangetic Valley is the intermediate between the desert and the Indus Valley described in the preceding pages. Dudgeon (1919) has described conditions within an area of radius of ten miles about Allahabad, which is representative of conditions in the upper Gangetic valley. The vegetation is influenced by the biotic factor more than the climate and soil. The main biotic factors are the agricultural population of about 530 persons per sq. mile and 470 grazing animals per sq. mile. Tree cutting, grazing and the cultivation of the area have been very old practices which have greatly modified the development and succession of vegetation. He gave the following main features of this vegetation:—

(1) Distinct seasonal succession due to well defined climatic seasons.

(2) A secondary climatic climax which represents degradation from the true climatic climax of the area. This is in a thorn scrub stage or dry meadow stage.

(3) Obscure topographic succession which is very slow due to human interference.

The following stages of the topographic succession have been recognised by him.

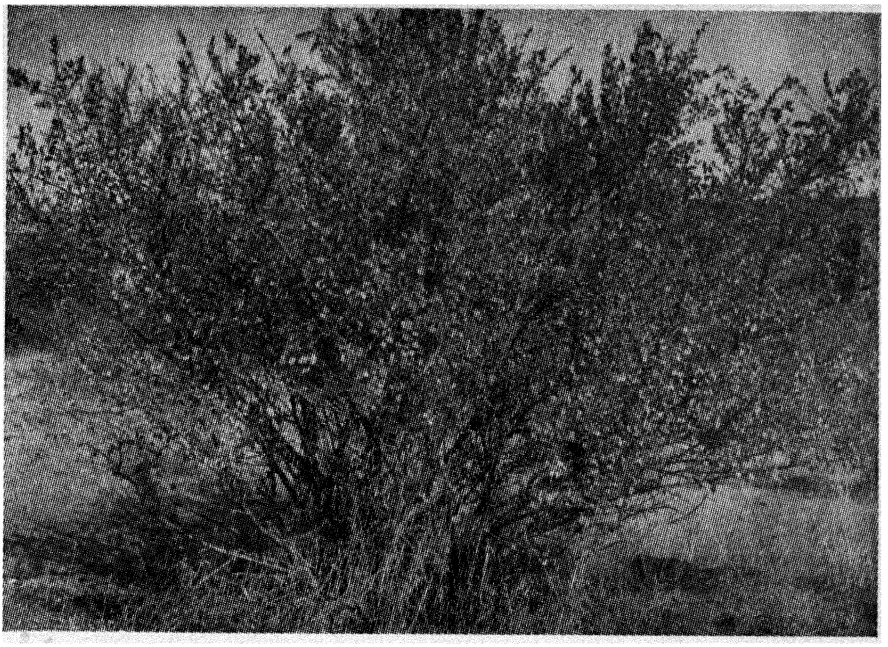
(a) **Aquatic stage**: This is found in pools and ponds which may be temporary or permanent. The succession is clearly seen in monsoonic shallow pools in which free floating aquatic and attached submerged aquatic and attached emersed aquatic stages are recognised. The characteristic plants of the three types are given in table 82.

Table 82.

CHARACTERISTIC PLANTS OF THREE STAGES OF AQUATIC VEGETATION OF THE GANGETIC VALLEY

(Compiled from Dudgeon, 1916).

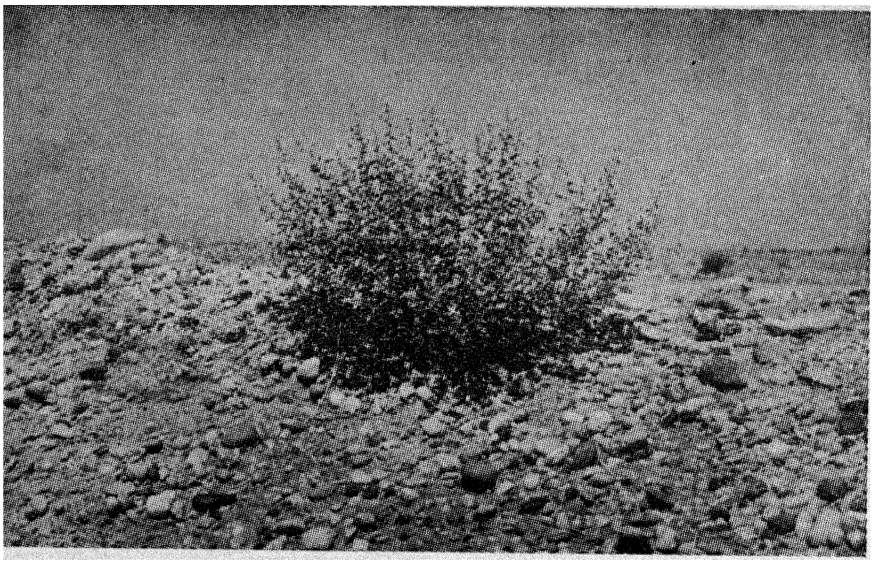
Free floating aquatic stage.	Attached submerged aquatic stage.	Attached emersed aquatic stage.
This is dominated by Algae, chiefly, *Spirogyra, Cladophora, Oedogonium, Hydrodictyon* and *Vaucheria.*	The plants of this stage are *Potamogeton pectinatus*, L., *Hydrilla verticillata*, Casp., *Naias graminea* Delile, *Vallisneria spiralis* L., *Zannichellia palustris* L. *Chara* spp., and *Nitella* spp.	The plants of this area are *Nymphaea lotus* L, *Eleocharis plantaginea* Br. *Scirpus maritimus* L., and *Marsilia* sp., (Photo 176 & 173).
Besides these there are a few free floating aquatic vascular plants of *Ceratophyllum demersum* L, *Azolla pinnata, Lemna minor* L., *Wolffia arrhiza,* etc. (Photo 175).		In addition a few characterteristc species rooting in shallow water, are: *Ipomaea reptans* Poir., *Panicum paspaloides* Pers., *P. punctatum* Burn. (Photo 178).



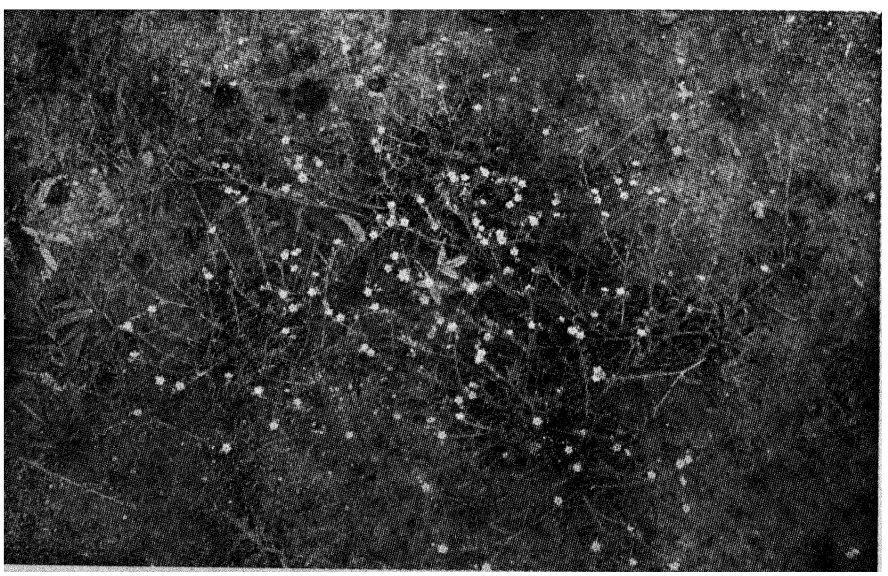
158. A large bush of *Grewia populifolia* in *Acacia—Grewia—Zizyphus* community on calcareous sandy plains — Jaisalmere — **G. S. Puri.**



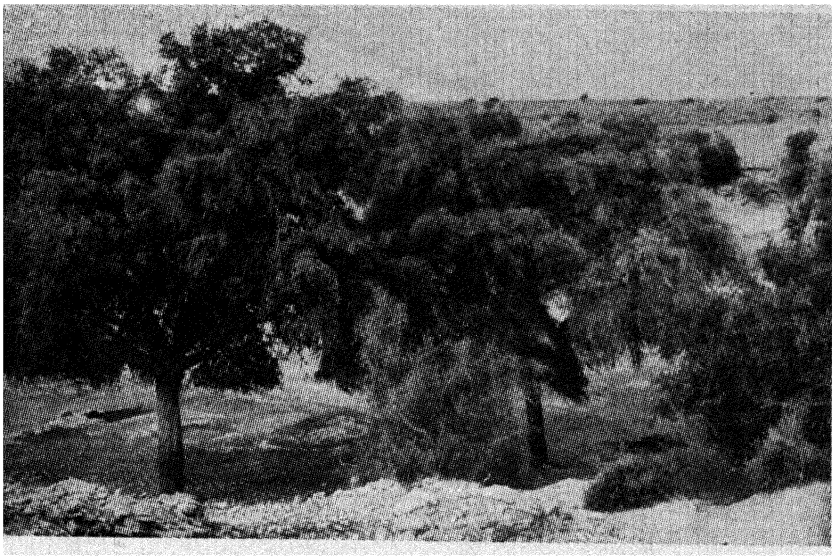
159 *Capparis decidua* with cucurbitaceous plants in Jaisalmere — **G. S. Puri.**



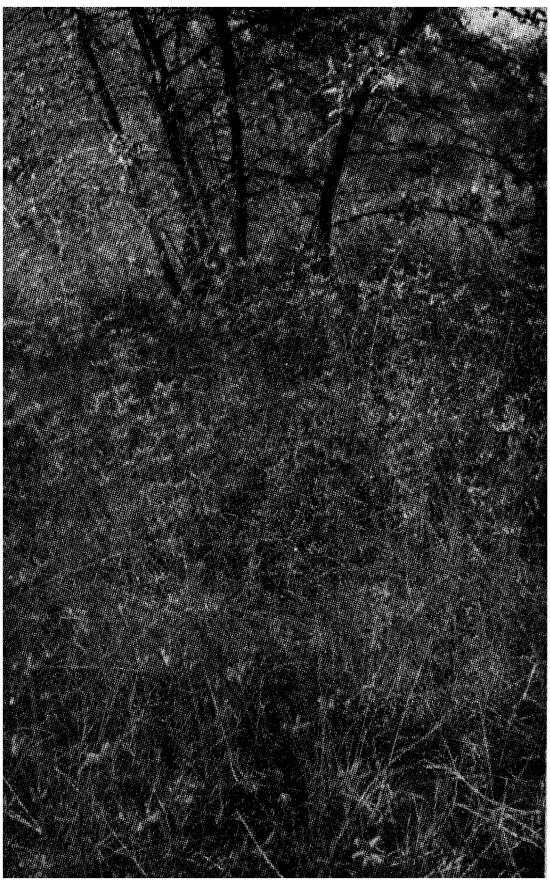
160. A view of gravel habitat near Jaisalmere —G. S. Puri.



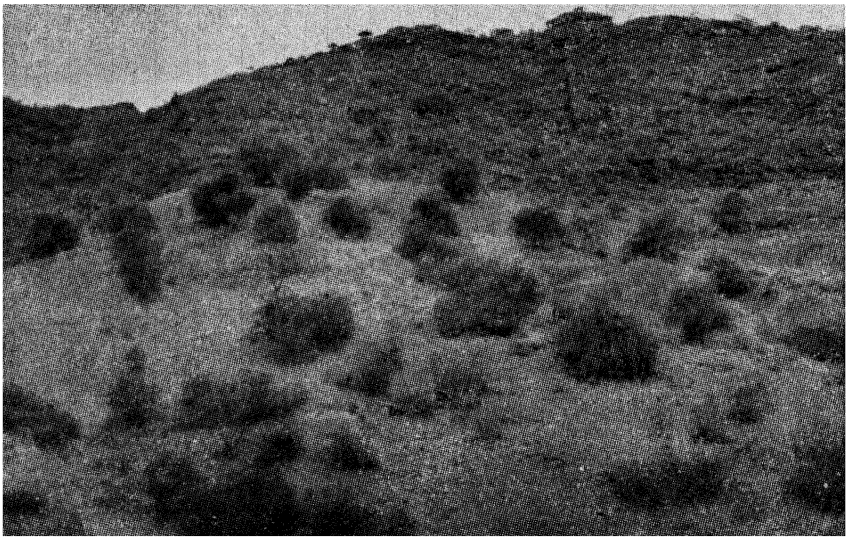
161. A *Heliotropium* community on sandy, gravelly soil in Rajasthan —G. S. Puri.



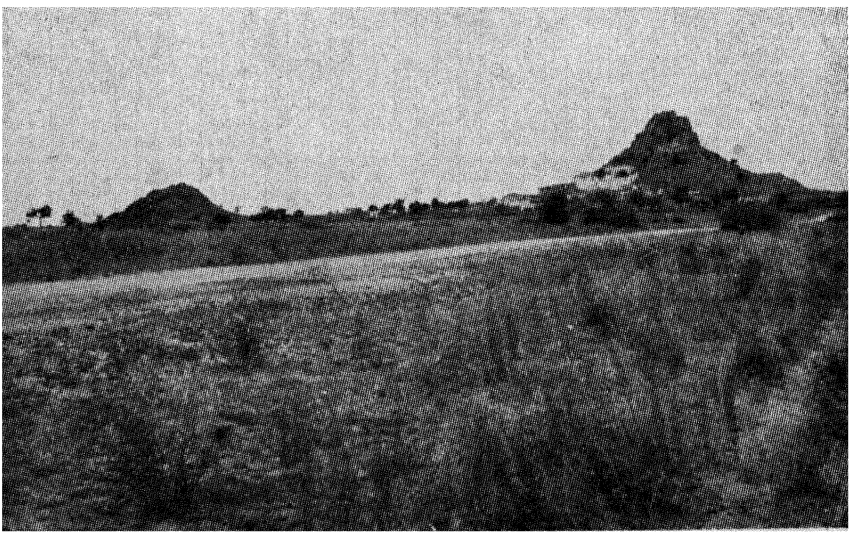
162. A community of *Prosopis spicigera* - *Capparis* - *Salvadora*, etc. in Rajasthan —G. S. Puri.



163. Closed area on rocky plateau near Jodhpur. Note the luxuriance of grassy undergrowth —G. S. Puri.



164. Scrubby vegetation in un-fenced areas of Sandstone rock near Jodhpur. Scattered clumps of *Euphorbia*, bushes of *Capparis*, etc. are present — G. S. Puri.



165. Limestone hills in the Jaisalmere area. Note the situation of villages in sheltered sites between two continuous hill blocks — G. S. Puri.

(b) **Wet meadow stage** is represented by vegetation occurring on the margin of damp soil between pools and dry meadows. During the rainy season it extends to the dry meadow and during the hot season it recedes towards the centre of the pool. The typical plants are Cyperaceae and *Cynodon dactylon*. Other plants in the wet meadows are *Scirpus maritimus*, S. *quinquefarius* Hain, *Cyperus difformis* L., *Fimbristylis diphylla* Vahl., *Ammannia baccifera* L., *Ranunculus scleratus* L., *Cynodon dactylon*, *Eragrostis tenella* R. & S.

The zone of wet meadow fluctuates with seasonal changes and erosion. In areas with intense biotic interference annuals are replaced by perennials. The annuals in this stage are *Juncellus pygmaeus, Scirpus michelianus, Potentilla supina, Gnaphalium indicum, Grangea maderaspatana. Rumex dentatus. Ranunculus scleratus, Polygonum plebejum, Alternanthera sessilis, Bergia ammannioides, Riccia sanguinea, Hydrolea zeylanica,* and *Glossostigma spathulatum.* Photo 179 shows wet meadow stage plants in Sagar in M.P.

The aquatic and wet meadow stages described from the U.P. are of universal occurrence in India. Similar types have been described from M.P. by a number of workers and Misra from Sagar. Recently Puri and Mahajan (1958) have described these two stages from Deccan areas. They recognised the following communities of plants occurring in temporary and permanent pools:—

Caesulia axillaris (Photo 180) community occurs almost pure, or sometimes mixed with *Asteracantha longifolia.* This is a rooted community.

Another similar community is *Typha latifolia* (photo 181). This is also a rooted community occurring wherever permanent moisture in pools is available.

The community of *Ipomaea* either pure or mixed with *Eichhornia* (Photo 182) occurs in various lakes. *Eichhornia* is an exotic, but it has taken roots very well in Indian conditions.

Another noticeable community in ponds is of *Polygonum glabrum* (Phto 183). In wet meadow stage *Saccharum* occurs at several places.

(c) **Dry meadow stage:** Merges with the wet meadow stage by *Cynodon dactylon* and *Eragrostis tenella.* The dry meadow is typically characterised by two perennial grasses, *Andropogon intermedius* and *Eleusine aegyptiaca.* Under shady conditions *Desmodium triflorum, Indigofera enneaphylla* and *Alysicarpus monilifer* are characteristic species. During rainy season *Crotalaria medicaginea, Cassia obtusifolia* and *Eragrostis tenella* develop extensively. Dry meadow plants develop tap roots and if grazing is intense and aridity is high they take a rosette-like habit. Some of the common plants of the dry meadow are: *Convolvulus pluricaulis, Lepidagathis trinervis, Justicia simplex, Euphorbia thymifolia, Boerhaavia repens, Vernonia cinerea, Corchorus antichorus, Launaea asplenifolia, Heliotropium strigosum, Calotropis procera* and *Tephrosia purpurea.*

In over-grazed areas *Aristida adscensionis* becomes dominant.

(d) **Thorn scrub stage:** The thorny shrubs and small trees in this type of vegetation represent remnants of a pioneer type of vegetation. These are *Capparis sepiaria, Acacia arabica, A. leuco-phlaea, Balanites aegyptiaca, Flacourtia sepiaria, Jatropha gossypifolia, Zizyphus jujuba* and *Alangium lamarckii.*

Of these *Balanites* is successful as a pioneer in dry areas and *Acacias* come in in somewhat moist depressions. *Butea frondosa* is also present in the scrub vegetation. There are a number of climbers that occur on *Acacia*

and *Zizyphus*. These are *Hemidesmus indicus, Cocculus villosus, Tinospora cordifolia, Vitis trifolia*, etc. Photo 184 shows this type of vegetation in the Ganges canal area.

This scrub vegetation would develop in all the areas occupied by wet and dry meadows if the biotic factor is removed. But this is being continually cut for fuel and fodder, as a result of which conditions somewhat similar to those shown in photo 185 develop.

The ecology of the upper Gangetic plains was studied by Varma (1936) in the vicinity of Lucknow. He found that during the rainy season the water content of the soil increases, air and soil temperatures decrease. Nitrates are washed down to the lower layers of the soil and a tendency of the decrease of the total carbonates in the soil and increase of organic matter on the surface is seen. The soil becomes less alkaline and conditions for the growth of vegetation are at its best. The largest number of herbaceous plants are found during the rainy season. The characteristic vegetation during the season is hygrophillous and the tropical aspect of this flora and its composition appears more clearly during the rains.

In the winter season between October and end of February the temperature is lower and the humidity of air is high and dew is copius. Some variations in nitrates, carbonates and water contents of the soil are seen but there is no observable difference between the plants growing in this area. The number of plants per unit area decreases considerably from the summer maximum and ephemeral species disappear. The hygrophillous annuals give place to mesophytic annuals and perennials lose their tropical luxuriance. The summer season starts from March to June. The temperature increases, humidity becomes low. Soil water becomes very low and there is accumulation of salts on soil surface, nitrate content increases and soil becomes alkaline, with chlorides and sulphates of sodium as the main constituents. All the annuals die and trees and shrubs give a new flush of leaves.

These studies show that there is a seasonal change in climatic and soil features which bring in changes in herbaceous vegetation.

Within the course of a year a seasonal change of flora from tropical to temperate and to desert conditions takes place, the vegetation, therefore, consists of a mixed population of plants. The seasonal variation of the climatic factor is so great that a species can, only with difficulty, remain dominant throughout the year; thus restricting the number of indigenous species.

Interesting studies were made by Puri (1954) on soil climate in four types of plant communities in the Siwaliks at Dehra Dun. The plantations studied were *Pinus roxburghii, Shorea robusta, Tectona grandis*, and open grassy areas. Samples of soils were collected in freshly dug pits from 0′, 6″, 18″, 26″, 48″, 60″, and 72″ and the various soil constituents were examined. These will be discussed in details in the chapter on the soils. Along with these studies, the foliar constituents of the various tree species occurring in these areas were also studied by Puri (1954a). There was a marked relationship between the changes in the soil and in the foliage of trees in the various nutrients and plant foods. These results were further correlated with the succession of ground flora species in the forest plantations of New Forest at Dehra Dun by Puri and Dabral (1957) and the results show that the phenomenon of seasonal changes in climate and soil features described by Varma from the Gangetic valley seems to be over wide areas. There is not only a change in the herbaceous vegetation, but also change occurs in trees and shrubs in phenology.

14

GRASSLAND VEGETATION OF INDIA

Nearly all the grassland vegetation in this country owes its origin to one, or the other kind of interference of the natural forest vegetation by man. The favourable climate for the development of the grassland as a climax unit would be the frequent rainfall, even if of a small amount, and a sufficient warmth and moisture during the growing season. Since both these factors are not generally present in this country, the grassland vegetation changes to one or the other type of forests, under natural conditions. The biotic and sometimes edaphic features of the habitat help in the perpetuation of grassland over extensive areas. There are extensive grassy flats in the Nilgiris, alpine meadows, Savannahs and grassy plains, which are biotic or bio-edaphic and seral in nature and are comparatively stable under the existing factors of the habitat. Once the tree vegetation takes hold of the area grasses begin to dwindle and the composition of the ground flora changes considerably as was shown by Krishnaswamy and Puri (1954) in the New Forest plantations.

The changes due to biotic interference may affect the grassland vegetation in a number of ways. Fire may burn seeds before maturing, or destroy mature seeds. Nutrients in grass vegetation are released and added to the soil on burning. By continued cropping these may be lost from the soil for ever.

The grasslands of India may be classified under the following broad types:-

(1) **Xerophilous grasslands:** These are of dry regions of north-west India under semi-desert conditions. *Eragrostis* species predominate and other common species are *Aristida adscensionis, Andropogon contortus, A. faveolatus, Chloris virgata, Apluda varia, Cenchrus ciliaris, C. barbatus* and *Elionurus hirsutus*. Other species of scruby vegetation may be *Prosopis spicigera, Capparis* spp., *Balanites* sp., and *Acacia* spp.

