A SURVEY OF ECONOMIC IMPLICATIONS OF FAST-GROWING TREE PLANTATIONS FOR UTTAR PRADESH IN INDIA

by

JAGDISH CHANDRA NAUTIYAL

B. Sc., Agra University, 1951

Associate of the Indian Forest College,

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Department of Forestry

The University of British Columbia
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ABSTRACT

The state of Uttar Pradesh occupies about 9 per cent of the total geographical area of India, supports more than 16 per cent of its 440 million people, but has less than 6 per cent of the Indian forests. It is, in many ways, an underdeveloped part of a developing nation. There is a great potential for contributions of Uttar Pradesh to the economic development of India, by the expansion of the U. P. pulp and paper industry.

Per capita consumption of paper and paper-board in India is expected to increase from about 1.3 Kg in 1965 to 6.2 Kg in 2000. If the production in the country increases as anticipated in this thesis, and if more raw materials are not made available, shortages of both long-fibred and short-fibred raw materials will begin to be felt strongly by about 1975 and will progressively increase.

To reduce these shortages the Uttar Pradesh Forest Department is establishing plantations of fast-growing tree species. The Mysore hybrid eucalypt is being planted to provide short-fibred pulpwood and plantations of the bamboo (Dendrocalamus strictus) will yield long-fibred pulp. Present plans of the U. P. Forestry Department have not paid enough attention to growing long-fibred material. The Department should concentrate mainly on the production of long-fibred material because much short-fibred material is available as sugar cane bagasse in the U. P. It also could be secured when needed if eucalypt and poplar plantings were made by farmers.

Eucalypts, pines, poplars and bamboos have been discussed regarding their suitability for production of pulpwood in the forest areas of U. P. Greatest attention has been given here to eucalypts but it is concluded that pines and bamboos are the most desirable.

The need for producing within India all of the pulp and paper required domestically has been considered more important than that for supplying paper and paper-board to Indian consumers at world prices. At present it appears as if the foreign exchange conserved by reducing pulp and paper imports can be more usefully spent in buying machinery, fertilizers, and technical knowledge.

India can become self-sufficient in its paper and paper-board needs after 1980 only if enough long-fibred raw materials are produced. Therefore, major trials of potentially suitable, fast-growing, long-fibred species should be established soon. The paper industry in U. P. should continually strive to improve its technology and bring down its costs of production because in the long run it will have to become competitive in world markets.

The U. P. Forest Department should not judge its efficiency solely by the size of net surplus created in a plantation program. It should also consider the potential contributions of its plantations in the growth of Indian industry and improvement of real national income.

Intensive economic analyses of the problems discussed here should be undertaken to refine objectives for the long-term development of U. P.'s forest industry.