(2) **Mesophilous grasslands:** Called as savannahs, are the extensive grassy blanks, typical of the moist deciduous forests of U.P. consisting of *Saccharum munja, S. narenga* and *Vetiveria zizanioides*. The alpine meadows of the Himalayas and the grassy downs of the Nilgiris are temperate variations of this type.

(3) **Hygrophilous grasslands:** Called the wet savannahs, are densely stocked with *Erianthus elephantinus* and *Saccharum arundinaceum*. On the drier side *Erianthus ravennae* and on the wetter side *Phragmites* and *Arundo* occur.

All these types being biotic controlled are inferior to the temperate grasslands and suffer considerably from the monsoon nature of the climate and the lack of a proper legume mixture.

MAIN GRASSLAND TYPES OF INDIA

Recently, The Indian Council of Agricultural Research have started a grassland survey of India. In a preliminary paper published Whyte, Venkataramanan and Dabadghao (1954) have established eight grassland types in the country which are shown in table 83.

Table 83.

INDIAN GRASSLAND TYPES AND THEIR ENVIRONMENT

Grassland type.	Environment.
Sehima/Dichanthium.	Black soils.
Dichanthium.	Sandy loams.
Phragmites/Saccharum.	Marshy areas.
Bothriochloa.	Paddy tracts and high rainfall belt.
Cymbopogon.	Low hills.
Arundinella.	High mountains.
Deyeuxia/Arundinella.	Mixed temperate climate.
Deschampsia/Deyeuxia.	Temperate alpine climate.

Fairly detailed ecological studies and grassland survey of India were done by the Indian Council of Agricultural Research on some of the important types. A brief note was recently published by Dabadghao and Patil (1956). These authors brought out the well known fact that grassland is not a climax vegetation in any part of India, but since grasses are of very great importance in Indian economy the management of grasslands is an important problem. About five grassland types from different parts of the country were indicated by these authors.

Dabadghao (1957) in an unpublished paper on grassland survey of India has given following account of the various grassland types occurring in India.

(1) **Dichanthium - Cenchrus - Elionurus type** occurs in the plains of Punjab, PEPSU, western U.P., northern Rajasthan in dry and somewhat arid conditions with a rainfall of below 30" in a year. The type occupies alluvial sandy to sandy loam soils, where extremes of temprratures exist. The perennial grasses in this community are *Dichanthium annulatum* (Photo 186), *Cenchrus ciliaris, Cenchrus setigerus, Elionurus hirsutus, Eleusine flagellifera, Cynodon dactylon, Sporobolus pallidus, Panicum turgidum* and *Heteropogon contortus.* Excepting the three spreading grasses, namely *Eleusine, Cynodon* and *Sporobolus* the remaining are erect grasses reaching to a height of 4 to 5 ft. In overgrazed areas *Aristida* species, *Eragrostis* species, *Echinochloa colonum* are conspicuous. Photo 187 shows *Echinochloa* on drying mud of a pond in Cutch.

With further deterioration *Sporobolus pallidus* readily increases in the first two years and in the third year *Cynodon dactylon* or *Eleusine flagellifera* begins to appear. After five years of protection *Cenchrus* and *Dichanthium* begin to appear. In areas of more arid conditions *Aristida* and *Cenchrus catharticus* increase and these species are then replaced by *Dactyloctenium scindicum* and *Eleusine flagellifera.* After about 10 years of protection *Elionurus hirsutus* attains the complete dominance and persists for a long time, however bunding brings in *Dichanthium annulatum.* The following sub-types are recognised:—

(a) **Dichanthium - Cenchrus - Elionurus sub-type** gains dominance in the semi-arid areas in excellent conditions. *Elionurus* species are as a rule absent in this condition but other perennials as *Cynodon* sp., *Eleusine flagellifera, Sporobolus pallidus, Heteropogon contortus* are persent.

(b) **Cenchrus - Elionurus sub-type** occurs in good conditions in semi-arid or arid regions. Other species in this sub-type are *Cynodon dactylon, Eleusine flagellifera* and *Dichanthium annulatum.* At this stage no annual enters the grassland community except on very localised patches. An *Elionurus* grassland in Rajasthan is shown in Photo 188.

(c) **Cynodon - Eleusine sub-type** occurs in fair conditions in which very much reduced plants of second sub-type occur to a certain extent. A number of annual species chiefly *Aristida* and *Eragrostis* come in.

(d) **Aristida - Eragrostis sub-type** occurs in poor conditions in which annual grasses predominate (photo 189). The only perennial species would be *Sporobolus pallidus* in semi-arid parts and *Dactyloctenium scindicum* in arid tracts. Dying or dead plants of *Cenchrus* and *Elionurus* may be met with in this sub-type. *Panicum antidotale* (photo 190) forms conspicuous communities on sandy soil and sand dunes.

(2) **Sehima - Dichanthium type** occurs in most parts of tropical India in the Deccan plateau extending to South Bihar and eastern parts of West Bengal. The type is common in the upper Damodar valley near Hazaribagh. The topography is undulating with intervening valleys. The rainfall in the area varies between 20 to 55 inches and summer temperatures are high, though winters may be milder. The type occurs on a number of soil types such as red and yellow, red gravelley and mixtures of various types of red and black and on lateritic conditions. There are as many as 120 grass species in this type in which 45 are perennial grasses. The important perennial species are *Sehima nervosum, Dichanthium annulatum, Iseilema laxum, Chrysopogon montanus, Bothriochloa pertusa, Eremopogon foveolatus, Heteropogon contortus, Cymbopogon* species, *Cynodon dactylon, Aristida setacea, Chrysopogon aciculatus, Dichanthium caricosum, Eragrostis coarctata.* Except, *Aristida setacea, Cymbopogon* species and *Eremopogon foveolatus* all other species are excellent fodder grasses.

Out of 75 annual species *Heteropogon contortus, Aristida* spp., *Oropetium thomaeum, Eragrostis* species, *Chloris tenella* (photo 191), *Alloteropsis cimicina, Andropogon pumilus, Urochloa panicoides, Digitaria marginata, Brachiaria ramosa, Tragus racemosus, Sehima ischaemoides* and *Perotis indica* are prominent.

Special annual associates found are *Apluda aristata, Themeda quadrivalvis* and *Capillipedium* species in medium rainfall regions and in open areas in the humid forests: *Diectomis fastigiata, Sehima ischaemoides, Schizachyrium exile* and *Schizachyrium brevifolium* are on lateritic or acidic soils.

This type is also divided into sub-types:—

(a) **Sehima - Dichanthium sub-type** occurs in excellent conditions. On gravelly soil *Sehima nervosum* forms a dominant stand while on well decomposed soil on level ground *Dichanthium annulatum* is dominant. The associated species are *Chrysopogon montanus, Bothriochloa pertusa, Cymbopogon* species (photo 192), *Heteropogon contortus, Eremopogon foveolatus, Dichanthium annulatum* and the annual species *Apluda aristata, Themeda quadrivalvis* and *Capillipedium* species. On level soils with good moisture content *Dichanthium annulatum* or *Iseilema* species forms almost pure stand while on soils intermediate in moisture conditions these are associated with *Bothriochloa pertusa, Eremopogon foveolatus, Dichanthium caricosum, Chrysopogon montanus* and *Sehima nervosum.*

(b) **Chrysopogon - Bothriochloa sub-type** occurs in good conditions where *Sehima nervosum* is partially eliminated and there is a corresponding increase in *Chrysopogon montanus* and other perennial species but *Chrysopogon* giving its character to the grassland (Photo 193). Besides the above two species constituting the type, *Bothriochloa pertusa, Eremopogon foveolatus, Cymbopogon* species, *Heteropogon contortus* are perennial species. The annuals are *Apluda aristata* and *Themeda quadrivalvis.* In level soils the sub-type has the following composition: *Dichanthium annulatum, Iseilema laxum, Bothriochloa pertusa, Eremopogon foveolatus, Dichanthium*

caricosum, Heteropogon contortus and the annual species like *Echinochloa colonum, Manisuris granularis, Paspalidium flavidum.*

(c) **Heteropogon - Eremopogon sub-type** occurring in fair conditions in which *Sehima* and *Chrysopogon* have scattered stands. The annual species increase considerably in this type and *Heteropogon contortus* (photo 194) is the main constituent. Other annuals are *Andropogon pumilus, Aristida* species, *Gracilea royleana, Tragus racemosus, Chloris tenella* and *Eragrostis* species.

In the plains this condition is represented by stand of *Dichanthium annulatum* and *Iseilema* species associated with *Heteropogon contortus, Bothriochloa pertusa, Eremopogon foveolatus* and other annuals described above.

(d) **Aristida - Eragrostis, etc. sub-type** (photo 195) occurring on the poorest conditions with a large number of annuals such as *Gracilea royleana, Urochloa panicoides, Dactyloctenium aegyptium, Oropetium thomaeum, Brachiaria ramosa, Tragus racemosus* and *Alloteropsis cimicina.* Dying plants of *Sehima, Chrysopogon, Dichanthium, Bothriochloa* and *Eremopogon* may be present.

(3) **Phragmites - Saccharum type** occurs in the plains of Punjab, PEPSU, Western U.P. and Assam and Manipur States in low lying, poorly drained areas. They are found on sandy soils with alkaline to strongly acidic reactions. The type has about 40 perennial and 24 annual species. The characteristic species are *Phragmites karka, Saccharum spontaneum, Saccharum arundinaceum, Saccharum munja, Sclerostachya fusca, Imperata cylindrica, Desmostachya bipinnata, Hymenachne amplexicaulis, Leersia hexandra, Themeda villosa, Vetiveria zizanioides, Sporobolus indicus, Chrysopogon aciculatus* and *Narenga porphyrocoma.* Common annual species are *Paspalum* species, *Echinochloa* species, *Eragrostis* species and *Eleusine indica.*

In semi-arid region where soil is generally neutral to slightly alkaline, the type is represented by only a few species as *Phragmites karka, Saccharum spontaneum, Saccharum munja, Saccharum arundinaceum, Imperata cylindrica* and *Desmostachya bipinnata* (Photo 196).

This has also numerous sub-types:—

(a) **Phragmites karka sub-type** is associated with excellent conditions in which other grasses are *Saccharum spontaneum, Imperata cylindrica, Sclerostachya fusca, Narenga porphyrocoma* and *Arundinella,* etc.

(b) **Phragmites - Saccharum sub-type** representing good conditions is brought into being by annual burning of the grassland (photo 197). Other species in this type may be *Narenga* and *Arundinella.* The soil in this condition is not too moist but only slightly resistant to treading.

(c) **Imperata cylindrica sub-type** occurs in fair conditions with further burning as a result of which *Sclerostachya fusca* is eliminated and a poor form of *Imperata cylindrica* dominates. Other grasses in this community are *Narenga porphyrocoma, Saccharum spontaneum, Cymbopogon* species, *Arundinella* species, *Sporobolus indicus, Paspalum* species and *Chrysopogon aciculatus.*

This stage becomes suitable for grazing as a result of which *Imperata* stand is broken and gaps are created in which *Sporobolus indicus, Paspalum* species, *Chrysopogon aciculatus, Cynodon dactylon* and *Eleusine indica* gradually appear. This may mark the beginning of next sub-type.

(d) **Sporobolus - Paspalum sub-type** is associated with poor conditions as a result of continued grazing. In a closed cover of *Sporobolus* and *Paspalum,* species such as *Chrysopogon, Cynodon dactylon, Imperata cylindrica* are present. The annual species like *Panicum, Echinochloa,*

Eleusine indica and *Eragrostis* species are present. In inundated areas *Leersia hexandra* and *Hymenachne amplexicaulis* may be also represented. In semi-arid regions good and fair conditions are represented by a dominant stand of *Vetiveria zizanioides, Desmostachya bipinnata* and *Imperata cylindrica.* In good conditions *Vetiveria zizanioides* forms almost a pure stand while in fair conditions *Desmostachya bipinnata* predominates. In ponds and running water communities of *Coix* (photo 198) and *Sacciolepis interrupta* (photo 199) are found at many localities in the Deccan.

Succession of Grassland Communities: This was studied by Indian Council of Agricultural Research and Dabadghao gives tentative successional trends of three types as below:—

(1) First type:—

Dichanthium — *Cenchrus* — *Elionurus*

Protection ↑ ↓ Grazing
Cenchrus ——— *Elionurus*
Protection ↑ ↓ Grazing
Cynodon ——— *Eleusine*
Protection ↑ ↓ Grazing
Aristida ——— *Eragrostis*

(2) Second type:—

Sehima ——— *Dichanthium*

Burning | (gravelly soils) ↑ | (well decomposed soils) | Increased soil moisture.
Protection ↓ Grazing
Cymbopogon *Iseilema*
Chrysopogon ——— *Bothriochloa*
Protection ↑ ↓
Heteropogon ——— *Eremopogon*
Protection ↑ ↓
Aristida - *Eragrostis* - *Gracilea*

(3) Third type:—

Phragmites ——— *Saccharum* ———
Protection ↑ ↓ Annual burning | Grazing
Saccharum - *Sclerostachya* - *Imperata* (tall) |
Protection ↑ | ↓ Burning *Vetiveria*
Imperata (depauperate) ←———
Protection ↑ ↓ Burning & Grazing
Sporobolus ——— *Paspalum*

Regressive stages in the type in semi-arid region.

Phragmites ——— *Saccharum*
↓ Annual burning & grazing.
Vetiveria
↓ Burning & grazing
Desmostachya - *Imperata*

GRASS ECOLOGY

This is a specialized subject in which much detailed studies have not been made in this country. The subject is, however, treated under Agronomy in various research institutes in the country and on account of the use of grass as fodder studies become mainly of a very specialized nature. For a book on Forest Ecology, therefore, these detailed studies are not included.

Forest Ecologists are interested in forming grassland types corresponding to the forest types and efforts have been made in the country to find out the relationship between the two. In the Grassland Reconnaissance Survey Scheme Report for the year 1954–55 and 1955–56, detailed composition of the three main grassland types described in the last two pages is given. These are summarised in Table 84 on pp. 277-280.

Grassland types of the Punjab: Mohan (1955) has described the grass communities from the chief forest types met with in the state. These are summarised in table 85 on pp. 281-282.

He studied the succession of grasslands in the Siwaliks by cultivating a number of grass species at Nurpur at an altitude of 2,000 ft. in the Kangra valley, where the soil is thin, generally less than a foot in depth with sandstone as underlying rock. The common grasses of the locality viz. *Chrysopogon montanus, Dichanthium annulatum, Heteropogon contortus, Bothriochloa pertusa, Themeda anathera* were tried.

The compound was closed to grazing in 1937 and contour-trenched in 1938 and divided into fields. The results discussed below were at the end of the year 1938.

Cenchrus ciliaris was sown in fields Nos. 1, 4 (iii), 6 & 8(i) and in no plot has it been able to maintain its dominance; in fact it has completely disappeared in one plot, while in others it is being suppressed. The chief invader has been *Dichanthium annulatum,* an indigenous grass which seems to have been greatly assisted by increase in moisture content consequent upon contour trenching. Obviously *Cenchrus* cannot stand competition with grasses like *Dichanthium annulatum, Bothriochloa pertusa* and *Heteropogon contortus. Cenchrus* is thus more suited as a pioneer crop where competition is absent or less keen.

Dichanthium annulatum on the other hand seems to be in its optimum locality in Nurpur fields. Its plots have remained pure or almost pure, and field Nos. 2(i) 3, 4(ii) (5) its only associates so far were *Heteropogon contortus* and *Apluda aristata.* The latter is restricted to the berms or newly made up earth near the trenches.

Cynodon dactylon field was bound to be invaded as *Cynodon* requires a special treatment maintenance as a dominant grass. *Heteropogon contortus* had made great inroads but there was no *Dichanthium* so far.

Heteropogon contortus is vigorous in its field. Its only associate is *Apluda* but so far its area is restricted.

With *Sorghum halepense* it was hoped to cover the entire field but it only succeeded in selected places. The rest of the area was colonised by *Bothriochloa pertusa* and *Apluda aristata.*

Apluda aristata had maintained its dominance though on account of its special partiality for fresh soil and moisture it could form a pure crop over the entire field. Its associates were *Bothriochloa pertusa* and *Heteropogon contortus.*

Chrysopogon montanus is a very common grass of the Kangra division but inspite of its having been sown and tended it had not been able to maintain its dominance and had been replaced by *Bothriochloa pertusa.*

Themeda anathera had almost entirely disappeared.

The succession so far studied in Nurpur fields had tended to show that *Themeda anathera, Cenchrus ciliaris* and *Chrysopogon montanus* are lower in the scale of succession (i.e. are pioneer species) than *Dichanthium annulatum, Heteropogon contortus* and *Bothriochloa pertusa.*

Table 84.

DETAILED FLORISTIC COMPOSITION OF THE THREE GRASS TYPES

*(Compiled from Grassland Survey Scheme Reports for 1954-55 and 1955-56).

Grassland types.	GRASS		WEEDS AND HERBS	SHRUBS AND TREES
	Perennials	Annuals		
Dichanthium--Cenchrus--Elionurus.	*Bothriochloa pertusa* A. Camus., *Cenchrus ciliaris* Linn., *C. setigerus* Heyne, *Chloris digitata* Steud., *C. inflata* Link., *Cynodon dactylon* Pers., *Dactyloctenium scindicum* Boiss., *Dichanthium annulatum* Stapf.. *Eleusine flagellifera* Nees, *Heteropogon contortus* (L) Beauv., *Sporobolus pallidus* Benth.	*Aristida redacta*., *A. adscensionis* L., *Brachiaria ramosa* Stapf., *Dactyloctenium aegyptium* Beauv., *Digitaria marginata* Link, *Echinochloa colonum* Link. *Eleusine indica* Gaertn, *Eragrostis ciliaris* Link., *E. tremula* Hochst. *E., tenella* Beauv., *E. viscosa* Trin., *E. interrupta* Beauv., *Eriochloa procera* Hubb., *Hackelochloa granularis* O. Ktze., *Panicum trypheron* Schult., *Paspalum* sp., *Paspalidium flavidum* A. Camus., *Perotis indica* O. Ktze., *Setaria glauca* Beauv., *Sporobolus coromandelianus* Kunth., *Tragus biflorus* Schult.	*Abutilon indicum* Sweet., *Achyranthes aspera* L., *Aeschynomene* sp., *Alysicarpus* sp., *Ammannia baccifera* L., *A. jucifera*, *Asparagus* sp., *Boerhaavia repens* L., *Cassia tora* W. & A., *Chenopodium album* L., *Corchorus* sp., *Crotalaria medicaginea* Lamk., *Cyperus* sp., *Euphorbia hirta* L., *Indigofera cordifolia* Heyne, *I. linifolia* Retz., *Justicia diffusa* Willd., *Kochia indica* W., *Leucas* Sp., *Malvastrum* sp., *Marsilia quadrifolia* L., *Medicago hispida*, *Portulaca oleracea* L., *Rhyncosia* sp., *R. minima* DC., *Ruellia* sp., *Trianthema decandra*., *T. portulacastrum*, *Trigonella polycerata* L., *Vicoa indica* DC., *Vernonia cinerea* Less.	*Acacia arabica* Willd., *A. leucophlaea* Willd., *A. modesta* Wall., *Azadirachta indica* Juss., *Butea monosperma* O. Ktze., *Capparis aphylla* Roth., *Calotropis procera* Br., *Carissa congesta* Wt.,*C. opaca* Stapf., *Dalbergia sissoo* Roxb., *Ficus glomerata* Roxb., *Prosopis* sp., *P. spicigera*, *Salvadora* sp., *Sesbania* sp., *Zizyphus jujuba* Lamk., *Z. nummularia* Wt. and Arn.
Phragrmites-Saccharum.	*Apluda mutica* Linn., *Arundinella bengalensis* Druce. *A. decempedalis* Janowski, *Arundo donax* Linn., *Bothriochloa intermedia* A. Camus, *B. pertusa* A. Camus, *Chloris digitata* Steud., *Chionachne* koenigii Thw., *Chrysopogon aciculatus*	*Aristida adscensionis* L,. *Brachiaria ramosa* Stapf., *Coix lachryma - jobi* L., *Digitaria setigera* Roth., *D. marginata* Link., *D. stricta* Roth., *Echinochloa colonum* Link., *E. crus-galli* Beauv., *E. nigra* Nees, *Eriochloa procera* Hubb. *E. stagnina*	*Aerua lanata* Juss., *A. tomentosa* Forsk., *Ageratum* sp, *Alysicarpus* sp., *A. monilifer* DC., *Alpinia nutans Roscoe*, *Atylosia* sp.. *Aeschynomene*, *Artemisia* sp., *Boerhaavia repens* L., *Cannabis sativa* L., *Combretum* sp., *Corchorus* sp., *Conyza* sp., *Costus* sp.,	*Acacia arabica* Willd., *A. catechu* Brand. *A. leucophlaea* Willd., *Adhatoda vasica* Nees., *Aegle marmelos* Correa., *Albizzia procera* Benth., *A. lucida* Benth, *Antidesma* sp., *Artocarpus chaplasha* Roxb., *A. integrifolia* L.f.. *Barringtonia acutan-*

*Since this book was sent to press Whyte (1953) has completed his assignment with the Indian Council of Agricultural Research and has published the account given early in these reports.

Table 84 (Contd.)

Grassland type.	GRASS		WEEDS AND HERBS	SHRUBS AND TREES
	Perennials	Annuals		
	Trin., *Cymbopogon iwarancusa* Schult., *C. clandestinus* Stapf. *C. martini* Watson, *Cynodon dactylon* Pers., *Desmostachya bipinnata* Stapf., *Dichanthium annulatum* Stapf., *Erianthus fulvus* Nees, *E. elephantinus* Hook. f., *E. longisetosus* Anders., *Eulalia quadrinervis* Kunth, *Heteropogon contortus* (L) Beauv, *Hymenachne amplexicaulis* Nees, *Imperata cylindrica* Beauv., *Leersia hexandra* Sw., *Mneisthia laevis* Kunth., *Microstegium ciliatum* A. Camus., *Narenga prophyrocoma* Bor., *Neyraudia reynaudiapa* Keng., *Ophiurus corymbosus* Gaertn., *Paspalum longifolium* Roxb., *Phragmites karka* Trin., *Pseudosorghum fasciculare* A. Camus., *Saccharum spontaneum* Linn., *S. munja* Roxb., *S. arundinaceum* Retz. , *S. procerum* Roxb., *Setaria palmifolia* Stapf., *Sorghum halepense* Pers., *Sporobolus indicus* R. Br., *Themeda villosa* Dur et Jack., *Vetiveria zizanioides* Nash.	Beauv., *Eleusine indica* Gaertn., *Eragrostis unioloides* Nees, *E. major* Hook, *Hackelochloa granularis* O. Ktze., *Ischaemum rugosum* Salis., *Panicum humile* Nees, *Paspalidium punctatum* A. Camus, *P. flavidum* A. Camus, *Paspalum scrobiculatum* Linn., *P. conjugatum* Berg., *P. orbiculare* Forst., *Sacciolepis indica* A. Chase., *Seturia glauca* Beauv. ,	*Crotalaria medicagenia* Lamk., *Desmodium* sp., *Entada scandens*, *Eupatorium* sp, *Euphorbia hirta* L., Ferns, *Hydrilla* sp., *Indigofera cordifolia* Heyne, *I. linifolia* Retz., *I. enneaphylla* L., *Ipomoea* sp., *Eichhornia crassipes* Solms., *Justicia diffusa* Willd., *Justicia* sp., *Leucas aspera* Spr., *Lagasca mollis*, *Medicago hispida*, *Mikania scandens* Willd., *Mimosa pudica* L., *Mucuna* sp., *Phaseolus* sp., *Polygala* sp., *Polygonum* sp., *Phyllanthus maderaspatensis*, *Pueraria* sp., *Rhynchosia* sp., *R. minima* DC., *Scleria* sp., *Smilax* sp., *Tephrosia candida* DC., *T. purpurea* Pers., *Tribulus terrestris* L., *Uraria picta* Desv., *Urena lobata* L., *Vicia hirsuta* Gray., *Vernonia* sp.,	*gula* Gaerth., *Bauhinia purpurea* L., *B. variegata* L., *Butea monosperma* O. Ktze., *Buddleia* sp., *Calotropis procera* Br., *Careya arborea* Roxb., *Capparis aphylla* Roth, *Carissa opaca* Stapf., *Calamus rotang*, *Cedrella toona* Roxb., *Dalbergia sissoo* Roxb., *Desmodium cephalotes* Wall., *Dillenia pentagyna* Roxb., *Elaeocarpus* sp., *Erythrina indica* Lamk., *Eugenia operculata* Roxb., *Encalyptus* sp., *Flemingia*, *Grewia asiatica* L., *Kydia calycina* Roxb., *Lagerstroemia parviflora* Roxb. *Lannea grandis* Engl. *Mallotus phillippinensis* Muell, *Moringa* sp., *Morinda angustifolia* Roxb., *Morus alba* L., *Osbeckia fulva*, *Ophiorrhiza* sp., *Pandanus* sp., *Phyllanthus emblica* L., *Priotropis cytisoides*, *Prosopis spicigera* L., *Pueraria hirsuta*, *Quercus oblonga*, *Randia dumetorum* Lamk., *Salmalia malabaricum* Scholt and Endl., *Sesbania* sp., *Shorea robusta* Gaertn. f., *Tamarindus indica* L., *Terminalia bellerica* Roxb., *Trewia nudiflora* L., *Urena lobata* L., *Zizyphus* sp.
Sehima—Dichanthium.	*Bothriochloa odorata* Syn., *Amphilophis odorata* A.	*Alloteropsis cimicina* Stapf. *Andropogon pumilus* Roxb,	*Abutilon indicum* G.Don., *Achyranthes aspera* Linn.,	*Acacia arabica* Willd., *Acacia catechu* W. & A.,

Kunth., *Apocopis burmahica* V. Narayanswami, *Aristida setacea* Retz., *Arundinella bengalensis* Druce., *Bothriochloa intermedia* A. camus, *Bothriochloa pertusa* A. camus, *Cenchrus ciliaris* Linn., *Cenchrus setigerus* Heyne., *Chloris bournei* Reg. & Ted., *Chloris incompleta* Roth., *Chrysopogon aciculatus* Trin., *Chrysopogon lancearius* Haines., *Chrysopogon montanus* Trin., *Cymbopogon coleratus* Stapf., *Cymbopogon gidarba* Haines., *Cymbopogon iwarancusa* Schult., *Cymbopogon Khasianus* Stapf., *Cymbopogon martini* Stafp., *Cynodon dactylon* Pers., *Desmostachya bipinnata* Stapf., *Dichanthium annulatum* Stapf., *Dichanthium caricosum* A. Camus, *Eleusine flagellifera* Nees., *Enneapogon elegans* T. Cooke., *Eragrostiella nardioides*, (Jain) Bor., *Eragrostis coarctata* Stapf., *Eragrostis gangetica* Steud., *Eragrostis poaeoides* Beauv., *Eremopogon foveolatus* Stapf., *Eulaliopsis binata* C.E. Hubbard., *Heteropogon contortus* Beauv., *Heteropogon insignis* Thw., *Ischaemum aristatum* Linn., *Ischaemum ciliare* Retz., *Ischaemum pilosum* Hack., *Iseilema laxum* Hack., *Mnesithea laevis* Kunth., *Ophiurus longcalingii* Henr., *Sehima nervosum* (Rottl.) Stapf., *Sehima sulcatum* *Apluda aristata* Linn., *Aristida adscensionis* Heward., *Aristida funiculata* Trin, & Rupr., *Aristida hystrix* Duthie, *Aristida mutabilis* Trin et Rupr., *Aristida redacta* Stapf., *Arundinella setosa* Stapf., *Brachiaria distachya* Haines., *Brachiaria cruciformis* Griseb., *Brachiaria ramosa* Stapf., *Capillipedium hugelii Blatter* & Mc'Cann., *Chloris barbata* Sw., *Chloris pallida* Hk. f. *Chloris tenella* Koem., *Chloris villosa* Pers., *Chloris virgata* Sw., *Dactyloctenium aegyptium* Willd., *Dactyloctenium scindicum* Boiss., *Diectomis fastigiata* H. B. & K., *Digitaria marginata* Link., *Digitaria bicarnis* (Lamk) R. & S., *Digitaria longiflora* Retz., *Digitaria pedicellaris* Prain., *Digitaria royleana* Prain., *Dimeria ornithopoda* Trin., *Echinochloa colonum* (Linn.) Link., *Echinochloa stagnina* Beauv., *Eleusine indica* (Linn) Gaertn., *Elionurus royleanus* Nees., *Eragrostiella bifaria* (Vahl) Bor., *Eragrostis brachyphylla* Stapf., *Eragrostis ciliaris* Link., *Eragrostis cilianensis* (All) Link., *Eragrostis nutans* Blatter & Mc.Cann., *Eragrostis interrupta* Beauv., *Eragrostis minor* Host., *Eragrostistenella*, *Eragrostis tremula* Hochst., *Eragrostis amabilis* Wt. & Arn. *Eragrostis viscosa* (Retz) Trin., *Eriochloa procera* C.E. *Aeschynomene aspera* Linn., *Alysicarpus longifolius* W. & A., *Alysicarpus monilifer* DC., *Alysicarpus nummularifolius* DC., *Alysicarpus tetragonolobus* Edgw., *Argemone mexicana* Linn., *Atylosia scarabaeoides* Benth., *Barleria cristata* Linn., *Boerhaavia repens* L., *Borreria hispida* Schum., *Cassia absus* Linn., *Cassia occidentalis* Linn., *Cassia mimosoides* Linn., *Cassia tora* Linn., *Celosia argentea* L., *Cleome viscosa* L., *Clitoria ternatea* Linn., *Crotalaria burhia* Ham., *Crotalaria hirta* Willd., *Crotalaria medicaginea* Lamk. *Crotalaria orixensis* Willd., *Crotalaria prostrata* Rottl., *Crotalaria sparsiflora* Linn., *Crotalaria viscosa* Pursh., *Crotalaria willdenoviana* DC. *Croton spiciflorus* Thumb., *Cryptostegia grandiflora* R. Br., *Cyperus rotundus* L., *Desmodium diffusum* DC., *Desmodium triflorum* DC., *Digera arvensis* Forsk., *Eclipta alba* L., *Evolvulus alsinoides* L., *Euphorbia hirta* L., *Heylandia latebrosa* DC, *Hibiscus ficulneus* Linn., *Indigofera aspalathoides* Vahl. ex DC., *Indigofera cordifolia* Heyne., *Indigofera enneaphylla* L., *Indigofera glandulosa* Jacq., *Indigofera linifolia* Retz., *Indigofera pauciflora* Eckl. & Zeyl., *Acacia intsia* Willd., *Acacia latronum* Willd., *Acacia leucophlaea* Willd., *Acacia modesta* Wall., *Acacia monaliformis*, *Acacia planifrons* Wet A., *Acacia sundra* DC., *Anacardium occidentale* L., *Anogeissus acuminata* Wall., *Anogeissus latifolia* Wall., *Artocarpus integrifolia* Linn. f., *Bambusa arundinacea* Willd., *Bassia latifolia* Roxb., *Bauhinia racemosa* Lam., *Borassus flabellifer*, Linn., *Bridelia retusa* Spreng., *Buchanania latifolia* Roxb., *Calotropis gigantea* R. Br., *Calotropis procera* R. Br., *Capparis aphylla* Roth., *Carapa obovata* Blume. Syn. *Xylocarpus obovatus* A. Juss., *Carissa congesta* Grahm., *Carissa spinarum* A.DC., *Casuarina equisctifolia* Forst., *Cleistanthus callinus* Benth., *Clerodendron viscosum* Vent., Syn. *Clerodendron infortunatum* auct (Non Linn)., *Dalbergia latifolia* Roxb., *Dalbergia sissoo* Roxb., *Dichrostachys cinerea* W. & A., *Diospyros melanoxylon* Roxb., *Dodonaea viscosa* Linn. *Emblica officinalis* Gaertn., Syn., *Phyllanthus emblica* Linn., *Eugenia operculata* Roxb., *Eupatorium coloratus* Spreng., *Eupatorium odoratus* Walt., *Ficus bengalensis* Linn., *Flacourtia ramontchii* Wight., *Flemingia bracteata* Wight., *Gardenia turgida* Roxb.,

Table 84 (Contd.)

Grassland type.	GRASS		WEEDS AND HERBS	SHRUBS AND TREES
	Perennials	Annuals		
	Camus, *Sorghum halepense* Pers., *Sporobolus glaucifolius* Hochst., *Sporobolus virginicus* Kunth., *Themeda laxa* Stapf. ex Haines., *Themeda* triandra Forsk.,	Hubb., *Gracilea royleana* Hk. f., *Manisuris granularis* Linn. f., *Heteropogon contortus*, (Linn.) Beauv., *Iseilema anthephoroides* Hack., *Leptochloa chinensis* Nees, *Microchloa kunthii* Desb., *Oropetium thomaeum* Trin., *Panicum auritum* Presl., *Panicum humile* Trin., *Panicum trypheron* Schult., *Paspalidium flavidum* (Retz) A. Camus, *Pennisetum pedicellatum* Trin., *Perotis indica* O. Kuntze, *Polytoca barbata* Stapf., *Pseudanthistiria hispida* Hk. f. *Schizachyrium brevifolium* Nees, *Schizachyrium exile* Stapf., *Sehima ischaemoides* Forsk. *Setaria glauca* (Linn.) Beauv., *Setaria intermedia* R. & S., *Sporobolus coromandelianus* Link., *Sporobolus diander* (Retz.) Beauv., *Sporobolus tremulus* Kunth., *Thaumastochloa cochinchinensis* (Lour) Hubb., *Themeda quadrivalvis* (Linn) O. Kuntze., *Tragus racemosus* Scop., *Tripogon roxburghianus* Bhide., *Urochloa helopus* Stapf., *Urochloa panicoides* Beauv., *Urochloa reptans* Stapf.	*Indigofera tinctoria* Linn., *Indigofera wightii* R. Grab., *Ipomaea biloba* Forsk., *Ipomaea hispida* Roem & Sch., *Justicia diffusa* Willd., *Lippia nodiflora* Rich., *Malvastrum coromendelianum* Regal., *Medicago denticulata* Boiss. *Melilotus alba* Desr., *Molluga nudicaulis* Lamk., *Phaseolus aconitifolius* Jacq., *Phaseolus trilobus* Ait., *Rhynchosia capitata* DC., *Rhynchosia minima* DC., *Ruellia prostrata* Poir., *Striga lutea* Lour., *Stylosanthes mucronata* Willd., *Suaeda maritima* S. Wats., *Suaeda nudiflora* Thw., *Tephrosia candida* DC., *Tephrosia purpurea* Pers., *Tephrosia tenuis* Wall., *Tribulus terrestris* Linn., *Tridax procumbens* L., *Typha elephantina* Roxb., *Uraria alopecuroides* Wight., *Vernonia cinerea* Less.,	*Hardwickia binata* Roxb., *Helicteres isora* Linn., *Holarrhena antidysenterica* Wall., *Jatropha curcas* Linn., *Mangifera indica* L., *Martynia diandra* Glox., *Mimosa rubicaulis* Lamk., *Pandanus tectorius* Solander., *Pergularia erecta* Spreng., *Phoenix humilis* Royle., *Prosopis juliflora* DC., *Prosopis spicigera* Linn., *Pterocarpus marsupium* Roxb., *Salmalia malabarica* Sch. & End., *Salvadora oleoides* Dene., *Shorea robusta* Gaertn., *Solanum indicum* Linn., *Tectona grandis* Linn., *Terminalia bellerica* Roxb., *Terminalia chebula* Retz., *Terminalia tomentosa*, W. & A., *Xanthium strumarium* L.

Table 85.

GRASSLAND TYPES AND FOREST TYPES OF THE PUNJAB

(After Mohan).

Forest type of Champion.	Reference.	Ecological status of the forest type.	Locality.	Grasses.
1. Moist *sal.*	Page 19	Climatic Climax.	Kalesar Reserved Forests.	*Aristida cyanantha, Chrysopogon montanus, Cynodon dactylon, Eulaliopsis binata, Heteropogon contortus, Saccharum munja, Themeda arundinacea.*
2. Northern dry mixed deciduous.	Page 20	Climatic Climax.	Kangra Division.	*Apluda aristata, Chrysopogon montanus, Dichanthium annulatum, Digitaria adscensionis, Heteropogon contortus, Setaria glauca, Themeda anathera.*
3. Dry *sal.*	Page 20	Climatic Climax.	Hoshiarpur.	*Chrysopogon montanus, Heteropogon contortus, Themeda anathera.*
4. Northern desert thorn Forest.	Page 20	Climatic Climax.	Punjab.	*Aristida depressa, Cenchrus setigerus, Cenchrus barbatus, Chloris montana, Dactyloctenium aegyptium, Eleusine flagellifera, Sporobolus arabicus, Tragus biflorus.* On irrigation following species come up· *Dichanthium annulatum, Cynodon dactylon, Panicum antidotale, Desmostachya bipinnata, Imperata cylindrica, Saccharum munja* when the soil is sandy and *Vetiveria zizanioides* when clayey.
5. *Butea* Forest.	Page 21	Edaphic Climax.	Punjab.	*Cynodon dactylon, Desmostachya bipinnata, Saccharum munja, Vetiveria zizanioides.*
6. *Anogeissus pendula* Forest.	Page 21	Edaphic Climax.	Gurgaon District on the Aravali outliers.	*Aristida depressa, Cenchrus setigerus, Cenchrus barbatus.*
7. Inland dune.	Page 21	Edaphic Climax.		*Cenchrus setigerus, Aristida depressa, Cenchrus barbatus, Dactyloctenium aegyptium, Eleusine flagellifera, Tragus biflorus.*
8. Gangetic Saline scrub.	Page 21	Edaphic Climax.	Punjab.	*Aeluropus villosus, Sporobolus arabicus.*
9. Dry Bamboo brake.	Page 21	Edaphic Climax.	Hoshiarpur.	*Aristida depressa, Cenchrus ciliaris, Chloris incompleta, Chrysopogon montanus, Dichanthium annulatum, Heteropogon contortus, Setaria glauca, Themeda anathera.*
10. *Khair-Sissu* association.	Page 21	Primary Seral type.	West Punjab.	*Saccharum spontaneum, Saccharum munja.*
11. Dry deciduous Scrub.	Page 21	Secondary Seral type.	Kangra Division and Hoshiarpur.	*Chrysopogon montanus, Dichanthium annulatum, Eulaliopsis binata, Heteropogon contortus, Themeda anathera.*
12. Himalayan Sub-tropical pine.	Page 22	Climatic Climax.	Punjab from 2,000' onwards.	*Chrysopogon montanus, Cymbopogon* spp., *Dichanthium annulatum, Heteropogon contortus, Themeda anathera.*
13. Olive Associations would be of three types as follows.	Page 22	Climatic Climax.	Salt Range and Kala Chitta hills (in West Punjab).	

Table 85 (Contd.)

Forest type of Champion.	Reference.	Ecological status of the forest type.	Locality.	Grasses.
(a) *Olea cuspidata* with no *Acacia modesta.*	—	—	In the valleys of the principal rivers in the Punjab hills where the ground is flat and the valley broad.	
(b) Mixture of *Olea cuspidata* and *Acacia modesta.*			—	
(c) *Acacia modesta* with *Olea cuspidata.*			Katar Dhar In Hoshiarpur.	*Cenchrus ciliaris, Chrysopogon montanus, Dactyloctenium aegyptium, Eleusine flagellifera, Eulaliopsis binata, Heteropogon contortus, Themeda anathera.*
14. Himalayan moist temperate forests.				
(a) Lower oak-coniferous-Comprising both ban oak and deodar.	Page 22	Climatic Climax.	—	*Arundinella setosa, Arundinella nepalensis, Andropogon tristis, Agropyron longe-aristatum, Agropyron semicostatum, Bromus asper, Calamagrostis littorea, Cymbopogon distans, Digitaria biformis, Digitaria, Ischaemum, Isachne albens, Koeleria cristata, Muehlenbergia himalayensis, Melica scaberima, Oplismenus undulatifolius, Oplismenus compositus, Oryzopsis gracilis, Pennisetum orientale, Pennisetum flaccidum, Poa pratensis, Poa nemoralis, Poa annua, Pollinia hirtifolia, Spodiopogon dubius, Tripogon filiformis.*
(b) Middle oak-coniferous.	Page 22	Climatic Climax.	—	*Andropogon tristis, Agropyron longe-aristatum, Agropyron semicostatum, Bromus asper, Calamagrostis littorea, Digitaria, Ischaemum, Koeleria cristata, Melica scaberrima, Oplismenus undulatifolius, Oryzopsis gracilis, Pennisetum flaccidum. Poa pratensis, Poa nemoralis, Poa annua, Tripogon filiformis, Brachypodium sylvaticum, Bromus patulus, Festuca gigantea, Festuca modesta, Muehlenbergia sylvatica, Pennisetum lanatum, Stipa sibirica, Vulpia myuros.*
(c) Upper oak-coniferous.	Page 22	Climatic Climax.	—	*Andropogon tristis, Agropyron longe-aristatum, Agropyron semicostatum, Bromus asper, Calamagrostis littorea, Digitaria, Ischaemum, Koeleria cristata, Melica scaberrima, Oplismenus compositus, Oryzopsis gracilis, Pennisetum flaccidum, Poa pratensis, Poa nemoralis, Poa annua, Agrostis canina, Agrostis stolonifera, Agropyron longe-aristatum, Bromus inermis, Bromus oxyodon, Festuca rubra, Festuca valesiaca, Hierochloa laxa, Melica persica, Oryzopsis lateralis, Poa annua, Stipa concinna.*
15. Temperate dry deciduous.	Page 23	Seral.	Punjab.	Chief grasses have been mentioned under middle and upper oak-coniferous.
16. Alpine Forests.	Page 23	Climatic Climax.	—	*Agrostis stolonifera, Agropyron longe-aristatum, Agropyron semicostatum, Brachypodium sylvaticum, Bromus asper, Bromus patulus, Calamagrostis emodensis, Deyeuxia cachemyriana, Dactylis glomerata, Festuca kashmiriana, Koeleria aristata, Milium effusum, Oryzopsis gracilis, Pennisetum flaccidum, Phleum alpinum, Poa polycolea, Poa himalayana, Poa pratensis, Poa nemoralis, Poa annua.*

Table 86.

GRASSLAND TYPES AND FOREST TYPES OF U.P.

(Compiled from Seth).