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CHAPTER I

INTRODUCTION TO UTTAR PRADESH

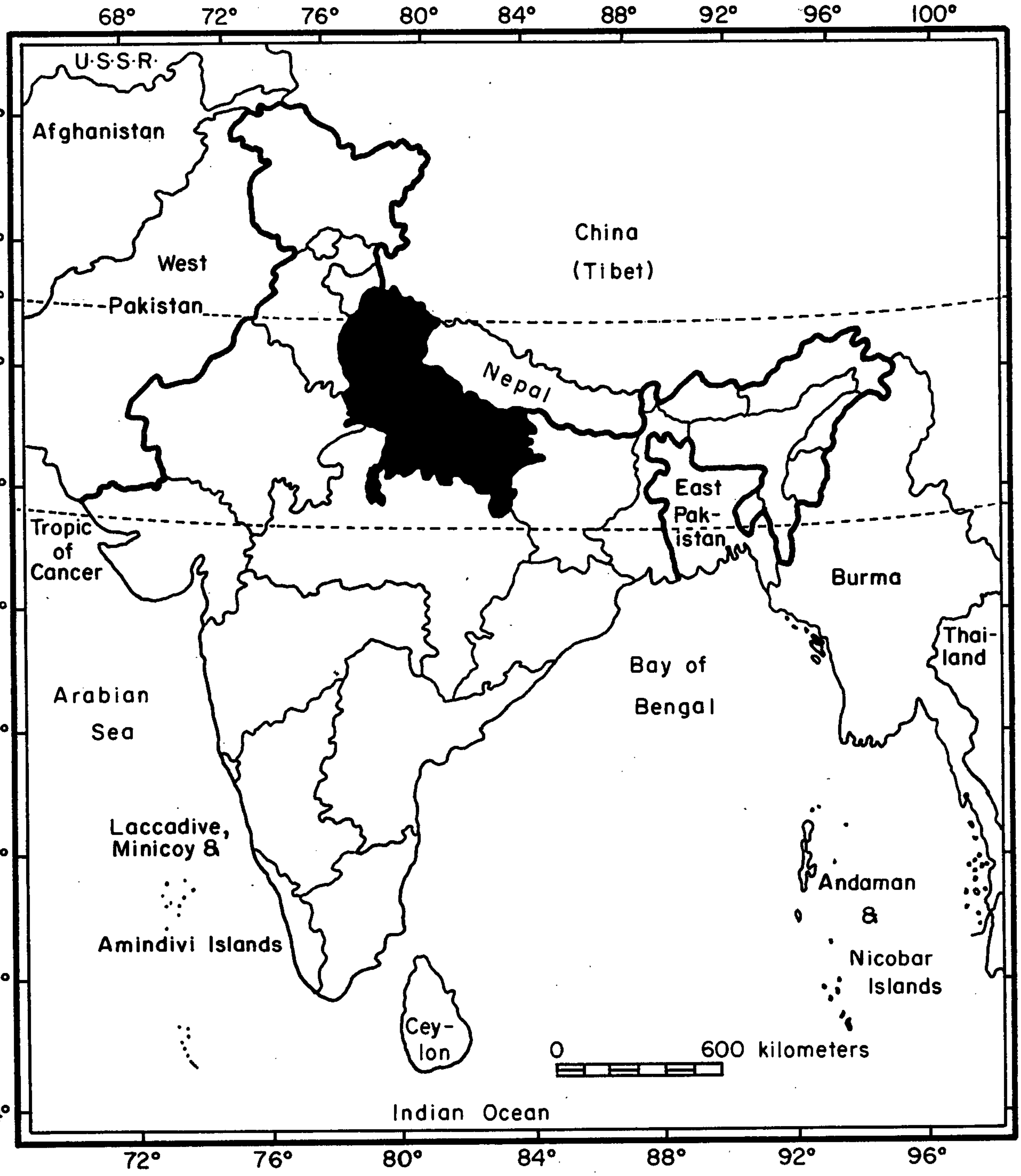
General

The state of Uttar Pradesh (U. P.) is situated roughly between 77° and 85°E longitude and 23° and 32°N latitude (U. P. Forest Department 1961). U. P. occupies a significant part of northern India (Map 1). Its population of 73.7 million (Publications Division 1964) in 1961 is estimated to be increasing at a rate of about one million per annum.

Physical features

The Southern foothills of the Himalayas roughly form the northern boundary of Uttar Pradesh, except in the north western parts where the entire Himalayan range south of the Tibetan plateau is included in it (Map 2). In the south of the State is a region of low hills forming the Vindhyan range which runs almost east-west. The highest peaks in the Himalayas within U. P. are above 25,000 feet (Nandadevi and Kamet). In between the Himalayas which have an average height of 19,000 feet and the Vindhyas which do not go above 600 feet in U. P., lies the large fertile plains region. It is formed by the alluvial deposits of the River Ganga and its tributaries. The elevation of the plain proper is not above 300 feet.