	Grassland community.	Forest community.	Floristics. Trees.	Floristics. Shrubs.	Floristics. Grasses.	Grassland climate.	Locality.	Geology and soil.	Biotic features.	Ecology, succession, etc.
A 1.	(i) *Aristida-Neyraudia* associes.	*Khair-sissu* forest.	*Dalbergia sissoo, Acacia catechu, Holoptelea integrifolia.*	*Zizyphus jujuba, Adhatoda vasica, Calotropis procera, Murraya koenigii, Orthanthera viminea.*	*Aristida cyanantha, Saccharum spontaneum, Neyraudia arundinacea, Erianthus munja, Chrysopogon montanus, Oplismenus burmannii.*	The mean annual temperature between 75° – 80°F. Winter cold, frost normally absent. The minimum rainfall is about 40″, or at places 50″.	Sub - Himalayan bhabar and dun terraces and gravels.	Recent alluvium along the rivers and streams. Soil is gravelly or stony, very dry with little moisture retentivity and almost devoid of humus. At moderate depth, there is ample moisture, the surface is usually very dry.	There may be severe early fires Grazing is prevalent.	The coarse gravel thrown up by most rivers is first of all colonised by *Aristida cyanantha*, with a few scattered clumps of *Chrysopogon montanus*. As the soil becomes more sandy due to deposition of finer particles, *Saccharum spontaneum, Neyraudia arundinacea*, and *Erianthus munja* appear. The *Chrysopogon* becomes more numerous and robust. With a greater proportion of fine silt *Erianthus munja* becomes dominant. *Neyraudia* becomes dominant where there is enough sand.
A 1.	(ii) *Chrysopogon-Eulaliopsis* associes.	Northern tropical dry mixed deciduous forest. Secondary dry deciduous. Dry deciduous scrub. Dry savannah forests.	*Acacia catechu, Lannea grandis, Ougeinia dalbergioides, Buchanania lanzan, Anogeissus latifolia, Aegle marmelos.*	*Nyctanthes arbortristis, Woodfordia fruticosa, Adhatoda vasica.*	*Chrysopogon montanus, Eulaliopsis binata, Heteropogon contortus, Arundinella nepalensis, Apluda aristata.*	Temperature: Mean ann. 75° – 80°F. Mean, ann. Min. 40°-45°F. Mean ann. Max. 102° – 107°F. Mean Max. over 110°F. Mean Min. 33° – 40°F. Rainfall 30″ – 45″ somewhere it may be 60″ or more.		Chiefly on the Indo-Gangetic alluvium and adjoining Tertiary Siwalik formation, also on crystalline and sedimentary rocks, in Bundelkhand, and older rocks of lower outer Himalayas.	Early annual fires and heavy grazing.	*Chrysopogon montanus* is dominant on the hot waterless, almost soilless ridges and slopes of Siwaliks. It also occurs on deeper moister pockets in association with *Heteropogon contortus. Eulaliopsis binata* is more abundnat on sandrock. *Pogonatherum paniceum* is typical of steep sandrock cliffs.
A 2.	(i) Dry scrub and ravine grassland.	Northern *Acacia* scrub.	*Acacia arabica, A. leucophlaea.*	*Prosopis spicigera, Balanites aegyptiaca, Salvadora oleoides, Capparis aphylla, Carissa spinarum, Adhatoda vasica.*	*Aristida adscensionis, A. hystrix, Chloris pallida, Heteropogon contortus, Eremopogon strictus, Apluda mutica* and *Cenchrus ciliaris.*	Mean ann. 75° to 80°F. Mean ann. Max. about 105°. Mean ann. Min. about 48°. Mean Max. about 115° Mean Min. about 40°. From 40″ down to 20″, the average for U.P. areas about 25″–30″. The number of rainy days is about 40. The main rainfall occurs in June to September.	In the west, south west and south, abutting the thar desert and the central Indian Plateau. In the ravine tracts of Yamuna-Chambal system and the less arid portions of the thorn forest.	Mostly on flat alluvial soils, extending over low hilly country. Patches of alkaline soils with concretionary limestone, and blown sand occur in places. Soils are intensively drained and dry porous. The ground is usually low, hilly or broken due to erosion of unconsolidated alluvial formation with shallow soils overlying a hard lime pan, not far below the surface.	Heavy grazing.	*Aristida* species are pure and gregarious on superficial outcrops of Kankar. *Andropogon pumilus* is gregarious on stretches of eroded and sterile clayey black subsoil in the southern zone where it is mixed with some *Sehima nervosum* also. *Cynodon dactylon* occupies the moister silted up ravine bottoms and *Eragrostis tremula* occurs on bottom sand. *Cenchrus ciliaris* is found on dry rugged sandy soil. *Eremopogon strictus* occurs more on the clayey, black soils, although, it is found on barren ground also. *Iseilema laxum* prefers moister loamy pockets and *Heteropogon contortus* and *Apluda mutica* are common all over. *Bothriochloa pertusa* is sporadic and *Dichanthium annulatum* is restricted to moister shady places.
A 2.	(ii) *Themeda-Sehima* associes.	South Indian dry deciduous forest. Northern tropical dry mixed deciduous forest.	*Anogeissus latifolia, Terminalia tomentosa, Boswellia Serrata, Anogeissus pendula.*	*Pheonix* and thorny shrubs are common.	*Heteropogon contortus, Iseilema laxum, I. anthephoroides, Sehima nervosum, Themeda quadrivalvis, Dichanthium annulatum, Chrysopogon montanus, Aristida* spp.	Temperature. Mean ann. about 75°F. Mean ann. Max. about 100 – 104° Mean ann. Min 48°–50°. Mean Max. about 110° Mean Min. 36 – 40° Rainfall typically 33″–45″ upto 60″ on dry sites and soils.	In northern most part of C.I. plateau occuring in southern U.P.	Usually on dry arid loamy or shallow, clayey soils overlying the Vindhyan formations and crystalline rocks. Shallow soiled welldrained hillsides and undulating topography is typical. The black soils have a lime Kankar zone at some depth and free carbonates. The red soils on crystalline rocks are light, friable, porous, without free carbonates, with low soluble salts content and deficient in N.P. and humus.	Annual burning and grazing.	Annual fires and grazing are the chief biotic influences responsible for the fixity of the type. *Sehima nervosum* occurs on black clayey soils and *Iseilema* in moist loamy pockets.
B	(i) *Saccharum-Vetiveria* associes.				*Saccharum spontaneum, Vetiveria zizanioides, Eulaliopsis binata, Heteropogon contortus.*			The soils are typically water logged and clayey on the surface.	Annual fires.	
B	(ii) *Sporobolus-Chloris* associes.	Gangetic saline scrub.	*Acacia arabica, Butea frondosa, Azadirachta indica, Phoenix sylvestris.*		*Sporobolus pallidus, Chloris montana, Cyanotis axillaris, Artistida hystrix, Paspalidium flavidum, Desmostachya bipinnata, Cenchrus ciliaris, Dichanthium annulatum,* etc.		Lower levels of the Gangetic plain.	Soil is known as usar. It is a recent alluvium, usually clayey with restricted drainge. There is a Kankar pan within a few feet of the surface. The salts are Na, Ca, Mg, with a lesser amount of alkali chlorides. The pH varies from 7.5 to over 10 They are poor in P. N. and organic matter.		Good fodder grasses like *Dichanthium annulatum, Cenchrus ciliaris, Iseilema laxum, Bothriochloa pertusa,* etc., appear in places where soil alkalinity is less than usual i.e. about 7 to 8 pH. Such neutral islands usually occur near isolated plants of *Calotropis procera, Azadirachta indica* or *Acacia arabica. Butea frondosa* is characteristic of clayey waterlogged soils. Where rainwater accumulates, wild paddy; *Paspalum scrobiculatum, Ischaemum rugosum, Echinochloa colonum*, etc. make their appearance.

Table 86 (Contd.)

Grassland community.	Forest community.	Floristics. Trees.	Shrubs.	Grasses.	Grassland climate.	Locality.	Geology and soil.	Biotic features.	Ecology, succession, etc.
C. Alpine meadow.		*Rhododendron, Juniperus.*	*Anemone, Fritillaria, Corydalis,* etc.	*Festuca, Bromus, Poa, Lolium, Phaceluras, Cymbopogon, Eragrostis, Danthonia, Deyeuxia, Phleum,* etc.	The climate is too cold and severe with limited precipitation mostly as snow which covers the ground for 5 to 6 months.	At an altitude of 11,000 ft. and over.			
D. Himalayan Thach park land.	Oak-fir regions.	*Prunus padus, Acer, Festuca modesta, F. lucida, Bromus apser, B. unioloides, Calamagrostis pilosula, Arthraxon serrulatus, Oryzopsis lateralis, Oryzopsis aequiglumis, Koeleria cristata, Lolium perenne, Poa annua, Poa supina, Poa angustifolia, Poa stewartiana, Poa pratensis, Eriophorum comosum, Eriophorum microstachyum, Muehlenbergia sylvatica, Meuhlenbergia himalayensis, Brachypodium sylvaticum, Tripogon filiformis, Polypogon fugax, Capillipedium subrepens, Helictotrichom virescens,* etc.				In the Himalayas at an altitude of of 8,000 ft. or over.	The soils are brown earths.		
E. 1 (i) *Narenga* associes.	Northern tropical moist *sal* forest. North Indian upper alluvial savannah.	*Lagerstroemia parviflora, Lannea grandis, Adina cordifolia, Salmalia malabarica.* The chief grasses are *Narenga porphyrocoma, Erianthus munja, Themeda arundinacea, Saccharum spontanevm, Imperata cylindrica, Vetiveria zizanioides, Bothriochloa,* etc.			Mean ann. temp. typically between 71° to 77°F. January mean 55° to 61°F. Mean Min. 45° to 50°F. May mean. 82° to 89°F. Mean Max. 94° to 101°F. Frost may be frequent and heavy. Rainfall mean annual 40″ to 80″. No. of rainy days 55 to 84. Months with less than 2″ ——— 6 to 8.	Terraces of high alluvium in the sub-himalayan tract.	Indo-gangetic alluvium, including duns and valleys in the Siwalik formations, and older alluvium. Soils sandy to clayey, a fairly deep and fertile sandy loam being typical. The soils are usually acidic with low to fair lime status. The topography is plain to undulating or hilly, usually well drained.	Clearing, felling, fire and grazing lead to the formation of the savannah sere which may persist indefinitely under fire and grazing.	The *Narenga* savannah is usually well marked but in small local patches of a drier nature, *Narenga* may occur with *Erianthus munja* or *E. ravennae* due to retrogressive changes in soil conditions. If the area is exposed to drying factors less mesophilous forms of *Imperata cylindrica* and *Saccharum spontaneum* may appear. *Heteropogon contortus* (on loam) or *Chrysopogon montanus* (on sand) are established.
E. 1 (ii) *Saccharum-Vetiveria* savannah. (a) *Sal chandars* in south Kheri and Pilibhit division. (b) *Sal phantas* in North Kheri division.		Dominant grasses are: *Themeda arundinacea,, Saccharum spontaneum, Vetiveria zizanioides.* Other associates are *Narenga porphyrocoma, Imperata cylindrica, Bothriochloa intermedia, Cymbopogon iwarancusa, Desmostachya bipinnata, Chionachne koenigii,* etc. Typical grasses are *Saccharum spontaneum, Vetiveria zizanioides, Themeda arundinacea, Imperata cylindrica, Bothriochloa intermedia,* etc.							
E. 1 (iii) Low moist wet Savannah.	North Indian lower alluvial savannah.				Typical of the Gangetic plains, frost frequent.	Throughout the Gangetic plains, especially in the sub-montane bhabar and tarai tracts.	Recent alluvium, According to the vegetation two types of soils are recognised (i) Chiefly sandy, with the sub-soil water level sinking to 6′ – 12′ (ii) Chiefly clayey in shallow silted-up channels and depression, moist to wet, not well aerated and apt to water logging in rains, capillary movement of moisture being sluggish.	Annual fires, restricting the tree growth of the hardy species. Moist savannah is a natural heavily utilised grazing ground.	
E. 2 (i) *Erianthus munja* associes (moist savannah).	Dry miscellaneous forest.	*Dalbergia sissoo, Acacia catechu, Salmalia malabarica, Holoptelea integrifolia, Lagerstroemia parviflora, Lannea grandis, Zizyphus jujuba, Helicteres isora, Erianthus munja, Saccharum spontaneum, Themeda arundinacea,* and *Erianthus ravennae, Imperata cylindrica, Desmostachya bipinnata, Chrysopogon montanus* and *Neyraudia arundinacea.*							The grass land is typically seral and gradually with the accumulation of finer soil, its character changes and the more mesophilous grasses gain a foothold, *Erianthus munja* occupies a larger area on moist sand than any other species in northern India.
E. 2 (ii) *Erianthus ravennae* associes (wet savannah).	Moist deciduous and evergreen miscellaneous forest.	*Dalbergia sissoo, Salmalia malabarica, Butea monosperma, Adina cordifolia, Stereospermum suaveolens, Terminalia tomentosa, Syzygium cumini, Gmelina arborea, Cedrela toona, Trewia nudiflora, Mallotus philippinensis.*							
F. *Phragmites-Arundo* associes (reed swamps).		*Phragmites maxima, Typha elephantina,, Arundo donax, Imperata cylindrica, Saccharum spontaneum, Vetiveria zizanioides, Erianthus ravennae, Coix lachryma-jobi, Chionachne koenigii, Bothriochloa intermedia,* etc.			Climatic requirements are met with any where in the tropical and sub-tropical zone				The soil conditions correspond to a typical marsh, with clayey, permanently wet and saturated, badly aerated soil with some water standing in the depression all year or in all months except the driest.

Grassland types of U.P.: Hole (1911), Bor (1947) and others have studied grass vegetation of the Uttar Pradesh. The most recent and comprehensive study of the grassland vegetation of the U.P. was made by Seth (1954), a summary of his main types is given in table 86 on pp. 285 & 286.

Grassland vegetation of Central India: Pandeya (1955), Tiwari (1953–54), Misra (1955) and his students have studied the grassland vegetation of this region. Tiwari recognises eight types of grassland in Madhya Pradesh and succession of the types is given in table 87 and their succession is given in table 88.

Table 88.

SUCCESSION OF VEGETATION AT SAGAR

Note:—Black trap soil mixed with intertrappean calcareous clay 50—60″ Pre-existing Vegetation Mixed deciduous forest of *Diospyros-Butea-Terminalia.*

	Soil depth.	Anthropogenic influence.	Cutting and pasturing, Firing.
Retrogressive Stages	30—40″	Severe felling.	*Butea-Diospyros-Acacia.*
	20—30″	Cutting.	*Flacourtia-Carissa-Zizyphus* (on eroded slopes on table land).
	10—20″	Cutting and pasturing.	*Themeda-Ischaemum-Apluda - Dichanthium-Bothriochloa-Iseilema.*
	8—10″	Pasturing.	*Themeda-Cymbopogon-Iseilema.*
	6—8″	Further pasturing.	*Dichanthium-Bothriochloa-Heteropogon.*
	4—6″	Over pasturing.	*Andropogon-Heteropogon-Tripogon.*
	2—4″	Maximum Regression.	*Aristida-Eragrostis-Melanocenchrus.*
	4″	Closure from grazing.	*Andropogon-Heteropogon-Tripogon.*
	6″		*Dichanthium-Bothriochloa-Heteropogon.*
	8″		*Themeda-Cymbopogon-Iseilema.*
	10″		*Themeda-Ischaemum-Apluda.*
	20″		*Terminalia-Butea-Diospyros* mixed deciduous forest. (Climatic climax).

Discussing the succession in grassland communities of Sagar, Pandeya recognises a primary succession and a secondary succession. The primary succession develops on patches of basaltic rocks, which are undergoing rapid erosion. He recognised the following development:

Aristida — *Melanocenchrus* ——— I

(Barren primary parent material and coarse sand)

↓

Tripogon — *Andropogon* ——— II

(Fresh coarse soil — upto 4″ deep)

↓

Heteropogon contortus

(More building processes, increase of organic matter)

↓

Bothriochloa — *Dichanthium* ——— III

(Premature soil)

↓ ↓

Patches of fresh soil collected by transportation on the plateau tops.

Themeda — *Iseilema* (Stabilised mature soil with high organic content).

↓

Transported soil collected in between boulders, etc., on slopes.

Table 87.

GRASSLAND TYPES OF MADHYA PRADESH

(Compiled from various sources quoted)

Grassland community.	Floristics.	Grassland climate	Locality.	Geology and soil.
A. *Andropogon pumilus -Indigofera* type.	*Andropogon pumilus, Aristida adscensionis. Eragostis viscosa, Eragrostis tenella, Eragrostis unioloides, Melanocenchris royleana, Indigofera cordifolia* and *Indigofera linifolia* are common species. Besides these are *Fimbristylis diphylla, Kyllinga triceps, Boerhaavia diffusa, Polygala chinenis, Spermacoce stricta, Enicostema littorale, Trichodesma indica, Tridax procumbens, Convolvulus pluricoulis, Evolvulus alsinoides, Scilla indica, Cassia tora* and *Cassia obtusifolia.*	Average annual raifall is 48 inches. Average monthly minimum and maximum temperatures are 52 °F and 77 °F in January. 78.°5F and 105 °F in May and 74 °F and 83 °4F in July. Frost is common during the colder months.	On level table land and plains.	The soil is purple brown sedentary sandy loam about 1-4 inches deep. pH value ranges between 6–7.
B. *Andropogon pumilus - Heylandia latebrosa* type.	*Andropogon pumilus, Aristida adscensionis, Alysicarpus* spp., *Bothriochloa pertusa, Cassia pumila, C. tora, Dichanthium annulatum, Digitaria* spp., *Desmodium parvifolium, Eragrostis* spp., *Heteropogon contortus, Heylandia latebrosa, Iseilema anthephoroides, Indigofera* spp., *Manisuris granularis, Melanocenchris royleana, Rhynchosia minima, Setaria* spp., *Sporobolus diander, Tripogon lisboae, Zornia diphylla.*	as above.	On the hill top pastures.	The soil is thin, gritty sand of light red colour. pH value is 6–7.
C. *Bothriochloa pertusa-Heylandia latebrosa type.*	*Andropogon pumilus, Aristida adscensionis, Alysicarpus* spp.. *Bothriochloa pertusa, Cassia pumila, C. tora, Dichanthium, Heteropogon contortus, Heylandia latebrosa, Indigofera* spp., *Manisuris granularis, Melanocenchris royleana, Rhynchosia minima, Setaria glauca.*	as above.	On hill slopes.	The soil is grey, gravelly loam, locally admixed with intertrappean chalk. The intermittent appearance of sedimentary beds are present. The soil remains fresh and poor supporting a meagre vegetational cover to protect itself from denudation and transportations. Outcrops of basalt are also common. pH 6–8.

D. *Themeda caudata - Alysicarpus* type.	*Apluda aristata, Amphilophis* spp., *Ischaemum, Atylosia platycarpa, Alysicarpus* spp., *Bothriochloa pertusa, Cassia pumila, Cymbopogon martini, Cenchrus ciliaris, Crotalaria* spp., *Dichanthium annulatum, Desmodium parvifolium, Digitaria* spp., *Eragrostis* spp., *Eulalia trispicata, Heteropogon contortus, Heylandia latebrosa, Indigofera* spp., *Iseilema anthephoroides, Ischaemum rugosum, Flemingia congesta, Manisuris granularis, Phaseolus* spp., *Rhynchosia minima, Rottboellia exaltata, Sehima nervosum, Setaria* spp., *Sorghum halepense, Themeda caudata, Tragus racemosus.*	as above.	In the reserved meadows.	The soil is deep black clay, rich in organic matter, carbonate and nitrates, pH between 6-7.
E. *Heteropogon contortus-Indigofera* type.	*Andropogon pumilus, Aristida adscensionis, Alysicarpus* spp., *Bothriochloa pertusa, cassia pumila, C. tora, Dichanthium annulatum, Digitaria* spp., *Desmodium parvifolium, Eragrostis* spp., *Eleusine* spp., *Heteropogon contortus, Heylandia latebrosa, Iseilema anthephoroides, Indigofera* spp., *Manisuris granularis, Phaseolus trilobus, Rhynchosia minima, Setaria glauca, Sporobolus diander, Tripogon lisboae, Zornia diphylla.*	as above.		Soil is light brown sandy loam, 6–8 inches in depth, pH ranges between 6–7.
F. *Coix lachryma-jobi-Heylandia latebrosa* type.	*Apluda aristata, Alysicarpus* spp., *Atylosia platycarpa, Bothriochloa pertusa, Cymbopogon martini, Cassia* spp., *Crotalaria* spp., *Coix lachryma-jobi, Cynodon dactylon, Chloris virgata, Dichanthium annulatum, Desmodium* spp., *Digitaria* spp., *Echinochloa colonum, Eragrostis* spp., *Eleusine* spp., *Heteropogon contortus, Heylandia latebrosa, Iseilema anthephoroides, Indigofera* spp., *Ischaemum rugosum, Paspalum* spp., *Setaria* spp., *Saccharum spontaneum, Themeda caudata, Tripogon lisboae, Zornia diphylla.*	as above.	Along the stream banks.	The soil is deep black clay, rich in organic matter, carbonate and nitrate contents, pH value is 6–7. It has slightly more moisture than in type D.
G. *Dichanthium annulatum- Desmodium* type.	*Apluda aristata, Alysicarpus* spp., *Bothriochloa pertusa, Clitoria* spp., *Cassia tora, C. pumila, Cynodon dactylon, Dichanthium annulatum, Desmodium* spp., *Digitaria sanguinalis, Desmostachya bipinnata, Eragrostis tenella, Heteropogon contortus, Iseilema anthephoroides, Indigofera glandulosa, Oplismenus* spp., *Paspalidium flavidum, Rhynchosia minima, Sporobolus diander, Setaria glauca.*	as above	Occur in the pasture land existing under the shade of a tree canopy.	Soil similar to type "D".
H. *Iseilema anthephoroides - Alysicarpus* type.	*Alysicarpus* spp., *Bothriochloa pertusa, Cassia pumila, Cynodon dactylon, Eragrostis tenella, Heteropogon contortus, Iseilema anthephoroides, Indigofera linifolia, Sporobolus diander, Setaria glauca, Zornia diphylla.*	as above.	This develops in the pasture land which was burnt down by fire in the previous year.	

These three stages are conditioned by increased moisture content of the soil and in the final third phase with the moderate grazing the grassland remains for a long time in this condition. Further he recognised the following three other types dependent upon the soil conditions.

(i) On calcium rich soil.

Associes — *Sehima* — *Tripogon*

(Facies)	(Socies)
Sehima *Tripogon* *Eragrostis*	*Sehima nervosum, Andropogon pumilus, Tripogon lisboae, Bothriochloa pertusa, Eragrostis elongata, Eragrostis tenella, Eragrostis unioloides, Eragrostis amabilis, Dichanthium annulatum, Digitaria sanguinalis, Setaria glauca,* etc.

(ii) Associes — *Eulalia* — *Cymbopogon.*

(Facies)	(Socies)
Cymbopogon *Eulalia* *Rotboellia*	*Eulalia trispicata, Cymbopogon martini, Rotboellia exaltata, Digitaria species, Arundinella nepalensis, Heteropogon contortus* and *Dichanthium annulatum.*

The stabilised mature soil supports the highest grass-community under the present climatic conditions. Under protection it may progress into the mixed deciduous forest growth. It consists of:—

Association - *Themeda - Iseilema.*

(Faciation)	(Society)
Themeda *Iseilema* *Apluda*	*Themeda caudata, Iseilema anthephoroides, Apluda aristata, Apluda mutica, Ischaemum rugosum,Cenchrus ciliaris,Sorghum purpureosericeum, Amphilophis, Cymbopogon martini, Paspalidium flavidum,* etc.

In the secondary succession he recognised that communities of *Bothriochloa pertusa* and *Dichanthium annulatum* are the major dominants on the grassland stabilised soil. In this community *Themeda caudata* when increases, shows the ecological succession while the increase in the coverage of the first two species indicates retrogression. The reduction in the intensity of grazing helps the increase of *Bothriochloa* and *Dichanthium* and the reduction in *Chloris, Eleusine aegyptiaca, Heteropogon contortus* and *Eragrostis* species.

S. D. N. Tiwari (1954) has studied grassland vegetation of Madhya Pradesh. Some grasses of Madhya Pradesh are of economc importance too, as for example, *Eulaliopsis binnata,* is an important raw material for manufacturing paper. He gave a list of grasses, occuring in Madhya Pradesh, the chief ones with their habitat and economic importance are given below.

Table 89.

GRASS HABITAT AND USES OF SOME GRASSES OF M.P.

(After Tiwari, 1954).

Species.	Habitat.	Economic Importance.
Alloteropsis cimicina.	A very common sp. in waste land compounds on sandy loam soil.	A good fodder.

Table 89 (Contd.)

Species.	Habitat.	Economic Importance.
Amphilophis glabra.	Common in rocky places.	A good fodder.
Andropogon ascinodis.	Common in forest blanks in hilly areas.	A good fodder.
Apluda aristata	Grows sporadically in hills plantations on slopes and on bunds of fields in Mandla.	
Apocopsis pallida.	Common in the *sal* forest blanks.	A good fodder grass.
A. wightii.	Found in wet places on poor soil, along rocky nallahs, etc.	
Aristida funiculata.	On sandy soil in Dhaba range.	
Arundinella bengalensis.	In marshes near nullahs on sandy loam soil.	
Brachiaria ramosa.		A good fodder grass.
Cenchrus ciliaris.	Rare.	Excellent fodder.
Chrysopogon aciculatus.	Found in heavily grazed grassland and seldom seen in forest.	Good fodder.
Cymbopogon martini.	Very common in Betul, Chhind wara, Mandla and Bastar.	Yields the commercial Rusa grass oil.

Grassland types of Assam: Bor (1940) described grasses of Assam under the following different habitats:—

Tropical habitats: Grasses most commonly found in forests or along margins are *Pseudostachyum polymorphum, Bambusa pallida, Melocanna bambusoides, Lophatherum gracile* and *Centotheca lappacea.*

On moist habitats outside the forest predominant species include *Panicum humidorum, Saccolepis interrupta, Hymenachne assamica, Eleusine indica, Dactyloctenium aegyptiacum,* several species of *Paspalidium, Oryza sativa, Vossia cuspidata* and *Leersia hexandra,* etc.

The typical savannah of the uplands consists almost entirely of *Imperata cylindrica,* but associated with it are *Saccharum spontaneum, S. narenga, Apluda aristata, Cymbopogon pendulus, Arundinella* sp. and *Ophiurus megaphyllus,* etc.

Sub-tropical habitats: In forests and along margins species of *Dendrocalamus* and *Bambusa* abound, but majority of bamboos belong to the genus *Arundinaria.* Herbaceous forest species include *Oplismenus compositus, Cyrtococcum radicans, Polypogon monspeliensis, Isachne albens, Ichnanthus vicinus, Panicum khasianum,* etc.

On moist habitats outside the forest the most common species are *Alopecurus myosuroides,* several species of *Panicum, Eragrostis, Paspalidium, Echinochloa* and *Isachne, Deyeuxia elatior, Arundinella khasiana, Saccolepis indica, S. myosuroides,* several species of *Arthraxon, Dimeria fuscescens, Coelachne pulchella,* etc.

On xerophytic habitats, *Imperata cylindrica* is the main species over large areas. Associates include several species of *Themeda, Erianthus* and *Eulalia, Andropogon ascinodis, Sorghum nitidum, Saccharum narenga, Cymbopogon khasianus, Thyrsia* and *Zea,* etc.

Temperate habitats: The common grasses are *Danthonia cachemyriana, Bromus asper, Calamagrostis emodis, Deyeuxia scabrescens, D. mugarum, Capillipedium pteropechys, Tripogon filiformis* and several species of *Arundinaria.*

In the Shillong plateau, Assam, Bor (1942) states that the grassland is almost devoid of trees. Certain tree species such as *Careya arborea, Callicarpa arborea,* and *Sehima wallichii* form a loose associes. Chief grasses are *Saccharum narenga, Sorghum nitidum, Themeda triandra, Andropogon ascinodis, Erianthus longisetosus, Imperata cylindrica, Ophiurus megaphyllus,* etc. This grassland community reaches its full luxuriance in the autumn and the majority of the grasses flower at the end of the rains or during cold weather. By spring the grass completely dries up and fire, raging everywhere, rapidly reduces the hills to smoking black wastes.

The chief associates of the grasses in the community are *Atylosia elongata, Crotalaria humifusa, Desmodium sambuense, Eriosema chinense, Flemingia latifolia, Indigofera atropurpurea, Lespedeza stenocarpa, Priotropis cytisoides, Aletris khasiana, Crinum amoenum, Hedychium spicatum,* etc. *Phoenix acaulis* is very common.

Rowntree (1954) described the following communities from Grasslands and savannahs of Assam.

(i) *Imperata-Saccharum-Themeda* associes is found on higher well drained land throughout Assam and has the following consocies:—

Apluda mutica.	*Arundinella bengalensis.*
Crotalaria striata.	*Eupatorium odoratum.*
Imperata cylindrica.	*Leea* sp.
Narenga porphyrocoma.	*Themeda arundinacea.*

(ii) *Alpinia-Phragmites-Saccharum* associes occupies the flood plains of rivers all over the Assam valley, occurring on recent alluvium which contains a fair amount of clay, the consocies of this type are:—

Alpinia sp.	*Erianthus ravennae.*
Phragmites karka.	*Saccharum procerum.*
Saccharum spontaneum.	*Albizzia procera.*
Bombax malabaricum.	

Grassland vegetation of Kathiawar: Kapadia (1951) gave an interesting account of the ecology of grasses of Kathiawar where the grasses are herbaceous except *Dendrocalamus strictus.* Of the 84 species, 27 are annuals and 42 are perennials. Some of the annuals acquire or possess adaptations which induce a perennial habit. Their erect stems becoming decumbent at the base are modified into creeping root stock. Among these are *Eremopogon foveolatus, Andropogon pumilus, Themeda quadrivalvis, Brachiaria isachne* and *Brachiaria ramosa.*

Grassland are a conspicuous feature of Kathiawar and they have been included under the general ecological type savannah. The characteristic species of savannah are *Ischaemum rugosum, Apluda varia, Dichanthium annulatum, Eremopogon foveolatus, Cymbopogon martini, Heteropogon contortus, Themeda quadrivalvis,* etc.

Many species of the grasses of this place prefer moist places, such as *Coix lachryma-jobi, Polytoca barbata, Ischaemum rugosum, Saccharum spontaneum, Vetiveria zizanioides, Iseilema wightii, Brachiaria isachne, Paspalum vaginatum, Pasaplidium flavidum, P. geminatum, Echinochloa colona, E. crusgalli, Phragmites maxima, Panicum antidotale, Heleochloa setulosa, Eragrostis ciliaris* and *Cynodon dactylon.* The other species are mostly xerophytic.

Psammophytes are represented chiefly by *Pollinidium binatum, Panicum turgidum, Cenchrus biflorus, Eragrostis ciliaris,* etc.

Therophytes are chiefly represented by *Manisuris granularis, Eremopogon foveolatus, Heteropogon contortus, Pennisetum ciliare, Arundinella setosa, Aristida adscensionis,* etc.

Heleochloa setulosa, Sporobolus indicus, S. virginicus, S. glaucifolius, S. pallidus and *Halopyrum mucronatum* represent the halophytes.

Cymbopogon schoenanthus, C. martini and *Nazia racemosa* are particularly xerophytic in nature.

Saccharum spontaneum is very a variable species. It is xerophyllous on dry sandy soils, hygrophyllous on swamps and intermediate on loamy soils.

Some species prefer shade and are found growing underneath big trees, in hedges and amongst bushes. They are chiefly *Apluda varia, Sorghum halepense, Dichanthium annulatum, Themeda cymbaria, Paspalidium flavidum.*

These grasses sprout with the first shower of rain and in a short time they are well grown. In October and November they reach full luxuriance. The majority of the species flower at the end of the rains and wither and dry up in January. Minimum number of species flower in January while the maximum number flower in October.

Desert Grasslands: The grasslands of arid region are found mainly in Rajasthan, parts of Kutch and Saurashtra. These were recently studied by Puri and Vasavada (1958). These are found mostly on sandy dry loose types of soil, which continuously shift from place to place to form sand dunes.

There are hardly 2 – 3 types of communities. The number of species in each is always limited.

One type is a *Cenchrus catharticus - Aristida adscensionis* community found all over the arid regions. The grasses are very coarse and rough and do not reach noteworthy height. *Cenchrus catharticus* has several ecotypes in one region only. The other associates are a few herbs, such as *Fagonia cretica* Linn., *Aerua tomentosa* Forsk., *Heliotropium* sp., *Leptadenia spartium* Wt., *Crotalaria burhia* Ham., *Citrullus vulgaris,* etc.

The shrubs are few, namely, *Capparis aphylla* Linn., *Zizyphus nummularia* DC. and *Tephrosia purpurea* Pers. The first two are scattered all over but *Tephrosia* grows densely. Blue panic - *Panicum antidotale* Retz., grows very luxuriously when mixed with *Capparis aphylla* due to its getting protection from grazing.

The other type is the *Elionurus hirsutus* Munro community which thrives in an average annual rainfall of about 6″ – 8″. This grass forms pure communities and attains the height of about 5′–6′ and the tufts have a girth of almost 3′. Its associates are very few, being trees like *Salvadora oleoides* Dene. and *Acacia leucophlaea* Willd. Here also *Crotalaria burhia* Ham., *Leptadenia spartium* Wt. and *Tephrosia purpurea* Pers. occur.

In both the types, the number of species is limited. In the second the vegetation appears dense as compared to the first.

The second type is grazed much more due to the palatibility of the grass and its being tender.

In a few places wherever there are ponds or pools tufts of *Saccharum spontaneum* Linn. are found, mixed with species of *Cyperus, Fimbristylis ferruginea* Vahl. and *Fimbristylis dichotoma* Vahl.

Cutch Grasslands: There are vast tracts of grasslands in the northern part of Kutch, called the Banni grasslands, which were recently studied by Puri and Jain (1958). There are more than a dozen grass species growing in these areas. These grasslands are a great asset in the economy of Kutch as they sustain all the cattle-wealth of the area. The tract is saline and does not support anything else.

In addition to these, small patches of poor grasslands occur scattered between the scrub jungle also where soil is poor and shallow.

Apluda aristata, Cenchrus, Pennisetum, Cymbopogon, Eragrostis and *Elionurus* are commonly met with on rocky areas. *Paspalidium* grows abundantly in moist places near banks of ponds.

Grasses of Bhopal: Chitwadge has made a brief study of the pastures on the *Mather Plateau* in Bhopal, Central India. The area is hilly with an altitude of about 1,500 ft. above sea level. The main rocks are Vindhyan Sand-stone inter-spersed with out-crops of Deccan Trap. The area receives the annual rainfall of 40" to 50". The Grasslands are biotic communities in the Forest Areas: the forest type being tropical dry deciduous with teak as the main constituent. The other associates in the forest are *Terminalia, Butea, Dalbergia latifolia, Diospyros, Lagerstroemia,* etc.

The following three Grass communities have been recognised: (1) *Iseilema-Dichanthium* type, (2) *Themeda* and (3) *Saccharum-Vetiveria* type.

Short descriptions of these types were given by Chitwadge.

Grasslands of South India: Grasslands of South India may be classified in the following categories:—

1. Probable climatic climax (according to Ranganathan).
   (i) The upland grass areas of Nilgiris.
2. Probable edaphic climax formation.
   (i) Low riverain swampy grassland.
   (ii) Frost hallows in forest land.
3. Transition stages in the colonisation of new soil.
   (i) Dry riverain grassland.
4. Transition stages in the recolonisation of denuded land.
   (i) Abandoned cultivation.
   (ii) Site of severe forest fires.
5. Retrogression stages from forest land.
   (i) Typical minor blanks in forest.
   (ii) Grassland due to repeated firing.
   (iii) Grassland due to over-grazing.
   (iv) Grassland due to over-felling.
6. Irreversible retrogression stages from forest.
   (i) Grassland due to failure of trees from changes in drainage.

(a) **Grasslands of Nilgiris and Anamalai Hills:** Large stretches of Shola forests and grasslands occur in the South Indian Hills (photo 200). Ranganathan (1938) observed that grassland dominates over forest in the Wenlock Downs and in the Kundahs of the Nilgiri plateau, where the country is a vast expanse of grass interspersed with small, isolated shola patches. The species composing the grass complex are *Andropogon pertusus, Ischaemum pilosum, Themeda imberbis, Cymbopogon polyneuros,* and *Eragrostis nigra. Orchis mascula* occurs in small societies in Bison swamp and in the valley of the Billithadahalla and the Mukurti. While describing succession in these grasslands he noted that three exotic species viz., *Eupatorium glandulosum, Ulex europeus* and *Cytisus scoparius* have recently made considerable inroads into the grasslands. Scattered *Rhododendron* trees along with

natural regeneration are often seen on grassy slopes. *Rhododendron* trees seem to be the vestiges of sholas which were destroyed by fire in the past. But the presence of regeneration of this species suggests that they are pioneers. *Rhododendron* may be an early species in the shola succession, tending to disappear with the mature development of the shola. The perpetuation of the Nilgiri grassland is considered by Ranganathan to be due to climate, especially frost action, which does not permit tree species to gain a permanent foot hold in the grasslands. He, therefore, considers that this community is also climatic climax like the shola forests, and the two climaxes occur side by side (photo 201).

Grassland type of the Anamalai hills from 3,000 feet to the highest point has been subdivided by Fischer into the following two subtypes:–

(a) **Lower grassland subtype,** below 6,000 feet, is distinguished by 2 species of *Viola, Linum mysorense, Crotalaria wightiana, Desmodium rufescens, Drosera burmanni, Bupleurum mucronatum, Conyza stricta, Campanula fulgens,* 3 species of *Burmannia, Andropogon naidus, Pteris aquilina, Selaginella rupestris,* etc.

(b) **Upper grassland subtype**, above 6,000 feet, comprises of *Hypericum japonicum, Polygala sibirica, Geranium nepalense, Impatiens oppositifolia, Indigofera pedicellata, Fragaria indica, Hedyotis* sp., *Valeriana hookeriana, Jasminum bignoniaceum, Polygonum alatum, Rumex nepalensis, Arundinella wightiana,* etc.

Large patches of grasslands also occur in the Western Ghats in Mysore, where forests have been cleared up. On generally shallow, dry soil, derived from the decomposition of granite a few grasses are present.

A view of grassy hillocks and patches of evergreen forest along Mudigere-Aldur road is shown in Photo 202.

The patches of evergreen forest have the following tree and shrub species: *Lagerstroemia indica, L. lanceolata, Canthium dicoccum, Careya arborea, Zizyphus rugosa, Pavetta indica, Lasiosiphon eriocephalus, Kydia calycina, Terminalia tomentosa, Bridelia retusa, Terminalia bellerica,* and *Mallotus philippinensis.*

Ephiphytic orchids are abundant on trees and Lichens and epiphytic ferns are also present. Among epiphytic ferns, *Pleopeltis linearis, Pleopeltis memberanacea* and *Niphobolus adnascens* are abundant. Grassy hillocks give the view pale green colour. Among the grasses, the following species are common: *Lophopogon tridentatus, Arundinella spicata, Chrysopogon* sp., *Heteropogon* sp., *Themeda* sp., *Pseudanthistiria* sp., *Chloris* sp., etc.

Other herbaceous species among the grassy patches are: *Commelina, Cyanotis, Trichodesma indicum, Eriocaulon* sp., *Microstylis versicolor, Impatiens* sp., *Oxalis corniculata,* etc.

Grassland Vegetation of Bombay - Deccan: The Deccan Traps bear extensive patches of grassland where forests have been cleared and the soil is shallow and dry on account of intense leaching and erosion. Here and there along with grasslands, saplings and seedlings of trees may be present which are mainly species of *Acacia.* Descriptions of these grassland types have recently been given by Puri and Jain (1957). Some Grassland communities were also studied from the Bhimashankar area (Puri and Vasavada, 1957), Mahabaleshwar (Puri and Mahajan, 1958), and Khandesh (Puri and Mahajan, 1958). The Deccan Grasslands can be conveniently divided into two main types according to high and low rainfall. The two types of grasslands are described below briefly:

(1) **High Rainfall Grasslands:** High Rainfall Grasslands are found in the Western Ghats, usually above the altitude of 2,500 ft. above

mean sea level in areas of average annual rainfall above 150".

There are three main types of grasslands in this area given below:—

	1	2	3
Rainfall	Between 150" – 170".	Above 200".	Above 200".
Geology and rock	Basalt overlain by amygdaloid. The amygdaloid layer is thin.	Basalt with the covering amygdaloid washed off and remaining in few places only. Bare rocks exposed.	Basalt with amygdaloid covering. Collected clay.
Soil	Reddish, rocky, hard, gravelly and coarse.	Rocky, gravelly, stony, rough. Usually blackish in colour.	Moist, soft granular, red, sticky.
Moisture retention capacity of the soil.	Very little.	Nil.	Moisture retained almost upto Mid-winter.
Origin	In abandoned cultivated lands.	In destroyed forests or scrubs on hill slopes.	In destroyed forests or scrubs on plains or in valleys.
Biota	Overgrzaed.	Not much grazed.	Overgrazed. Presence of arthopods like crabs. Crabholes present.
Dominant grasss species.	*Andropogon pumilus* Roxb.	*Heteropogon contortus* R. & S.	*Sporobolus* sp., *Eragrostis amabilis* W. & A.
Other associates	*Leucas stelligera* Wall. *Cyathocline lutea* Law. *Linum mysorense* Heyne. *Crotalaria orixensis* Willd. *Glossocordia linearifolia* Cass.	*Leucas stelligera* Wall. *Senecio grahami* Hk. f. *Isachne elegans* Dalz. *Memecylon umbellatum* Burm. *Murrya koenigii* Hocht. *Randia dumetorum* Lamk.	*Arundinella tenella* Nees & Wight. *Isachne australis* R. Br. *Isachne elegans* Dalz. *Paspalum campactum* Roth. *Paspilidium flavidum* A. Camus.

In moist depressions, where water collects generally pure patches of *Dysophylla stellata* (photo 203) or mixed with *Arundinella tenella* (photo 204) form a conspicuous feature of these grasslands. *Cyathocline lutea* (photo 205) grows in dense patches on dry situations *Ischaemum semisagittatum* and *I. aristatum* (photo 206) are also found in depressions.

Low Rainfall Grasslands: Low Rainfall Grasslands are found towards the east of the Western Ghats in the rain shadow area, below the altitude of 2,000' above mean sea level, where the average annual rainfall ranges between 10" and 50".

These grasslands have originated by the destruction of the forests and the later erosion of the soil by water due to the loss of vegetation cover.

Three main types can be distinguished as given below:—

	1	2	3
Rainfall	Between 20" and 30".	Below 20".	Between 30" and 50".
Geology and rock	Basalt overlain by amygdaloid. Amygdaloid layer thin. Basalt exposed.	Basalt with the covering amygdaloid washed off in most places.	Amygdaloid cover on the basalt rather deep.
Soil	Brownish, hardest, gravelly, pebbly moist soil.	Hard, dry rocky soil grayish in colour.	Brownish hard soil, granular, gravelly hard moister than 1.
Moisture retaining capacity.	Low (about 15%).	Very low (about 2—5%).	Better than 1. (about 25%).
Origin	From destroyed scrub. Fairly advanced stage. Shallow soil left on rocky substratum.	From destroyed scrub. Very advanced stage. Very little soil left due to erosion.	From destroyed scrubs. Soil retained on the rocky substratum.
Biota	Overgrazed by cattle.	Overgrazed. Fit only for sheep & goats.	Overgrazed and cut freely.

	1	2	3
Dominant grass species.	*Lophopogon tridentatus* Hack. *Apluda varia* Hack.	*Aristida funiculata* Trin.	*Heteropogon contortus* R. & S.
Other species:	*Crotalaria orixensis* Willd. *Indigofera cordifolia* Hack. *Heylandia latebrosa* DC. *Desmodium triquetrum* DC. *Lepidagathis cristata* Willd. *Dichanthium annulatum* Stapf. *Habenaria longecalcarata* Rich. *Habenaria marginata* Coleb.	*Aristida hystrix* Linn. f. *Melanocenchris royleana* Nees. *Commelina* sp., *Cyanotis* sp., *Scilla indica* Baker. *Iphigenia indica* Gray.	*Apluda varia* Hack. *Themeda quadrivalvis* O. Kuntz. *Dichanthium annulatum* Stapf. *Eragrostis amabilis* W. & A. *Rotboellia exaltata* Linn. f. *Ophiurus corymbosus* Gaertn.

In low rainfall grasslands *Cymbopogon* and *Themeda* (photo 207) are common associates. *Bothriochloa* (photo 208) comes in sometimes on deeper soils.

Burns and Kulkarni (1927) considered that local differences in flora in the Deccan are related to the water content of the soil, as is shown them in table 90.

Table 90.

RELATIONSHIP OF GRASS FLORA WITH WATER CONTENT OF THE SOIL

(The Samples are from a depth of 2-6" over rock and 12-18" in good soil. Determinations made in December 1926, from Burns and Kulkarni).

S. No.	Grass species.	Locality.	Soil.	Water content of the soil.
1.	*Andropogon odoratus, Pollinia argentea, Ischaemum aristatum, Arundinella agrostoides, Anthistiria ciliata.*	Low-lying lands in Lonavla.	Deep land clayey.	13.6%
2.	*Andropogon annulatus, Andropogon pertusus, Panicum isachne, Aristida funiculata, Aristida adscensionis.*	Sirur.	Good soil of about 3 feet deep.	17.4%
3.	*Artisida, Andropogon pertusus, A. foveolatus, A. monticola, A. contortus.*	Sirur	Poorer shallow soil of less than a foot deep.	7.19%
4.	*Ischaemum laxum, Andropogon monticola.*	Hill.	Three inches deep soil.	—
5.	*Andropogon odoratus, Pollinia argentea, Ischaemum aristatum, Andropogon aristatum, Anthistiria ciliata,*	Low lying good lands at Kamshet.	Medium black soil of two feet deep.	18.4%
6.	*Pennisetum alopecuros.*	Low lying good lands at Kamshet.	Medium black soil of about two feet deep.	18.4%
7.	*Andropogon odoratus, Ischaemum aristatum, Pollinia argentea, Andropogon contortus, A. schoenanthus, Anthistiria ciliata.*	Kamshet.	Poor soil stream with stones.	4.9%
8.	*Andropogon contortus. Aristida funiculata.*	Kamshet.	—	under 4%
9.	*A. monticola, A. triticeus, A. purpureo-sericeus, Rotboellia divergens, Aneilema paniculata, Oropetium thomaeum, Cynotis fasciculata.*	Kamshet.	Medium soil, 6 inches deep.	1.8%

Succession of Deccan grasslands: Discussing the succession of grassland communities described by Burns, Garland (1932) gives the following successional trend:

1. Bare rock with some *Aristida* and *Andropogon contortus*. In this *Andropogon monticola* appears in crevices, etc.

2. A very few xerophytic bushes and shrubs come in. *Andropagon contortus* and *A. monticola* spread under bushes, shrubs and dwarf trees, under 6 feet average height.