Map I· India, showing the position of the State of Uttar Pradesh (solid)·



Geology and soil

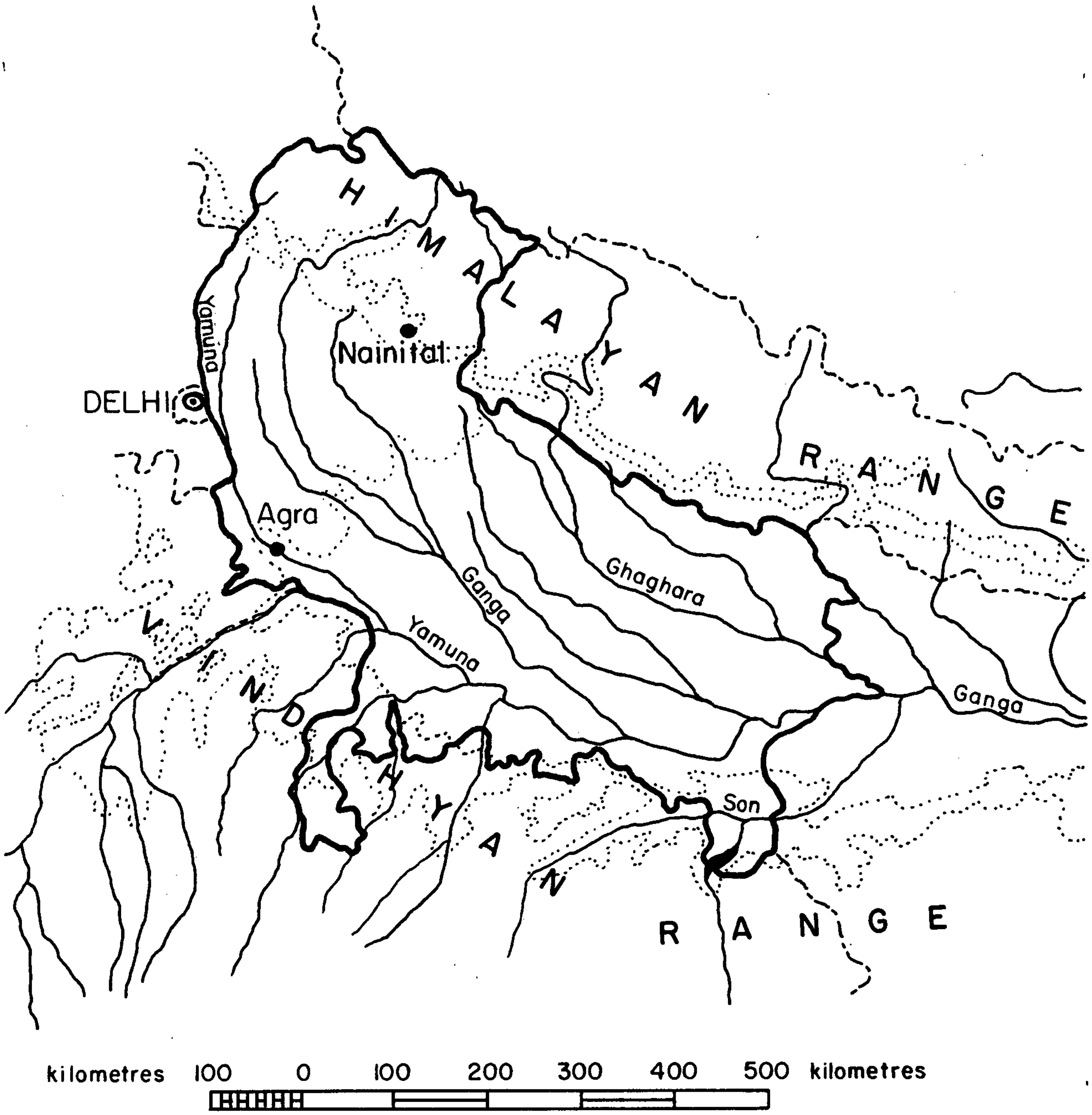
The Vindhyan hills are the harder rock masses of the ancient land mass that formed the peninsular part of India, and which have resisted weathering (Forest Research Institute 1961a). The softer ones have been worn out to the present plains in the Deccan plateau. The Vindhyas and the Deccan formed part of the vast land mass, the Gondwana-land, which stretched across from India to South Africa, South America, Australia and the Antarctica, from the Upper Carboniferous period through Permian, Triassic and Jurassic onto the Lower Cretaceous period.

The Himalayan range is a region of folded mountains of a comparatively late age, the Tertiary era. Having been disturbed by earth movements of great magnitude the rocks have been crumpled, folded, faulted, over-thrust and even carried over considerable distances as thrust-sheets. The topography is steep and rugged and the rivers are still actively eroding their courses. Prior to the disturbances of the Tertiary era the region formed part of the vast sea of Tethys, which is estimated to have extended from the Western Mediterranean to China.

In between these two geological features lies the Gangetic Plain. It has been built up over a depression or sag of great depth in the earth's crust, into which the material eroded from the hills was dumped during the Pleistocene and recent times, watered by the Ganga and Yamuna and their numerous tributaries.

Besides the three main regions, Himalayas, Vindhyas and the Plains, there are other sub-regions, the most important three of which are given here.

Map 2· The State of Uttar Pradesh, showing rivers and mountain ranges·



1. The Siwālik hills.

These were uplifted in an age later to the Himalayas and form a foothill zone to that mountain range. They are composed of coarse sandstone and clay.

2. The Bhabar tract.

This region fringes the foothills to their south and consists of great accumulations of coarse and porous detritus (boulders, shingles etc.), through which rain and river waters readily disappear.

3. The Tarai tract.

South of the Bhabar, at lower elevations where the water that seeps into the Bhabar emerges out and forms numerous sluggish streams, a narrow belt is called the Tarai.

The alluvial soil in the plains is hundreds of feet deep but may have layers of sand at different depths. It is very fertile and is the cradle of Indian civilization.

The soil in the Vindhyan region is very poor. In the Himalayan region it may be fairly fertile and deep in the valleys where it is formed of the transported material but on the hillsides and tops it is often poor.