Lantana tends to invade the area.
Apluda varia appears under shrubs.

3. When average height of bushes of which *Boswellia serrata* is the principal species goes up to 12 feet. *Aristida* disappears, *Andropogon contortus* becomes co-dominant with *A. monticola* and *A. pertusus*. *Apluda varia* becomes sub-dominant.

4. When the average height of trees goes up to 20 ft., with teak on reddish soils and *Anogeissus latifolia* on gray soils *Andropogon contortus*, becomes dominant. *A. monticola A. pertusus* become co-dominant with *Ischaemum laxum* and *I. sulcatum*.

5. Natural regeneration of various tree species increases markedly, especially *Terminalia tomentosa*, which becomes now 30 ft. in average height.

Andropogon contortus disappears.
Anthisteria ciliata begins to appear.

6. With the closing of tree canopy of the mixed deciduous trees with a general height of 30–59 feet.

Anthisteria ciliata is usually dominant.
Shrubs have disappeared.
Bushes are generally suppressed.

Grassland and wheat rust problem: In connection with the ecological studies of grasslands of India,it may not be out of place to make a mention in passing about rusts that affects wild grasses and Indian wheat. Mehta (1929) was probably one of the pioneers in the study of wheat rusts in this country and suggested that one of th ways to control wheat rust in India is that cultivation of wheat in some south Indian hills be supended for a few years. Misra (1953) has recently summarised the result of such recommendations.

He gave the data for the appearance of rust and its intensity of infection of wheat crop in south India in table 91.

During the three years 1948–51, the scheme prohibiting the summer cultivation of wheat and barley was enforced fairly effectively only in the last two years when there was relatively little or no rust in peninsular and central India and in parts of Rajasthan. The weather during the critical period for the development of rust in 1949-50 and 1950-51, was rather dry and as such it could not be determined whether the relative scarcity of rusts was due to the ban or the unfavourable weather or both. From a study of the development of black rust in sequence it is to be seen that the rust appears progressively earlier in southern regions. During the three years when observations were made, black rust was only sparingly observed in the hills; the common variety of local wheat *Triticum dicoccum* was not found affected. As the development of black rust depends much upon favourable weather, the possibility of the susceptible wheat and barley getting severly infected during August to September (prior to the appearance of the rust in the plains) cannot be overlooked. Even a relatively small amount of inoculum surviving in the hills on the crop or on tillers during cooler months

Table 91.

RUST ON WHEAT IN SOUTH INDIA

(After Misra, 1953).

State.	District.	Time of first appearance of rust during.			Average severity of rust during		
		1948—49	1949—50	1950—51	1948—49	1949—50	1950—51
Madras.	Nilgiris*	—	—	August*	—	—	Trace.
	Palnis.	August*			Trace.		
Mysore.	Chikmaglur.	November (1—2nd week).	—	—	Light Moderate.	—	Trace-Light.
	Chittaldrug.	November (1—2nd week).	End of November.	—	Moderate heavy.	Trace-Light.	Moderate.
Bombay.	Dharwar.	November (1—2nd week).	November (3rd–4th week).	November middle.	Moderate heavy.	Trace very light.	Light moderate.
	Belgaum.	November (1—2nd week).	November 3rd week.	Nil.	Moderate Heavy.	—	Nil.
	Satara.	—	November (4th week)	—	Nil.	Very light.	—
Madhya Pradesh.	Chanda.	December.	—	—	Moderate heavy.	—	—
	Akola.	January.	—	—	Light moderate.	Nil.	Nil.
	Udaipur.	February. (1—2nd week).	—	—	Trace, very light.	Nil.	Nil.
Rajasthan.	Ajmer.	—	March. (1st week).	—	Trace.	Trace.	Nil.
	Jaipur.	February (2—3rd week).	—	February (Middle).	Trace.	Nil.	Trace.

*Observations in Niligiris and Palnis made on the summer crop during August to September.
Rust observed, in traces, during the last week of August on the summer crop. The exact time of appearance is not known.

of October and onwards may serve as a source of infection, which may flare up at lower altitudes where the weather conditions are likely to be favourable for the development and spread of the rust.

Another, equally important source of infection may be the summer crop raised in plains. Because of long period of sowing and harvesting, the summer wheat crop is likely to overlap the winter crop in certain localities. The interval between the harvesting of the summer crop and the sowing of the winter crop is very little. Rust in these regions is likely to pass on from the summer crop to that raised during the winters.

Certain grasses act as collateral hosts of *Puccinia graminis tritici* in Mysore, Madras, Bombay. Even so the importance of a regular crop of wheat or barley during summers providing a most congenial and continuous host, which may get infected and perpetuate and disease cannot be minimized, because it may develop an abundance of inoculum which is so necessary for starting an epidemic.

A number of grasses act as host of rust in north India as well.

In the Simla Himalayas, Prasad (1949) found that *Puccinia graminis* was found on *Bromus patulus, Agropyron semicostatum, A. longe-aristatum* and *Poa nemoralis*. The rust from *Bromus patulus* infected wheat and barley but those from *Agropyron* and *Poa* failed to do so. They were *Puccinia graminis agroovri* and *P. graminis poae,* respectively. *Puccinia glumarum* occurring on *Agropyron semicostatum* and *Phalaris minor* also did not infect wheat or barley.

When *Agropyron longe-aristatum, A. semicostatum* and *Bromus patulus* were artificially inoculated with *Puccinia graminis,* they were heavily infected, *Brachypodium sylvaticum* and *Agropyron repens* were moderately infected and *Dactylis glomerata, Festuca gigantea* and *F. myuros* showed weak infection.

Puccinia graminis avenae infected *Avena aspera, A. fatua* and *Phalaris minor* moderately and *Lolium temulentum, Dactylis glomerata, Agrostis alba, Agropyron longe-aristatum, A. semicostatum, A. repens, Aegilops caudata* and *Bromus patulus* weakly. *Puccinia graminis secalis* infected *Agropyron longe-aristatum, A. semicostatum* and *A. repens* heavily, *Bromus patulus* moderately and *Dactylis glomerata* and *Aegilops caudata* heavily. *Puccinia glumarum* infected *Agropyron longe-aristatum, A. semicostatum* and *Aegilops caudata* heavily, *Agropyron repens* moderately, and *Dactylis glomerata* weakly.

The problem of rust control in India has now been tackled in a variety of other ways. In his address to Indian Botanical Society, Pal (1951) gave results of breeding rust resistant varieties. He also showed the control of rust by vernalization experiments. N. P. 710 wheat was shown to have attained a remarkable degree of adaptability under wide range of conditions.

15

BIO-EDAPHIC FORESTS OF INDIA

These forests are controlled partly by soil features and partly by the actions of man and his domesticated animals. The status of these communities is seral and they are called bio-edaphic. As a matter of fact some of the types mentioned under edaphic and biotic types in the early section of the chapter may probably come under this type, or some of the types described under this heading may need transfer to either of the two types, biotic or edaphic at some later date when a revision of types made by Champion is undertaken.

The bio-edaphic types occur scattered throughout India, in forests of varying climates. These are here treated under three main areas.

(A) PLAINS OF THE GANGES AND BRAHMAPUTRA.

1. **Anogeissus pendula forest** is distributed in Aravalli hills of Rajputana, Ajmer-Merwara, Bundelkhand, northwards to Jhansi and Bande and southwards to the Nerbudda in Nimar and the Panch Mahals on metamorphic and crystalline rocks of various types. The soil is always dry and often shallow. Climate is hotter and drier and rainfall is about 20 inches. *Anogeissus pendula* forms nearly pure crops, often quite well stocked, about 20 ft. high and 2–3 ft. in girth. There is a thin shrubby and grassy undergrowth with no bamboo, which is the result of biotic interference. The type was studied by the author on Sandstones of the Aravallis near Jodhpur. Along with *Anogeissus* there occur *Grewia populifolia, Euphorbia, Zizyphus, Gymnosporia, Acacia,* etc. .

Anogeissus pendula community is most commonly found in the Aravallis and the Vindhyan ranges. Puri and Jain (1958) have recently made studies on this community and found that the frequency of occurrence of the species varies at different places considerably. At Abu in the south-west end of Aravalli hills *Anogeissus pendula* is associated with other species of the genus such as *Anogeissus sericea, Anogeissus latifolia* and with tall shrubs and trees of *Carissa* and *Euphorbia.* In the Vindhyan ranges such as in Shahabad in Kota, *Anogeissus pendula* is the most dominant species on hill slopes (photo 209). The upper parts of slopes have *Anogeissus latifolia* mixed with *Anogeissus pendula.* The lower parts have *Acacia catechu* mixed with it, but the middle slopes have at places pure communities of *Anogeissus pendula. Grewia* and *Nyctanthes* are the commonest in the undergrowths. In some areas the canopy of the forest is dense and undergrowth is poor.

2. **Inland dune scrub** is chiefly distributed in southern Punjab and Rajputana on dry, sandy and usually unstable soil. The sand is mounded up by wind on the plains. The climate is dry. The scrub is an open and irregular community of stunted trees and bushes covering only a small portion of the soil. The trees are thorny and all vegetation is markedly mesophytic, determined partly by biotic factor and partly by the soil. The type was recently studied by the author from Rajputana. On sand dunes *Leptadenia spartium* (photo 210) was forming extensive patches with

Calligonum, Tephrosia purpurea (photo 211), etc. Among the grasses, *Dactyloctenium* and *Dinebra retroflexa* (photo 212), are common at different places.

3. **Gangetic saline scrub** is distributed in the lower levels of the Gangetic plain, where the soil is recent alluvium, usually clayey with salts concentrated in the upper layers. The type is an irregular semi-savannah growth with patches of low trees and shrubby growth with heavy grass. Palms are often scattered. There is frequently nearly bare ground where most saline conditions are found. This type was recently studied by the author near Lucknow. There are *Acacia* spp. scattered here and there. The grassy undergrowth was *Heteropogon contortus* (Photo 213) and other grasses like *Bothriochloa, Themeda* with scattered small trees and shrubs (photo 214). This type is now being afforested by the Forest Department.

4. **Dry Bamboo brakes** are locally distributed throughout the dry deciduous forests, especially in the Siwaliks of Hoshiarpur. The type occurs mainly on dry hillsides but also on alluvium in areas of about 35 inches of rainfall. The soil is dry and shallow. Only one species *Dendrocalamus strictus* forms low, rarely over 25 ft. high, dense brakes. It grows with grasses and thorny shrubs due to grazing. Dominance of the bamboo may only be secondary where there is a scattered over-wood of hardier species of the dry deciduous forest.

A summary of the floristic composition of the types is given in table 92, after Champion.

(B) PENINSULAR INDIA

1. **Hardwickia** forest is distributed in the drier parts of the Peninsula, especially in Madras, Andhra, Bombay, Madhya Pradesh and Mysore and in the central Indian States scattered in blocks and patches. The type is characteristic of shallow, hard, gravelly soils over Trap e.g., in Khandesh but occurs on a variety of other rocks in a more mixed state. In the Vindhyas, e.g., at Bag, Phartale Block, Sondhwa in Alirajpur and also in Sondhwa and Bai ghat, it occupies ridges of granite and gneiss. Teak and *Lannea grandis* are present in alluvial patches and valley bottoms. The annual rainfall is between 20–40 inches. Predominance of *Hardwickia binata* is the characteristic feature of the type but most of the forests have been much maltreated, grazed and burnt as *Hardwickia* leaf is an excellent cattle fodder and is much in demand everywhere (Photo 215).

2. **Boswellia** forest is chiefly distributed on dry Deccan Trap hills throughout peninsular India and also occurs in the Vindhyas over granite and gneiss all over Central India. The usual sites are the ridges and spurs where the soil is generally poor and shallow (Photo 216). The annual rainfall is between 20 – 50 inches with a long, hot, dry season. *Boswellia serrata* forms an overwood to stunted trees of the species of the dry deciduous type, about 40 – 50 ft. high and 4 to 6 feet in girth. There is low grass and the forests are usually burnt. Photo 217 shows a mixed deciduous forest of *Boswellia* in Khandesh. *Cochlospermum, Lannea, Diospyros, Acacia* spp. are common in *Boswellia* community. It occupies tops of amygdaloid hills near Poona (Puri and Patil 1957) where it may be occasionally accompanied by *Sterculia urens*.

3. **Butea** forest is characteristic of stiff, badly drained soils, particularly black cotton soil in valleys and hollows. It occurs in a variety of conditions, soils and situations. Fire is usual and frost may also occur. The type consists of scattered stunted trees with low rounded crown standing over dense grass and is more or less of a savannah type, where grazing is prevalent (Photo 218).

Table 92.

BIO-EDAPHIC FORESTS OF THE PLAINS OF THE GANGES AND BRAHMAPUTRA.

Sub-type and distribution.	I	II	III	IV
Anogeissus pendula forest. Aravalli hills in Rajputana, Ajmer, Merwara, Bundelkhand, northwards to Jhansi and Benda and south - wards to Nerbudda in Inmar and the Panch Mahals.				
(i) Ajmer.	*Anogeissus pendula, Boswellia serrata, Acacia catechu, A. rupestris, Albizzia odoratissima, Dalbergia lanceolaria, Dichrostachys cinerea, Bauhinia racemosa, Grewia* spp.			
(ii) Jhansi range, Jhansi division (U. P.).	*Anogeissus pendula, Acacia catechu, Anogeissus latifolia Lagerstroemia parviflora, Diospyros melanoxylon, Aegle marmelos, Zizyphus xylopyrus, Bauhinia racemosa, Lannea grandis, Butea frondosa.*			
2. Inland dune scrub. Southern Punjab and Rajputana.				
(i) Punjab.	*Acacia jacquemontii.*	*Crotalaria burhia, Leptadenia spartium, Sericostoma pauciflorum, Calligonum polygonoides, Calotropis procera,* etc.		
(ii) Rajputana.	*Leptadenia spartium, Calotropis procera, Aerua tomentosa.*		*Panicum turgidum, Cyperus arenarius.*	
3. Gangetic saline scrub. Usar lands of U.P. lower levels of the Gangetic plain.	*Phoenix sylvestris.*	*Phoenix sylvestris, Butea frondosa*	Grasses	
4. Dry Bamboo brakes. Locally throughout the dry deciduous types. Good examples in Hoshiarpur, Punjab.	*Dendrocalamus strictus.* with a sprinkling of tree and shrub species.			

In the Vindhyan Ranges near Darah, *Butea monosperma* is the commonest species in the valleys. A number of trees in the community occur along nalas also, such as *Cordia myxa, Terminalia arjuna, Phoenix sylvestris, Polyalthia longifolia* and *Ficus* sp. The trees of *Polyalthia longifolia* and *Terminalia arjuna* are about 50 ft. tall.

Phoenix sylvestris, Cordia myxa and *Butea monosperma* form the second storey.

The undergrowth consists of abundant growth of *Grewia pilosa* and *Anona squamosa.*

In more moist situations ferns also grow. Tall grass *Coix lachryma-jobi* and *Vetiveria zizanioides* grow along the bank of the nala.

Ottelia and *Marsilea* grow in some stagnant parts of the nala.

In the Madhya Pradesh, *Butea* forests occur mainly on the sandstone of the Aravallis and partly on the trap tongues that have crept in the sandstone. The types of soils are varied.

All over the area mostly pure communities of *Butea frondosa* Roxb. are present. This type is also found in mixture with other species such as teak, *Cassia fistula* Linn., *Zizyphus jujuba* Lamk., *Acacia catechu* Willd., *Acacia arabica* Willd., *Acacia leucophlaea* Willd., *Lagerstroemia parviflora* D. & G., etc. (Photo 219).

Amongst the second storey plants in such localities are *Holarrhena antidysenterica* Wall., *Gymnosporia montana* Benth., *Acacia concinna* DC., *Grewia tiliaefolia* Vahl., *Carissa carandas* Linn., *Zizyphus rugosa* Lamk., etc.

The ground flora is mainly grazed, the grasses being few. The chief amongst them are species of *Paspalum, Arthraxon,* etc. *Curculago orchioides* Gaertn., *Cassia tora* Linn., *Achyranthes aspera* Linn., etc. are other species.

4. **Babul** forest is associated with black cotton alluvial soils and is best developed in Berar. It is also met with elsewhere under similar conditions. *Acacia arabica* entirely dominates and forms a dense cover than usual in thorn forests. Wherever the canopy is broken a few associated species such as *Balanites, Phoenix,* Neem occur. There is a very little undergrowth with a thin soil cover of grass. The type owes its origin partly to biotic features and partly to soil conditions.

The best growth of *Acacia arabica* as a dominant species was seen by the author in Cutch in Bhivandyara area (Photo 220). The soil here is saline and vast areas are ordinarily covered with tall grasses. Some spots on the fringe of these grasslands are under dense *Acacia arabica* community.

A transect study in these areas revealed a 100% presence of *Acacia arabica* trees in the area. Shrubs of *Acacia senegal, Capparis decidua* are occasionally present in this community. The ground flora is of grasses and some hardy herbs such as *Corchorus* species.

5. **Laterite thorn forest** is chiefly distributed in Kanara on the west coast and the type is determined by hard laterite dry shallow soil, probably exposed, denuded and hardened by human influences. *Acacia sundra* dominates to form an irregular thorn scrub. It is associated with species of the dry deciduous type and an undergrowth including xerophytic evergreens.

The type was studied by the author near Karwar and Kumta on laterite near abandoned habitation, and heavily grazed places near habitations.

The main constituents are *Gardenia lucida, Randia dumetorum,*

Table 93.

BIO-EDAPHIC TYPES OF THE PENINSULAR INDIA

(arranged after Champion).

Sub-type and distribution	I	II	III	IV
I. *Hardwickia* forest. Scattered in blocks and patches in the drier parts of the Peninsula.				
(i) W. Khandesh, Bombay.	*Hardwickia binata, Anogeissus latifolia, Boswellia serrata, Acacia catechu,* etc.		*Cassia auriculata.*	
(ii) Nimar, Madhya Pradesh.	*Hardwickia binata, Boswellia serrata, Acacia catechu, Anogeissus latifolia.*			
(iii) Tirpati hills, N. Arcot Madras.	*Hardwickia binata, Pterocarpus santalinus, P. marsupium, Chloroxylon swietenia, Terminalia chebula, T. tomentosa, Albizzia lebbek, Dalbergia latifolia,* etc.			
2. *Boswellia* forest. On dry hills throughout Peninsular India.				
(i) Nimar, Madhya Pradesh.	*Boswellia serrata, Acacia catechu, Cochlospermum gossypium, Lannea grandis,* etc.	*Dendrocalamus strictus.*		
(ii) Seoni division (M.P.)	*Boswellia serrata, Cochlospermum gossypium, Sterculia urens, Lagerstroemia parviflora, Phyllanthus emblica.*		Practically no shrubs.	Grass very light.
(iii) Baretha, Betul division (M.P.).	*Boswellia serrata, Buchanania latifolia, Lagerstroemia parviflora, Soymida febrifuga, Terminalia tomentosa.*	*Nyctanthes arbor-tristis, Diospyros melanoxylon, Phyllanthus emblica, Ougeinia dalbergioides, Acacia catechu, Bauhinia racemosa.*	Very little grass, or herbs.	

Table 93 (Contd.)

Sub-type and distribution.	I	II	III	IV
3. *Butea* forest. Throughout the type where soil conditions are suitable.				
(i) Waingana and Partapgarh ranges Bhander div. (M.P.).	*Butea frondosa, Zizyphus* spp.			
4. Cotton soil *Babul* forest. Best developed in Berar but met with elsewhere under such conditions.				
(i) Berar, (M.P.).	*Acacia arabica, A. eburnea, Balanites roxburghii, Dichrostachys cinerea, Acacia leucophlaea, Prosopis spicigera, Capparis, Zizyphus vulgaris, Phoenix sylvestris* (wet grounds). *Azadirachta indica.*		*Cassia tora, C. auriculata, Capparis grandis.*	*Andropogon contortus, Ischaemum pilosum, Andropogon monticola, A. annulatus,* etc.
5. Laterite Thorn forest. On the west coast of Kanara.				
(i) N. Mangalore division.	*Acacia sundra, Litsaea wightiana, Buchanania latifolia, Lannea grandis, Anacardium occidentale.*	*Santalum album, Gardenia gummifera.*		
6. Secondary dry deciduous forest. Throughout the dry deciduous type extending into the drier parts of the moist deciduous.				
(i) Dharwar Taluka forest, Bombay.	*Bombax malabaricum, Buchanania latifolia, Grewia tiliaefolia, Elaeodendron glaucum, Schleichera trijuga. Lannea grandis,* etc.	*Limonia acidissima. Aegle, Dodonaea viscosa, Zizyphus xylopyrus, Careya arborea, Gardenia* spp., *Santalum album,* etc.	*Carissa spinarum. Holarrhena antidysenterica, Lantana.*	

Ixora sp., *Lantana, Leea sambucina,* and *Psychotria* and a number of grasses chiefly, *Ischaemum, Heteropogon, Eulalia, Isachne* sp., and others. Saplings of *Eugenia jambolana* and *Terminalia tomentosa* are also met with (Photo 221).

Adjoining the scrub is a deciduous forest, also occurring on laterite which consists of middle sized trees only. There are almost no shrubs and the ground flora too is poor. The commonest trees are of *Anogeissus latifolia, Lagerstroemia* sp., *Tectona grandis. Terminalia paniculata* and *Cordia myxa.*

6. **Secondary dry deciduous** forest is distributed throughout the dry deciduous type. The surface soil is usually hard and impervious from exposure and trampling. The forest has been under shifting cultivation in the past and has grown up again subject to heavy use for grazing, fuel, and small timber. In this type, the poor shape and size of the trees and the absence of old trees is remarkable. Thorny and unpalatable species tend to predominate.

A summary of the floristic composition of the types is given in Table 93 after Champion.

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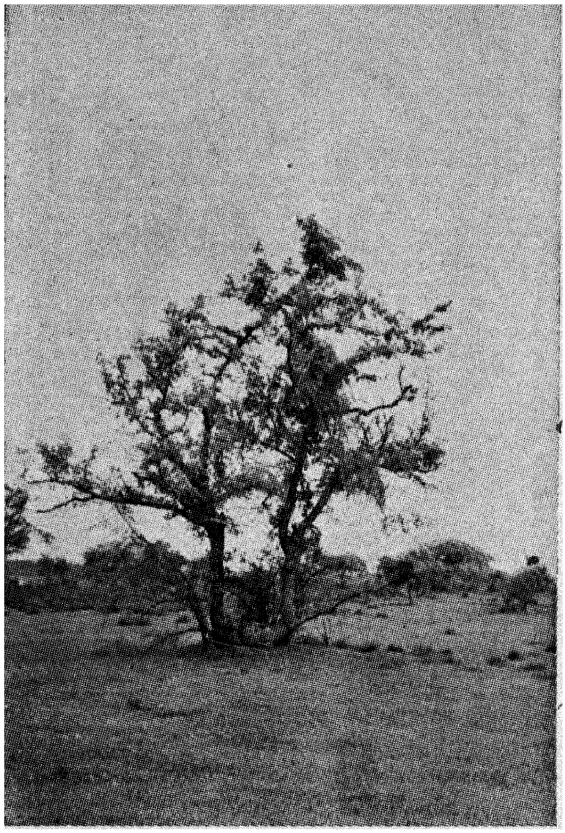
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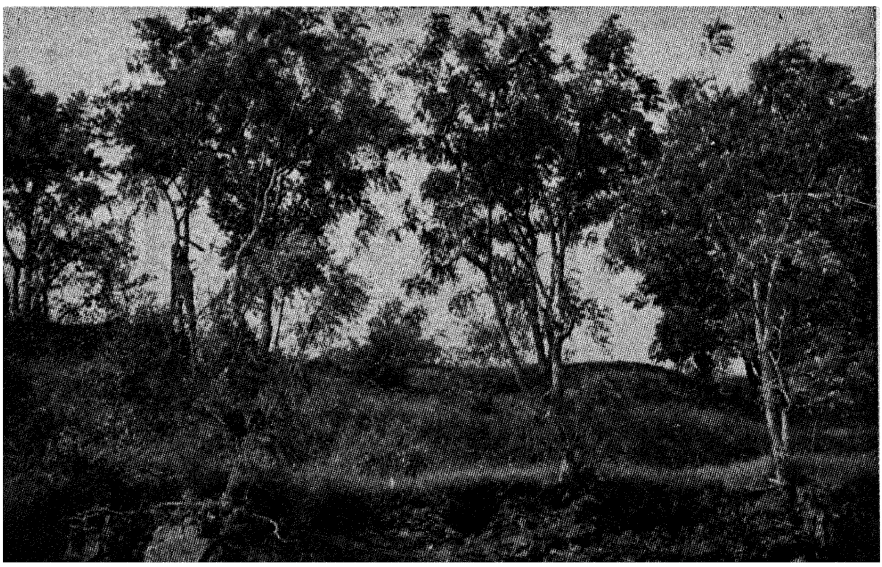
213. *Heteropogon contortus* community in saline scrub area near Lucknow. —G. S. Puri.



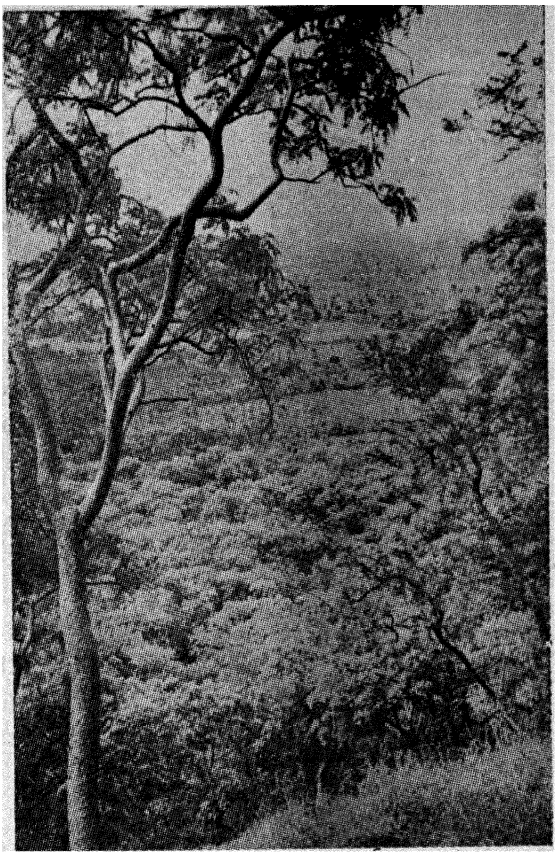
214. Grassy undergrowth of *Bothriochloa* etc. in a saline scrubby vegetation, near Lucknow. —G. S. Puri.



215. A heavily lopped tree of *Hardwickia* in forests of Khandesh at Laling. —G. S. Puri.



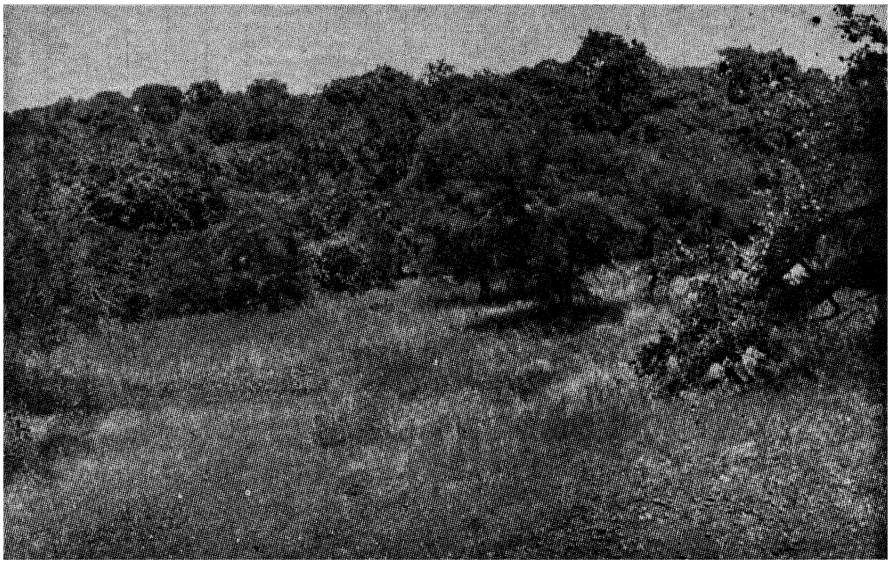
216. *Boswellia serrata* community on shallow, undecomposed gneissic rocks in Central India, Manghat, Indore. — G. S. Puri.



217. Deciduous forest of *Boswellia serrata* over the slopes of Takya hill, Laling. —S. D. Mahajan.



218. *Butea* community in Central India with stunted, lopped trees and heavy grazing. —G. S. Puri.



219. A mixed *Butea* community on Bhopal Road. —G. S. Puri.



220. *Acacia arabica* community at Bhirandyra, Cutch. —G. S. Puri.

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16

ARTIFICIAL FORESTS OF INDIA

Artificial forests are raised in India by planting indigenous and exotic tree species over large areas. The plantations are raised either in open areas in forests or by clearing already existing forests of economically inferior species. The following important indigenous and exotics have been raised into artificial forests in different parts of the country:—

1. Teak and *Sal.*
2. Chir-pine.
3. Deodar and other conifers.
4. *Eucalyptus* spp.
5. *Cryptomeria japonica.*
6. *Casuarina equisetifolia.*
7. Khair and sissoo.

Tectona grandis. The earliest artificial forests of teak were raised in India in 1840 at Nilambur, on the Malabar coast of Madras. These forests are of high quality growth and since then plantations have been raised in many parts of the states of Bombay, Madras, Coorg, Mysore, Travancore-Cochin, Madhya Pradesh, Eastern U.P. Bengal, Assam, and Bihar. Griffith (1942) estimated that uptill 1942 over 2,00,000 acres were under pure or mixed plantations and teak plantations are being raised at the rate of more than 4,600 acres per year in India.

A number of methods have been tried in teak planting and now stump planting is widely used. A lot of research work has been done on the size of stump, data of stump planting, stump splitting, etc.

Teak plantations have been raised in the following types of the forests, in different states of India.

Assam.	Moist mixed deciduous to mixed wet-evergreen. Rainfall 80 to 130 inches.
Bengal.	*Sal* and moist mixed deciduous to tropical evergreen. Rainfall 100 to 200 inches.
Bihar.	Dry mixed deciduous to moist mixed deciduous bordering on semi-evergreen. Rainfall 50 to 80 inches.
Bombay.	Dry mixed deciduous to wet mixed deciduous Rainfall 70 to 200 inches.
Madhya Pradesh.	Dry mixed deciduous to moist mixed deciduous. Rainfall 30 to 100 inches.
Madras.	Tropical moist mixed deciduous. Rainfall 50 to 150 inches.
Orissa.	Dry mixed deciduous to evergreen. Rainfall 50 to 65 inches.
U.P.	Well drained *sal* type. Rainfall 40 to 80 inches.
Coorg.	Moist mixed deciduous. Rainfall 60 to 80 inches.
Travancore.	Moist mixed deciduous to semi-evergreen. Rainfall 80 to 150 inches.

A good deal of research has been done on finding out localities most suitable for raising a teak plantation. On the whole, laterite and lateritic soils, deep clay, black cotton soils, sandy and gravelly soils derived from sandstones are unsuitable for teak. Alluvial deposits have so far shown the greatest amount of success for planted teak. Griffith and Gupta (1947) by detailed analysis of the soil have shown the superiority of the alluvial sites over others for teak in Nilambur. Bhatia (1954) has made detailed studies on teak soils in M.P. The Government of India has arranged in 1957–58 a study tour in teak areas to study teak ecology and soils and the results of this will be eagerly awaited.

Among the plant indicators that are generally used to show the unsuitable sites for teak plantations are *Imperata,* preponderance of *Xylia* and stunted trees of *Phyllanthus emblica, Terminalia tomentosa* and *Anogeissus. Alpinia* and Canes indicate sites, which are too wet for teak. A great deal of preparatory operations are done to make the area suitable for raising a good plantation of teak (photo 222). After raising the plantation, weeding is most generally done. The presence of Bamboo in a teak plantation is a serious problem. *Melocanna bambusoides* and *Dendrocalamus hamiltonii* in Assam, *Bambusa arundinacea* and *Dendrocalamus strictus* in the southern districts of Bombay, *D. strictus* in Central Provinces and *Bambusa arundinacea* in Orissa are a great menace to growing teak stumps.

Imperata grass also does harm. It is removed by intensive weeding, closing of the teak canopy or digging it up completely.

Eupatorium odoratum is troublesome in Assam, Bengal and Burma. *Lantana* does harm in Madras and Bombay and is destroyed by burning. Other pests are *Hibiscus, Ageratum, Calycopteris* and *Mucuna* in Madras, Bombay and several other provinces.

A number of climbers also create difficulty, *Dioscorea, Ipomaea, Convolvulus* and *Mucuna* have a nuisance value in Assam. *Eupatorium odoratum, Mucuna* and *Spatholobus* are troublesome in Bengal. *Convolvulus, Dioscorea, Combretum, Zizyphus* and *Cryptolepis* can be troublesome in Bihar. In Bombay, *Mucuna pruriens* creates a serious problem in the first three years; other climbing pests are *Carissa carandas, Calycopteris floribunda, Caesalpinia sappan, Wagatea spicata, Abrus precatorius, Jasminum arborescens, Combretum ovalifolium, Spatholobus roxburghii* and *Ipomaea digitalus.* In Central Provinces, climbers are not serious. *Calycopteris floribunda, Acacia pennata, Pterolobium indicum, Spatholobus roxburghii* and *Butea superba* are locally serious in Madras.

Climbers tend to be serious in the moister areas in Orissa. In U.P. climbers are serious in first year only. In Coorg climbers are not a menace. In Travancore *Lantana, Convolvulus, Calycopteris floribunda, Spatholobus roxburghii* and *Smilax zeylanica* may become serious. They are only a menace in poor areas where the burn was not good and the teak stocking is poor.

When plantations are raised under the taungya system, a number of crop plants are raised, chief of these are *Oryza sativa, Gossypium* sp., *Zea mays, Solanum melongena, Cucurbita* sp., *Capsicum annum, Ipomaea batatas, Dolichos lablab, Eleusine coracana, Nicotiana tabacum, Sorghum vulgare, Cajanus indicus, Triticum vulgare, Ricinus communis,* etc.

The most common parasite in teak plantations is *Loranthus.* The larvae of the moths *Hyblaea puera* and *Hapalia* (=*Pyrausta*) *machaeralis* bring about defoliation in many teak plantations. A number of borers have been described from Burma. Termite does some damage in nurseries, Grass hopper and locust may do local damage in Madras and Coorg.

Laurie and Griffith (1942) have discussed the problem of pure verses mixed plantations of teak of a number of species that occur in teak plantations. *Bambusa arundinacea* is considered to be harmful. Others such as *Grewia tiliaefolia, Lagerstroemia lanceolata* and *Dalbergia latifolia* in Madras have been considered to outgrow teak. On the whole, the present opinion is that any mixture in teak plantations would adversely affect the growth of the tree. Laurie and Griffith have given a number of species which have been tried for crown mixture and also in the undergrowth. Photo 223 shows a young plantation of teak in N. Kanara.

Shorea robusta. Unlike teak, *sal* is a gregarious species but on account of difficulties in its natural regeneration in some types of forests plantations of *sal* have been raised in the *sal* zone under taungya system. The earliest known *sal* plantation was made by Schlich in 1876 at Dhamanpur in Buxa division of Bengal in the Tarai type of soil. In 1896 to 1909 another plantation was raised in Jalpaiguri division, and still another was raised in 1887–1888 at Gorakhpur in U.P. Later on plantations of *sal* were raised in Bengal after 1910 in different types of soils under the taungya system.

The plantations are raised by sowing in continuous strips and the area between the two strips is planted with different types of field crops, depending upon the type of soil. The crops most prevalent are cotton and jute, dry paddy, maize and even vegetables. To save the plants against frost and other adverse features, cover crops of *Tephrosia candida* have been successfully used.

Usual weeding, tending, etc., that is required in artificial forests, is done.

Lately in some parts of U.P. *sal* plantations have suffered adversely and the raising of *sal* forests have become a problem. Champion's (1933) summary of the *sal* forest is still the most authoritative account.

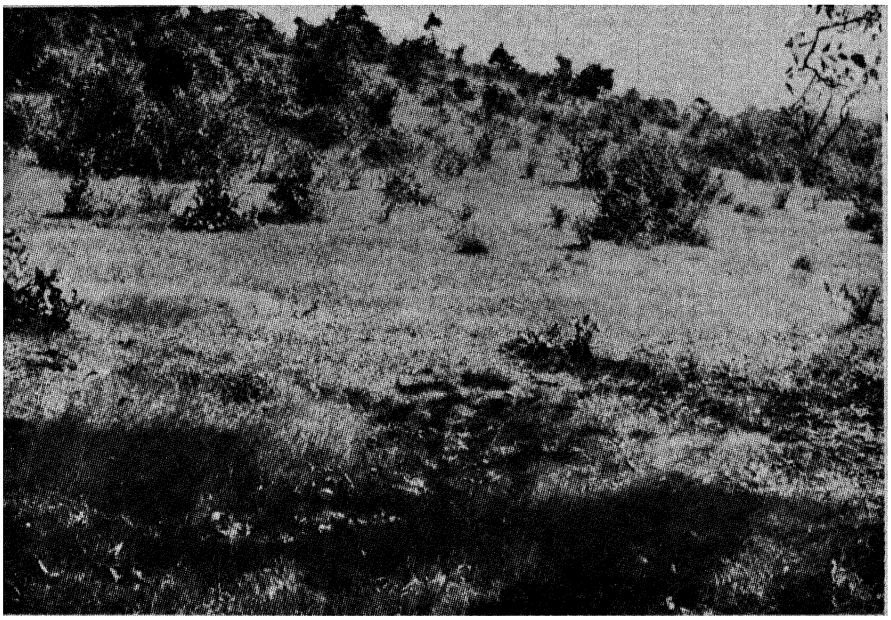
Pinus roxburghii: The best known plantation of chirpine outside its zone of distribution is at Supkhar in Madhya Pradesh. This was raised in areas where natural regeneration of *sal* had failed. Recent measurements of the crop show that the growth of the pine is of the first quality, better than either natural *sal* or planted teak.

The forests around Supkhar consists mainly of *Shorea robusta,* with associated species of *Terminalia tomentosa, Anogeissus latifolia, Eugenia jambolana, Pterocarpus marsupium.* Frost is so severe here that sometimes the tallest trees are affected. This results in hollowness and the production of profuse epicormic branches. A large number of seedlings, saplings and trees are killed due to frost and drought and grassy blanks are created. These grassy blanks are subjected to late fires which in combination with frost has resulted in the death of *sal* in the forests. *Pinus roxburghii,* a frost hardy species was planted during 1907, 11, 13, 17, 25, 26, 27 and 28 over a total of twelve acres on Deccan trap associated with laterite. The soil is red loam with plenty of humus.

The plantation was raised by clearing the area and sowing the seed after ploughing it. In 1928, pine was found uneconomical and raising of plantation was given up.

A number of plantations were also raised in Almora division on dry shallow, micaceous, or sandy soil on south-west to south-east aspects. Several plantations were raised in Kumaon hills where these have done well.

Chirpine has been cultivated in groups at many places in the plains of northern India. Photo 224 shows a good plantation in the New Forest Estate at Dehra Dun.



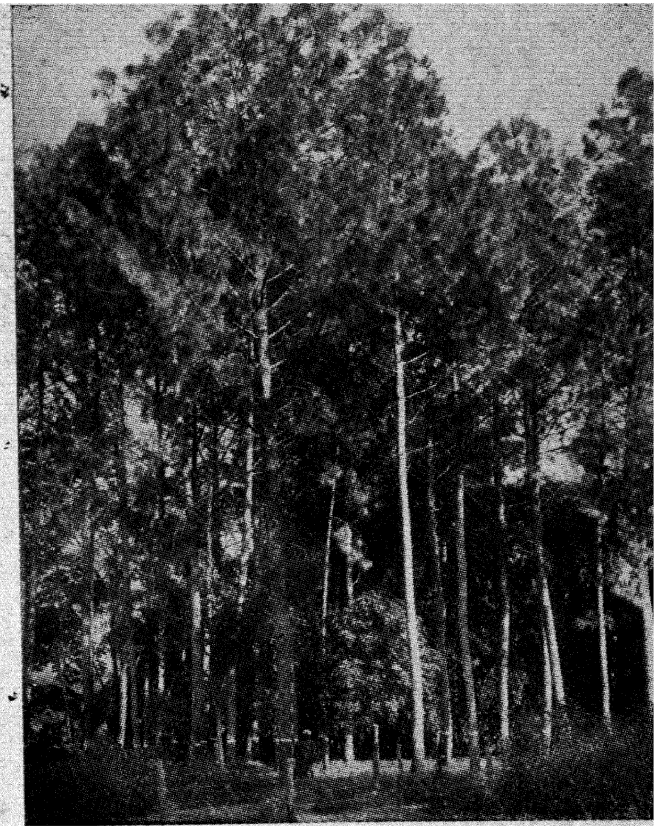
221. Laterite scrub with bushes of *Gardinia*, *Ixora*, *Randia* and grasses near Kumta. —G. S. Puri.



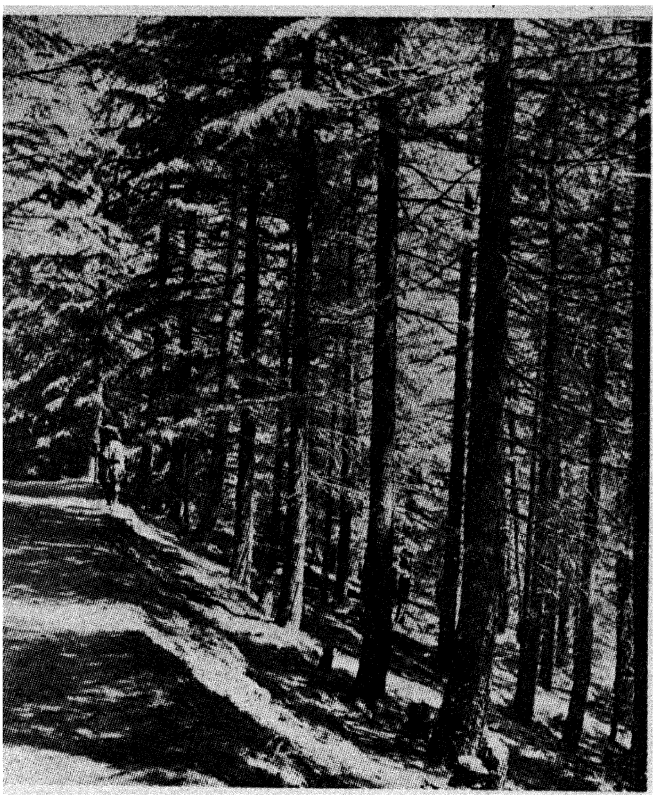
222. A young plantation of take raised after felling a moist deciduous forest in Top slip area —G. S. Puri.



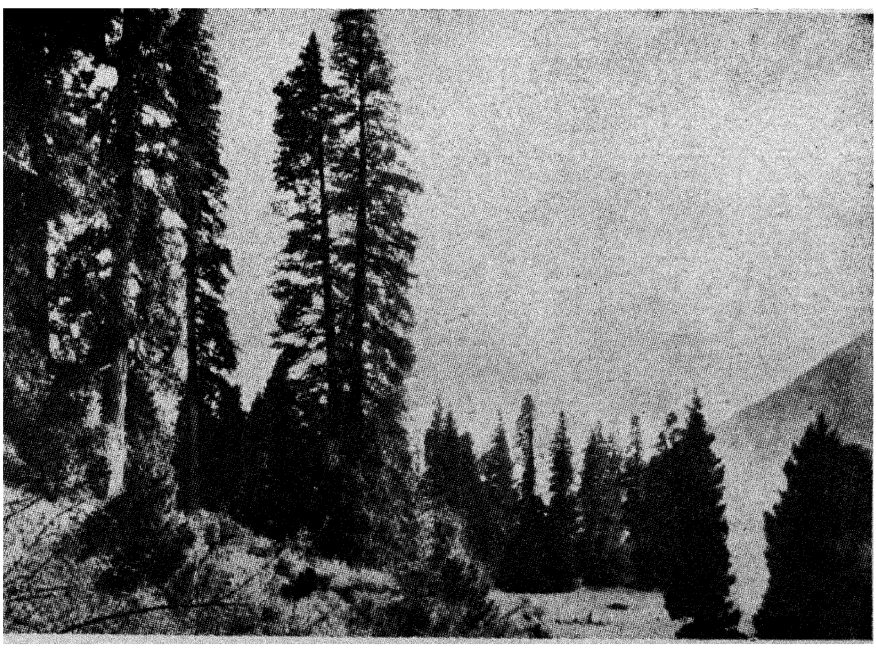
223. A young plantation of teak at Vincholi, N. Kanara. —G. S. Puri.