Climate

The most powerful influences exerted on the climate of the Indian sub-continent are not those of latitude but of altitude, aspect, proximity or remoteness from the sea and the disposition in relation to mountain ranges and prevailing wind currents (Forest Research Institute 1961a).

The Himalayan region exhibits a whole range of climate from tropical or sub-tropical at the base of the foothills, through temperate to the alpine and arctic conditions prevailing at the higher elevations. This is clearly reflected in the well defined altitudinal zonation of forest flora.

Due to the distance of the sea from U. P. its moderating influences are not felt and the summers over major part (except the higher Himalayas) are far more severe than the coastal regions of India much nearer to the Equator. The day temperature in summer may commonly go above 115°F and in the winter nights it may drop down almost to freezing point. At higher altitudes the summers are milder and the winters cooler. Frost is a feature of the western Gangetic plain of the sub-Himalayan region and the hills. At elevations above 5,000 feet light snow fall may be experienced during December-January, and above 12-13,000 feet snow may persist all the year round.

Rainfall is greatly influenced by the disposition of mountain ranges and the courses of the moisture bearing currents from the Bay of Bengal in the east and the Arabian Sea in the west. Although the latter is far greater in extent, it is the currents of the Bay of Bengal that cause heavier intensities of rain. The Bay current hits the Eastern Himalayas and the hills of Assam and creates conditions of heavy rainfall in north-eastern portions of India. The current swerves to the west and traverses along the plain of the Ganga, the precipitation decreasing with the distance travelled from the Bay.

The winds blowing over the Arabian Sea cause heavy precipitation along the hills on the west coast of India and sweep over the hot plains of the north-west for about 1,000 miles. Precipitation takes place only when the monsoon hits the Himalayas. Hence there is a large desertic region in Rajasthan, the effects of which are felt in western and south-western U. P. also.

The rainfall in U. P. therefore decreases as one moves from east to west and also as one moves to south, away from the Himalayas. The annual precipitation at Naini Tal which is in the outer ranges of the Himalayas, is about 110 inches, while at Agra (which is in the west), it is seldom above 30 inches. When it occurs rain usually falls with high intensity and rainfall intensities of 5 inches per hour are not uncommon (Champion 1960).

Seasons

Three main seasons are recognized in the major part of U. P. but in the Himalayas four (spring, summer, autumn and winter) can be distinguished.

(i) Hot Season

The four months of March, April, May and June constitute the hot season. The temperature increases steadily until June, the only relief coming from a few occasional thunder storms in April and May. The season is dry, especially in the southwest, and very hot. June is the hottest month of the year and the major part of the state experiences scorching hot winds during the day time in May and June.

(ii) Rainy Season

Relief comes in the middle or end of June in the form of monsoon showers. There may be a short spell of dry season after the first few showers but soon the monsoon 'sets in' and rains continue, intermittently, till the end of September. The entire countryside assumes a green look during the rainy season when more than half of the annual precipitation is received.

(iii) Cold Season

From October to February the temperature drops down to more comfortable ranges. The coldest month is January when it may go below freezing point in the higher Himalayas and between 30°F and 40°F in the plains. Except for a few showers in December or January caused by the retreating monsoon, the period is dry.

Drainage

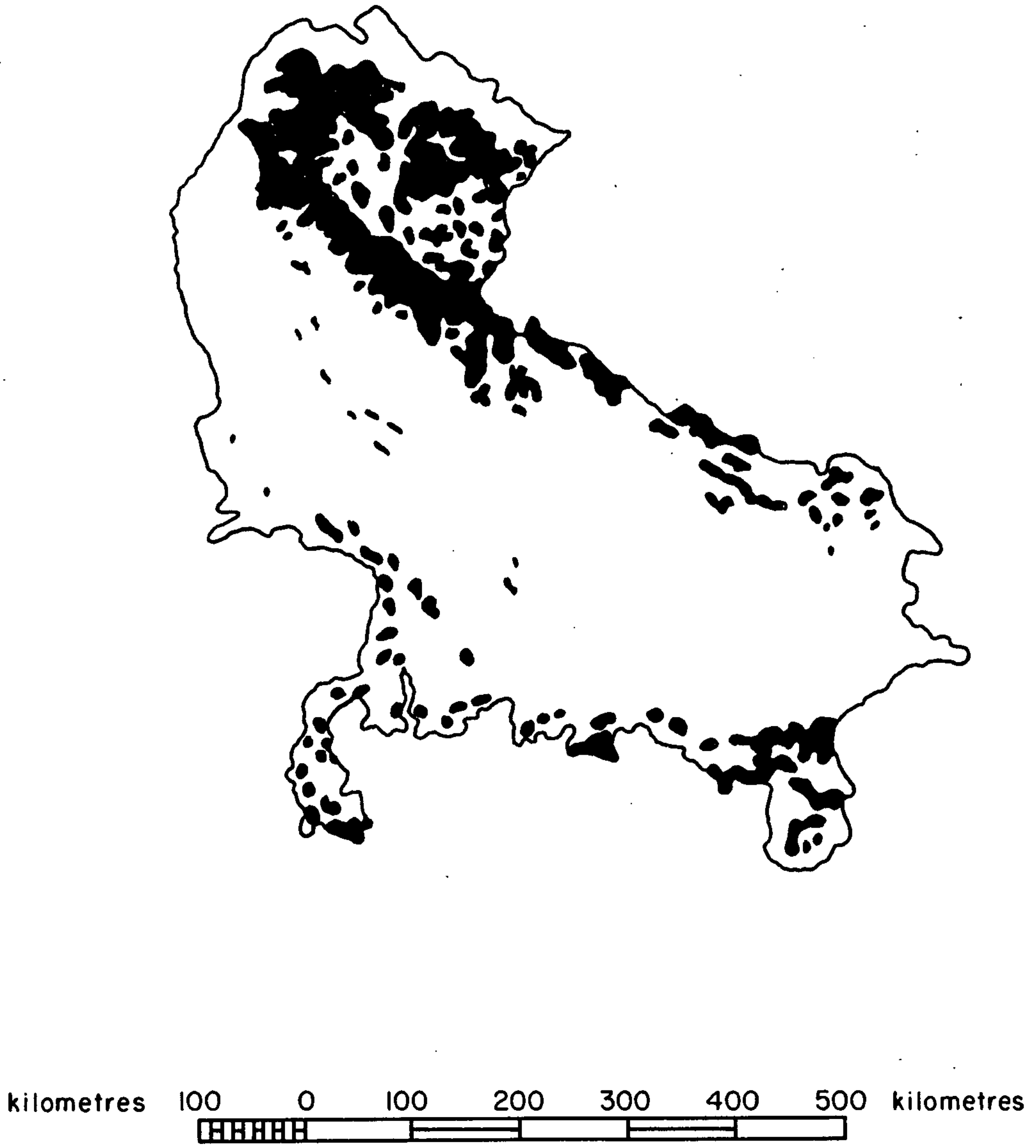
The State is served by two river systems - the Yamuna and the Ganga (U. P. Forest Department 1961). The main rivers have their source in the Himalayas and are snow-fed. They run generally from north to south in the mountains and thereafter turn southeast. The other rivers, namely the Chambal, the Betwa and the Son, have their sources in the Vindhyas and run from south to north or northeast before they join the Yamuna or the Ganga.

Distribution of forests

The major portion of the forests lies in the Himalayan and the submontane tracts, followed by a smaller proportion in the Vindhyan region in the south. The great Gangetic basin is practically devoid of forests (Map 3).

In the mountainous region about 48 per cent of the area is

Map 3. The State of Uttar Pradesh, showing the forest areas (solid).



covered with forests whereas in the plains it is only about 5 per cent. Of the total geographical area of 113,654 square miles (Publications Division 1964), only 17,509 square miles or 15.43 per cent is covered with forests in U. P. Almost all the forests are either owned by the State or village governments. A total of 13,524 square miles are managed by the State Forest Department (Forest Extension Officer U. P. 1964). Less than 2 per cent of the area is under private ownership.

The relative position of Uttar Pradesh, in India, can be partly visualized from the statistics given in Table 1.

Forest types

The chief forest types occuring in U. P. according to Champion (1961) are:

(i) Alpine scrub - This formation is found in the Himalayas above the tree line and below the permanent snow line between 12,000 feet and 14,000 feet. It includes shrubs such as Rhododendron campanulatum[1], R. anthopogon, Pyrus foliolosa, Juniperus recurva etc., with grasses and herbs occuring quite extensively.

(ii) Alpine forests - These are characterised by typically dense growth of small crooked trees or large shrubs with batches of coniferous overwood. Abies species and Betula utilis usually

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[1]The scientific names of all Indian species in this thesis have been written in the manner of the Forest Research Institute Debra Dun, U. P. India.

The scientific names of North American species have been given on the basis of Harlow and Harrar (1958).

The scientific names of all other species have been given as used by the Food and Agriculture Organization of the United Nations.