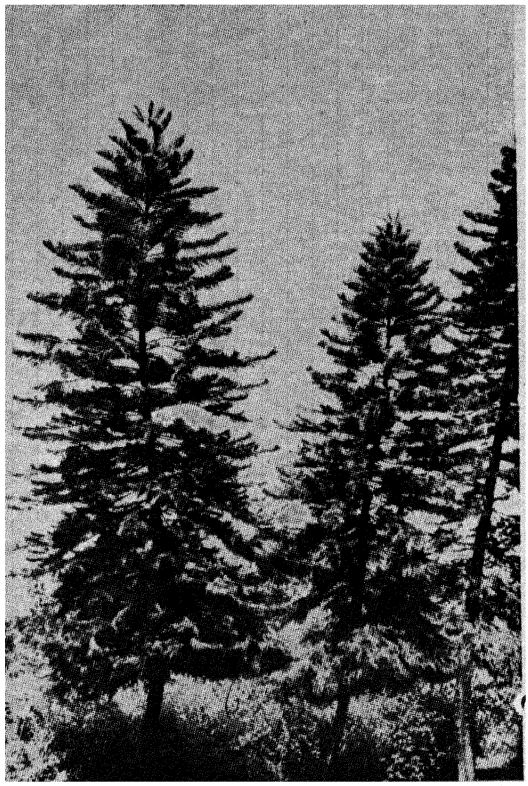
224. 30 Years old plantation of *Pinus roxburghii* at the New Forest Estate, Dehradun. —Silviculturist F.R.I.



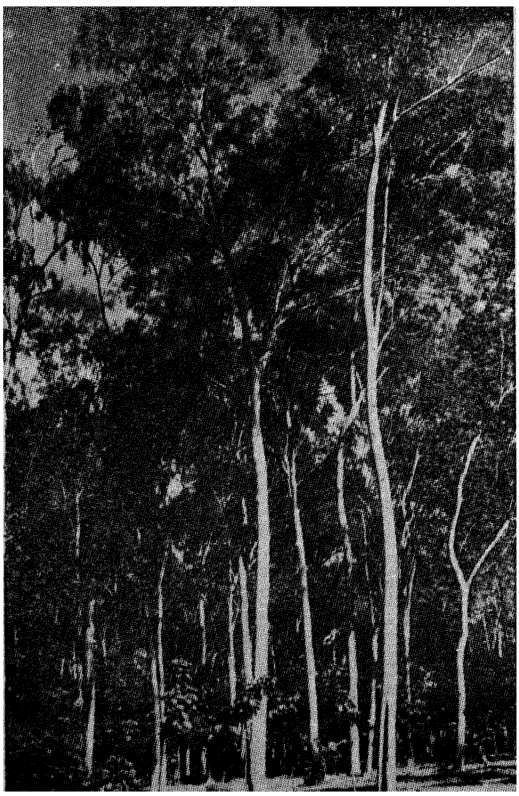
225. Plantation of *Cedrus deodara* at Nogli, Bashahr Himalayas. —A. L. Griffith.



226. A grove of large *Cupressus torulosa* trees round the temple Wan



227. *Araucaria* trees planted in the Indian Botanical gardens, Sibpur - Calcutta —G. S. Puri.



228. A beautiful grove of *Eucalyptus* in Lucknow. —G. S. Puri.

Deodar and other conifers: Artificial forests of deodar have been raised successfully at several places in the Parbatti valley in Kulu and in Kashmir. Deodar has also been planted at a number of localities in Almora district and in the Kumaon hills. Small plantations raised on alluvial deposits in the Kangra valley at Palampur have shown a very good growth. In all these areas deodar has shown best growth on flood plain deposits, especially where they are moist and fertile.

Deodar has also been planted in *Quercus incana* forests at Simla, Chakrata and Mussoorie. Both at Chakrata and Mussoorie flattening of tops has taken place after the tree has grown to 60–70 feet. Good plantations of deodar are raised in the Bashahar Himalayas at Sungri, Nankhari and in the Sutlej valley. Photo 225 shows a plantation of Deodar in Bashahar on abandoned cultivation.

Besides, a number of conifer are cultivated in India. Chief of these are the following:-

Cupressus spp. all over the Himalayas is grown round temples (Photo 226).

Podocarpus chinensis a native of Japan grows well in Calcutta, Saharanpur and Lahore. It is propagated by cuttings.

P. elongatus from Cape to Calcutta, has apparently never flowered and does not exist in Calcutta now. There is a specimen in Dehra Dun which also probably never flowered. This species is also grown in other gardens in Dehra Dun as well as in Saharanpur and it is propogated by cutting.

Seedlings of the following species are growing well in Dehra Dun.

P. elongatus.	Seed from S. Africa.
P. falcatus.	
P. gracilor.	Seed from British E. Africa.
P. thunbergii.	Seed from S. Africa.

Araucaria imbricata a temperate species is probably quite unsuitable for low elevations. The only known specimen in India is at Annandale, Simla which too is not growing well.

A. bidwilii Hook, *A. cookii.*

A. cunninghamii and *A. excelsa* are growing at Calcutta (Photo 227). Of these only *A. cunninghamii* does well at many places.

A. bidwilii is growing well in Dehra Dun and ripens its seeds in some years. Its germination is very peculiar. Young seedlings are sensitive to draught in Dehra Dun and require watering in the dry season. It does not stand heat well.

A. cunninghamii is the best of the genus for northern India and is grown at Lucknow, Saharanpur, Lahore and Dehra Dun where it produces cones freely but very little of seed appears to be fertile. *Araucarias* should be grown from fresh seeds, if kept the seed soon looses vitality. They can be rooted from cuttings.

Callitris glauca failed to grow in Lahore, but germinated well in Saharanpur and there are at least 4 specimens growing very well and making ornamental trees in Dehra Dun.

Exotic species:—

Eucalyptus: Of the many exotics that have been tried in this country successfully, *Eucalyptus* deserves the first importance (Photo 228). A number of species have been grown all over India. *Eucalyptus* are Australian trees and at the time of planting, Brandis (1876–77)

compared the climatic conditions of Melbourne with Ootacamund and Lucknow, where the trials were made. From the data given in table 94 similarity in climatic conditions between the home of *Eucalyptus* with the places in India is clearly seen.

Table 94.

COMPARISON OF CLIMATIC CONDITIONS OF AUSTRALIA WITH OOTACAMUND AND LUCKNOW

Seasons.	Melbourne.	Ootacamund.	Lucknow.
Latitude.	37°49' S.	11°23' N.	26°51' N.
Elevation.	91 ft.	7,490 ft.	535 ft.
		Temperature in degrees F.	
Spring.	57°.0	59°.4	71°.6
Summer.	65°.3	56°.6	86°0
Autumn.	58°.7	55°.4	78°0
Winter.	49°.2	52°.1	64°.3
Year.	57°.6	55°.9	76°0

In Northern India *Eucalyptus* were first tried in 1860 at Madhopur in Gurdaspur District. Plantations were then raised at Lucknow, Kapurthala and Saharanpur. The rate of growth of different species of *Eucalyptus* planted at Lahore with irrigation and at Saharanpur without irrigation was compared by Parker in table 95 in 1925.

Table 95.

RATE OF GROWTH OF EUCALYPTUS

Species.	Lahore with irrigation.			Saharanpur with no irrigation.		
	Age Years.	Height. Feet.	Girth. Ft. in.	Age. Years.	Height. Feet.	Girth. Inches.
Eucalyptus. alba.	12	45	1–11	—	—	—
E. bicolor.	12	65	2–11	—	—	—
E. crebra.	12	60	2–10	—	—	—
E. hemiphloia.	13	55	2—7	—	—	—
E. melanophloia.	13	65	2—8	11	40	6
E. melliodora.	13	65	2—7	10	20	4
E. microtheca.	12	60	3—4	11	35	6
E. paniculata.	12	75	3—3	11	30	6
E. polyanthema.	12	40	2—8	—	—	—
E. rostrata.	12	75	4—6	11	35	6
E. robusta.	13	33	2—8	11	35	6
E. rudis.	13	75	6—1	11	45	7
E. saligna.	12	60	2–11	11	25	4
E. tereticornis.	12	65	4—6	11	35	6
E. propinqua.	—	—	—	11	25	6
E. punctata.	—	—	—	11	40	6
E. siderophloia.	—	—	—	11	35	4

A number of species were tried at different altitudes in the Simla Himalayas. These are given below after Parker (1925).

(1) From 3,000 to 4,000 feet.

E. citriodora.
E. paniculata.
E. polyanthema.
E. punctata.
E. rostrata.
E. saligna.
E. tereticornis.

(2) From 4,000 to 5,000 feet.

E. claeophora.
E. globulus.
E. maidenii.
E. pilularis.
E. rostrata.
E. tereticornis.
E. viminalis.
E. dealbata.
E. eugenioides.
E. botryoides.
E. goniocalyx.
E. ovata.
E. eximia.
E. linearis.
E. corymbosa.
E. muelleriana.
E. piperita.
E. acmenioides.
E. rubida.

(3) From 5,000 to 6,000 feet.

E. claeophora.
E. globulus.
E. goniocalyx.
E. ovata.
E. maidenii.
E. pilularis.
E. siebcriana.
E. viminalis.
E. eximia.
E. linearis.
E. regnons.
E. risdoni.
E. macrorrhyncha.
E. gunnii.
E. haemastoma.
E. mulleriana.
E. piperita.
E. rubida.

Eucalyptus had been tried in a number of places in central and south Asia. Experiments were conducted and Blanford (1924) pointed out that the growth of *Eucalyptus* seedlings is very rapid and it is essential that the seedlings should be transplanted before they get too large for the bamboo tube. It is impossible to transplant all the seedlings at the same time and it is therefore essential to make successive sowings at suitable intervals, so that plants of the right size may always be available for transplanting. Root and stump cuttings can also be planted successfully.

In Bengal winter planting gives great promise with some of the most important species, meaning economy of labour and better start for the plants over weed growth. *Eucalyptus globulus* did well in Senchal Coupe 4, in 1922–23.

In Bihar, *Eucalyptus citriodora* was tried but was a failure.

In Madras, Sir Francis Spring (1905) suggested to the Government to plant the following species:—

Eucalyptus siderophloia, E. paniculata, E. cerebra, E. propinqua, E. punctata, E. microcorys, E. eugenioides, E. acmenoides, E. hemiphloia, E. pilularis.

The plantations at Aramby Block VI and Snowdon Block I were formed between 1910 and 1912 with *Eucalyptus pilularis, E. punctata, E. eugenioides, E. paniculata, E. propinqua, E. acmenoides, E. hemiphloia* and *E. cerebra.* After ten years it was found that *E. paniculata, E. pilularis* and *E. eugenioides* gave the best results.

The Doddabetta area was completely planted up with *E. eugenioides* during 1922 and 1923. In the Black bridge area 22 acres were planted in 1922, and it was a failure. The Doddabetta plantations though successfully established, are relatively of inferior quality. From 1924 to 1928

plantations consisting mainly of *E. eugenioides* and *E.paniculata* were formed in Bandy-shola, spring-field, Bingham and Brook lands.

In Ootacamund range compartment 3. was planted up with *Eucalyptus eugenioides*. It was partially damaged by frost. Compartment 4 planted with *Eucalyptus pilularis* in 1929 was obliterated by frost. Compartment 5 planted up in 1930 with the same species was again completely destroyed by frost. Compartment 4 which was replanted in 1930 faired equally badly. Artificial shading of the plants and the natural protection afforded by the *Acacia* growth could not save the plants.

Cryptomeria japonica: The Japanese Cedar is indigenous to China and in coastal hilly areas of Japan, it is widely cultivated and has since been introduced with success to many parts of the world.

Seeds were brought to India in 1844 and planted at Shillong between 4,000–6,000 feet. It did quite well at Ootacamund but was a failure in Simla. In 1915–1917 it was tried in the Kangra Division, Punjab without any success. It succeeded in sheltered valleys, upto 4,000 ft. in Jaunsar in U.P. It is successfully planted into large size forest blocks in Darjeeling District of Bengal between the elevations of 3,000 ft and 8,000ft. In this area it grows best in deep rich soils and in moist and humid places.

In the Darjeeling Division, the first plantation was raised in 1874–75 at Rangbul and again in 1888–1890 at Rangirum. *Cryptomeria* grows very fast in pure plantations. It has been tried in mixture with *Michelia excelsa, Alnus nepalensis.* Extensive artificial forests of *Cryptomeria* are now present in the Darjeeling district of Bengal (Photo 229).

Cryptomeria has been grown with success in Oak Laurel community, the main species of which are *Quercus lamellosa, Q lineata, Q lanceafolia, Q. spicata, Machilus gammieana, Michelia cathcartii, M. excelsa, M. lanuginosa, Nyssa javanica, Litsea salicifolia, Bucklandia populnea,* etc.

Casuarina equisetifolia: This species is indigenous on sand dunes and sandy plains along the coast of Chittagong, Tenasserim and Andamans. Outside India it occurs naturally in Malaya, Australia, Queens land and Pacific Islands. It is cultivated in India along the east and west coasts at many places in pure plantations for fuel. The best known artificial *Casuarina* forests are along the east coast of Madras in Srihari Kota Island. The forests have been raised after felling the indigenous vegetation (Photo 230).

The oldest plantation, called the Ullal plantation on the west coast was raised in 1868. The plantations on the east coast at Nellore are also fairly extensive and old. Plantations of Karwar were raised in 1868–69. In fact all sandy plains and dunes along the coast have been planted with this species and recently plantations have been raised in inland areas of Peninsular India as well. Along the western coast in Saurashtra it has recently been planted to stabilise sea sand. It has done very well on riverain soils of the Godavri, Krishna and Cauveri in south India. During 1950 and 1951 the Peninsular plantations had adversely suffered from drought and the fungus, *Trichosporium vesiculosum.*

In Madras, *Casuarina* plantations are raised after clearing the indigenous vegetation of *Calotropis gigantea, Memecylon edule, Albizzia amara, A. lebbek, Eugenia jambolana, Maba buxifolia, Strychnos nux-vomica, Feronia elephantum, Garcinia spicata, Ochna squarrosa, Sapindus emarginatus, Glycosmis pentaphylla, Pavetta indica, Ficus bengalensis,* etc.

Plantations are usually raised pure, but mixed plantations have also been suggested in order to improve conditions of soil (Puri, 1954).

The species that have been recommended for planting with *Casuarina* are *Anacardium occidentale, Pongamia glabra, Pithocolobium dulce, Dalbergia sissoo,* etc. These have high foliar nitrogen (Puri, 1954) and would improve soil fertility of the site. *Casuarina* is grown in gardens (Photo 231) along roads, banks, etc. and is lopped into beautiful hedges and ornamental slopes.

Khair and Sissoo plantations: Large scale plantations of these two species are raised in many parts of India. The Siwalik forests of uneconomical species have been converted into *Khair-Sissoo* artificial forests.

Khair and *Sissoo* were planted in U.P. in Dhakulia Chandar and it was found out that young seedlings of *Khair* and *Sissoo* have mostly survived the frost. Leaves and tender shoots of three and four year old plants were killed by frost but the main branches remained quite healthy.

Khair showed a great promise in Bihar and *Khair* and *Sissoo* plantation of the Rakti block in Bengal remained very successful.

OTHER PLANTATIONS OF INDIGENOUS AND EXOTIC PLANTS:-

There are numerous other species which are being planted on small scale but they constitute an important part of the vegetation. In the Himalayas, Poplars (Photo 232) is a common feature in Kashmir, Kulu and other areas. Plantations of *Populus nigra* are also raised as windbrakes in parts of north-eastern India now included in Pakistan (Photo 233). Besides the *Populus,* plantations of Willows are raised extensively in Kashmir, parts of north-west India and on the Nilgiris at Ootacamaund. These plantations are for sports-goods. Besides, willows, Mulbery is also taken up along canals for the same purpose.

In the Himalayas, several European Oaks, *Fagus* and *Castanea* were tried in Nursery scale in Kulu and Kashmir. There are possibilities of extending these to further areas.

In several parts of the country, small plantations of *Treuia* and *Anthocephalus* (Photo 234), *Ailanthus,* etc. are being raised for various purposes.

Palms of various types are popular in gardens and parks (Photo 235).

Several kinds of plants are planted in tea estates and coffee estates all over south India. These are mainly *Grevillia robusta,* and *Erythrina.* Tea and coffee plantations constitute a very important artificial type of vegetations in this country (Photo 236). Rubber plantations on a large scale are also being made in south India (Photo 237). *Cinchona* and *Eucalyptus* are now becoming less popular and *Wattles* are gaining ground, in South India. In the course of time these plantations will occupy an important position in the Indian Vegetation.

Another important plant which is taken up on a large scale for planting in arid region is *Prosopis juliflora.* This grows on a very poor type of soils and is finding favour for soil conservation and desert afforestation purposes. In recent years, extensive patches have been planted with this species (Photo 238). A large number of other species are also being used in the reclamation of the degraded soils in the Indian deserts and in the *Usar* soils in the Gangetic Valley.

Techniques of raising artificial forests: Artificial forests are raised both with irrigation and without irrigation. Mohan (1954) has recently presented a paper on plantation technique, summary of which is presented here:—

(a) **Irrigated plantations:** In the irrigated plantations of the Punjab water is derived from a canal or one of the subsidiary branches and the irrigation system practised is either flood irrigation or trench irrigation. Irrigation begins generally from the first week of April and till the end of September or middle of October. Planting is done as soon as the supplies of water become regularly available and necessary weedings are carried out. Thinnings are carried out in the sixth and the twelfth year and sometimes in between. The silvicultural system is coppice-with-standards, with a rotation generally of 18 years for coppice and 54 years for the standards. The species selected for planting in the Punjab are generally *Dalbergia sissoo* and *Morus alba,* the latter being inter or under planted after first thinning. *Melia azedarach, Acacia farnesiana* and *Prosopis juliflora* form the auxiliary species. Standards are kept along the roads and the main water channels and about 16 standards per acre are kept regularly scattered over the area.

Mohan suggested that in order to have a successful plantation (i) proportion of the area to be under irrigated plantations, their size and location must be fixed (ii) study of behaviour and distribution of water in the soil must be done (iii) mineralogical analysis of the soil should be done and (iv) the charting of vegetation should be completed before attempting plantation.

(b) **Unirrigated:** No organised large scale plantations have been formed in the plains of the Punjab due to extremely adverse conditions for plant growth. In dry localities the method of planting requires moisture conservation to help the plants to tide over periods of drought and intense dessication. Planting are therefore done on the berm of trenches of varying lengths: and patch sowings are only successful where conditions are better. The double trench method has also been very successful wherever attempted. In dry localities the chief inimical factors being the aridity and extensive stretches of sodium soils, the reclamation of which is of particular importance. The species are selected ecologically with reference to forest types in the area.

(c) **Taungya system:** Taungya is a Burmees word meaning (taung=hill, ya=cultivation) shifting cultivation where the cultivators cut some or all of the tree crop, burn it, and raise field crops for one or more years before moving on to another site and repeating the process. This system was practised in U.P. in Gorakhpur and was described by Bhola and Shaukat Husain (1931).

In the Pharenda range of the Gorkhpur forest division, where taungya was first started about 1,500 acres are under this system. The climate of the area is almost equable and the water table is comparatively near the surface. The soil varies from stiff clay to sandy loam. These areas produce the best *sal,* but regeneration from coppice generally fails. The regeneration of larger blanks has been completed by *sal* taungya and that of the smaller blanks by planting teak. Where *sal* is old, stunted and deformed, no attempt is made to get coppice, but as soon as the felling are finished in March, the areas are immediately given over to taungya. After the distribution of land for taungya all roots and stumps are removed during the first year and then the soil is prepared for the forest species. On well drained loam *sal* is sown with a mixture of *Ougeinia dalbergioides* and *Pterocarpus marsupium.* Forest species are not sown till one complete Kharif and one *rabi* crop have been taken from the area. The taungya grown *sal* grows spasmodically throughout the year and the rate of growth is as follows:—

After first	rains.	6" to 1"
,, second	,,	2" to 3"
,, third	,,	4" to 5"
,, fourth	,,	7" to 10"
,, fifth	,,	12" to 15"

The rate of growth of teak is as follows:—

After first	rains.	Upto 1"
,, second	,,	5" to 7"
,, third	,,	10" to 12"
,, fourth	,,	15" to 25"

Chaturvedi (1938) has described the taungyas of the Saharanpur forest division. He states that upto two years in advance of sowing, land is distributed to cultivators who uproot trees and raise agricultural crops. Cultivators sow forest species along lines 20 – 30 feet apart with their kharif in the intervening strips. Attempt is made to raise dense lines of seedlings to provide against many a grim contingency to which our unfenced plantations are prone. The proportion in which the species are distributed is determined by the objects of management. The rate of growth of most of the species attempted has been extraordinarily rapid. The earliest sowing of 1931 had reached an average height of 25 to 30 feet in 1938.

(d) **Ecological techniques of the introduction of Exotic plants in India:** The use of Exotic species for re-afforestation and for economic purposes is being favoured in India since long. The introduction of *Eucalyptus* and *Casuarina* and several other species was made for these reasons. In a number of cases, it was found that large scale plantations of various species made at such a tremendous cost had failed on account of the various reasons, such as drought, or insect diseases. The failure has occurred not only in the case of indigenous species but also plantations of teak and *sal* raised at many places had similarly failed. The drought conditions in parts of eastern U.P. have been so severe that not only the forests but plantations of these species had also suffered. As a result of these failures, the area has been invaded by pests such as, *Lantana, Eupatorium*, etc. Less important pests which have become prominent in some parts of the country are *Xanthium, Cannabis, Cassia tora*, etc. In recent years a good deal of work has been done in the U.S.A. by Nuttonson. Discussing the various methods used by Nuttonson and European and American authors and others, Puri (1954) has made a survey of the causes which have brought about the failure in the plantations of various species in India. He discussed the examples of *Cryptomeria japonica* in Darjeeling and *Casuarina equisetifolia* on eastern coast. By foliar and soil analyses, he showed that mixed plantations would be more beneficial from the point of view of soil conditions and also for other reasons. The mixed plantations technique may be difficult from foresters' point of view because it raises difficulties in management, exploitation, but the maintenance of soil fertility is no less important and it is ecologically more sound to have mixed plantations than pure. There may be differences of opinions on this subject, but further research into Indian plantations is urgently needed.

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