Table 1. Uttar Pradesh and India

	U. P.	India	U.P. as a % of India
Geographical area (1964)	113,654 sq.mi.	1,261,597 sq.mi.	9.0%
Population (based on 1961 census)	73,746,401	439,072,582	16.8%
Density of population (based on 1961)	649 per sq.mi.	370 per sq.mi.	175.4%
Total forest area	17,509 sq.mi.	302,688 sq.mi.	5.8%
Forest as % of total area	15.43	24.0	
Forest area per capita	0.148 acre	0.494 acre	
Per capita outturn of industrial & fuel wood (1957-58)	Ind. 0.24759 cu.ft. Fuel 0.91962 cu.ft.	0.49518 cu.ft. 1.09647 cu.ft.	
Per acre outturn of industrial & fuel wood (1957-58)	Ind. 1.86 cu.ft. Fuel 7.59 cu.ft. Total 9.45 cu.ft.	1.58 cu.ft. 3.58 cu.ft. 5.16 cu.ft.	117.7% 212.0% 183.1%
Total outturn of wood	Ind. 13,672,000 cu. ft. Fuel 58,402,000 cu. ft. Total 72,074,000 cu. ft.	156,279,000 cu.ft. 374,186,000 cu.ft. 530,465,000 cu.ft.	8.8% 15.7% 13.6%
Total revenue contributed by Forest Depts. 1959-60	R_s[1] 61,920,000	R_s 537,153,000	11.5%
Total expenditure incurred on Forest Depts. 1959-60	R_s[1] 27,969,000	R_s 241,852,000	11.6%

(Based on Publications Division 1964; Forest Extension Officer 1964; and Forest Research Institute 1961a)

[1] Rate of exchange for Indian Rupee and Canadian Dollar on June 22, 1965 was: R_s 100.00 = C $22.79; and C $1086.25 = U.S. $1000.00

form the overwood and Rhododendron and Lonicera species the underwood. The formation occurs between 10,500 and 12,000 feet.

(iii) Himalayan dry temperate forests - This type is found in some places in the inner valleys of Garhwal Himalayas. The main species is Cedrus deodara occuring with Abies webbiana, A. pindrow, Picea smithiana and Pinus wallichiana. The broadleaved associates are Acer, Fraxinus and Quereus semecarpifolia.

(iv) Himalayan moist temperate forests - This formation extends along the whole length of the Himalayas between sub-tropical pine and alpine formations, roughly at elevations from 5000 feet to 10,000 feet, where annual rainfall is more than 40 inches. Coniferous trees are more prevalent and predominate; chief species being Abies pindrow, A. webbiana, Picea smithiana, Cedrus deodara and Pinus wallichiana. Cupressus torulosa occurs as an edaphic climax, chiefly on limestones. The chief broadleaved species are Quercus semecarpifolia, Q. floribunda and Q. incana.

(v) Himalayan sub-tropical pine forests - This type forms the extensive, almost pure stands of Pinus roxburghii extending from 3000 feet to 7000 feet in the Himalayas.

(vi) Tropical moist deciduous forests - These are confined to the sub-montane and Tarai regions and to some limited extent to the eastern Vindhyan region. They can mainly be divided into (a) almost pure Shorea robustia (Sal) forests or (b) the moist mixed miscellaneous deciduous forests.

Sal occurs very extensively in a gregarious manner and forms the most valuable forests of the state. Its principal associates are Terminalia tomentosa and Lagerstroemia parviflora.

The miscellaneous forests, most of which can be classified as "Gangetic tropical moist deciduous riverain forest" (Champion 1961), have a number of species, many of which are of considerable industrial importance. This type has assumed more importance in the recent years as the bulk of planting of fast-growing tree species in U. P. has been done in it after felling the existing forest. Champion (1961) described the type as:

> "A mixed high forest in which the constituent species may occur in small groups but rarely form a pure crop of any extent. All top storey species are leafless in the hot weather. Under natural conditions a closed canopy and good height and bole formation are usual, but most of the forests have been greatly influenced by human activities involving burning, grazing, lopping and selective felling, so that a broken and irregular canopy and bad tree form is more usual. There is a number of small trees forming a lower storey but merging with the undershrubs, some of which are definitely gregarious: some of these are evergreen though with thin, not coriaceous leaves. Grass is sparse or absent in the moister types where the cover is dense and shrubs and ferns predominate, but more usually the annual fires and broken canopy ensure a dense grass growth. Climbers are few, and bamboo of decidedly local occurrence.
> Floristics:
> Top-storey:- Salmalia malabarica, Adina cordifolia, Lagerstroemia parviflora, Terminalia belerica etc.
> Under-storey:- Cassia fistula, Randia dumatorum, Zizyphus jujuba, Mallotus philippinensis, Phyllanthus emblica etc.
> Under-growth:- Adhatoda vasica, Helicteres isora, Pogostemon plectranthoides, Callicarpa macrophylla, Murraya koenigii, Glycosmis pentaphylla.
> Grasses:- Andropogon muricatus, Saccharum munja, S. narenga."

(vii) Tropical dry deciduous forests - Though Shorea robusta also occurs in this type, the bulk is under the various dry deciduous species, chief of which are Acacia catechu, Terminalia tomentosa, Anogeissus latifolia, Diospyros tomentosa, Anogeissus pendula and Boswellia serrata. To a limited extent teak (Tectona grandis) also occurs in the Vindhyan region.

(viii) Tropical thorn forests - These are confined to the south-western drier part of the state forming an open scrub consisting largely of Acacia arabica, Acacia leucophloea, Prosopis spicigera, Belanites aegyptica and Salvadora oleoides.

Forest resources

The woody plants in the state add up to about a thousand species (U. P. Forest Department 1961). Even if species which are herbaceous are excluded, there are upwards of 300 trees, almost 400 shrubs and over a hundred woody climbers. More than 220 species of grasses have been collected from the Gangetic plain alone and there are many more in the hills. The herbaceous flora is also very rich and many important species of medicinal plants like Rauwolfia serpentina, Viola serpens, Podophyllum hexandrum, Ephedra gerardiana etc. are found.

Following are common and scientific names of the principal timber trees, the first six of which are roughly in order of importance.

Sal (Shorea robusta)

Chir (Pinus roxburghii)

Deodar (Cedrus deodara)

Semal (Salmalia malabarica)

Sissoo (Dalbergia sissoo)

Khair (Acacia catechu)

Babul (Acacia arabica)

Sain (Terminalia tomentosa)

Haldu (Adina cordifolia)

Tun (Cedrela toona)

Kanju (Holoptelea integrifolia)

Spruce (Picea smithiana)

Blue pine (Pinus wallichiana)

Jamun (Syzygium cumini)

and Gutel (Trewia nudiflora)

The main produce from the forests of U. P. are timber (saw logs) and firewood. The principal tree species yielding structural timber are Sal, Chir, Deodar and Sain. A considerable proportion of available timber is supplied to the railways in the form of railway ties (track sleepers). In addition to timber Chir also yields resin which is the chief source of rosin and turpentine. Sissoo is mostly used for furniture while the heartwood of Khair yields Katha and cutch. Semal and Gutel are used as matchwood and Kanju finds use in the plywood industry. Babul bark is the principal tanning material of the state while the wood is very much valued for agricultural implements and firewood. Sabai (Eulaliopsis binata) grass and bamboo (Dendrocalamus strictus) as well as some twisted Chir provide important raw materials for paper industry. The leaves of Tendu (Diospyros tomentosa) are much in demand for biris (leaf rolled cigarettes). Canes (Calamus species) are used greatly for basketry and furniture making.

Annual wood production

According to U. P. Forest Department (1961) the annual harvests of the last few years in U. P. were as follows:

Timber

(i) Conifers

Chir (*Pinus roxburghii*)	3,346,000 cu. ft.
Deodar (*Cedrus deodara*)	357,000 cu. ft.
Blue pine (*Pinus wallichiana*)	120,000 cu. ft.
Spruce and silver fir (*Picea smithiana* and *Abies pindrows*)	681,000 cu. ft.

(ii) Broad-leaved

Sal (*Shorea robusta*)	4,606,000 cu. ft.
Sain (*Terminalia tomentosa*)	560,000 cu. ft.
Semal (*Salmalia malabarica*)	163,000 cu. ft.
Sissoo (*Dalbergia sissoo*)	264,000 cu. ft.
Jamun (*Syzygium cumini*)	128,000 cu. ft.
Kanju (*Holoptelea integrifolia*)	63,000 cu. ft.
Haldu (*Adina cordifolia*)	119,000 cu. ft.
Teak (*Tectona grandis*)	32,000 cu. ft.
Gutel (*Trewia nudiflora*)	12,000 cu. ft.
Sandan (*Ougeinia dalbergioides*)	34,000 cu. ft.
Tun (*Cedrela toona*)	11,000 cu. ft.
Bakli (*Anogeissus latifolia*)	22,000 cu. ft.
Other species	2,008,000 cu. ft.

Firewood

All species	30,459,000 cu. ft.

In addition, bamboos, canes, resin etc. are also extracted every year for purposes of sale. Roughly the following quantities are given free or at nominal rates to farmers in the vicinity of forests:

Timber	1,146,000 cu. ft.
Firewood	27,943,000 cu. ft.
Bamboo	170,000 pieces

Ringals (Arundinaria species) 6,618,000 pieces and grasses and other produce valued at about 250,000 rupees.

Centres of forest industries

The main centres of forest industries are:

Bareilly	Resin, match, katha and furniture
Sitapur, Jwalapur and Najibabad	Plywood
Saharanpur	Wood working and paper
Haldwani	Katha and furniture
Mirzapur, Dudhi and Jhansi	Biri and wooden toys
Gorakhpur and Allahabad	Cane furniture
Lucknow	Paper and sports goods
Varanási	Wooden toys
Meerut, Dehra Dun	Sports goods
Naini-Tal	Sports goods, wooden toys and walking sticks

Saw mills exist in a number of towns like Dehra Dun, Haldwani, Bareilly, Lucknow, Gorakhpur etc.

<u>Forest development</u>

From the early years of regular forestry more than a century ago, India's forests came to be organised and worked on a systematic basis, according to working plans drawn in advance and revised periodically. The need to conserve forest capital and attain a 'normal' forest was recognised. The forests were worked on a sustained yield basis, and some expenditure was also made for raising of plantations, cultural works and construction of roads, buildings, etc. This conservation policy served adequately till early in the present century. But during the two World Wars, especially the Second War there was such a heavy drain on the forests and their resources that their condition created anxiety for the future. The principle of 'sustained yield management' could no longer be adhered to and excessive fellings and even forest denudation became almost the order of the day. It was inevitable that all this had to be followed by intensive developmental activity, if the forests were at all to be restored to their normal productive condition. A post-war forest policy of India was drawn up in 1944 as the basis for a plan for future improvements in all the forests in India.

Accordingly post-war development schemes were initiated in most of the states in addition to regular working plan prescriptions. It was soon apparent that they were but on a meagre scale compared to the needs of the situation. Due to rise in price level after World War II, there were large-scale fellings in <u>Zamindari</u> and other private forests. Even individual trees standing on private properties were felled due to the high prices offered by the market. All these areas needed special rehabilitation measures. The extension of cultivation encouraged by a government-sponsored Grow-More-Food Campaign after Independence in 1947 also resulted in much clearing of forest areas. The pressure of rapidly increasing population, the demands on the forest and the growing imbalance between land under permanent vegetation and land under cultivation, all combined to force attention to the very unsatisfactory situation caused by them. It was therefore not long before the role of forests in the economic development of the nation was recognised a little more than before and special improvements undertaken.

In the post-war period (1945-51), plantations of valuable species began in earnest. Schemes were also initiated for special development and improvement of forest roads. For the first time proposals were put forward for the formation of soil conservation units, particularly to deal with the protection and management of important water catchment areas. The working plan organizations, many of which were retrenched in 1939, were restored. The Board of Forestry was reconstituted in 1948 to suit the altered conditions in the country and came to include each state's Forest Ministers, instead of technical heads of Forest Departments. Vanamahotsava, or the 'festival of trees', was inaugurated in 1950 as an annually recurring movement. Legislation was adopted in many states, U. P. being one of them, to halt the unregulated and excessive fellings in private forests and even to take them over for state management. It is as a result of these take-overs and the abolition of Zamindari that only 2% of the forests are under private ownership at present. The scale of these activities was limited mainly by considerations of financial resources.

The real development work in forestry started in 1951 when National Five-Year Plans for development were started on an all-India basis. The post-war development schemes were enlarged and consolidated into the First Five-Year Plan. This plan, though very modest, was an improvement over the earlier schemes. Subsequent Five-Year Plans have been gradually becoming more ambitious as is seen from Figure 1. The overall financial activities (including the Plans) of the Forest Departments in U. P. and India can be visualized from Figures 3 and 4 which give the revenue, expenditure and surplus in terms of 1952-53 constant rupees. The values in terms of constant rupees have been determined from the wholesale price indices for various years given in Figure 2.

Besides other programmes in the First Five-Year Plan an area of 12,500 acres was planted with species of commercial importance. Under the Second Plan a little over 3,500 acres were planted with species required for sports goods (Morus alba, and Fraxinus micrantha) and over 60,000 acres were planted with indiginous species of industrial importance (eg. Acacia catechu, Dalbergia sissoo, Holoptelea integrifolia, Salmalia malabarica, Tectona grandis etc.).

In the Third Plan there is a target for the planting of 46,000 acres in U. P. with species of industrial importance and a new scheme for "Plantation of Fast Growing Species" was started. This scheme was prepared primarily for the raising of plantations of fast growing species for production of raw materials for pulp. Plantations of hardwood tree species and of bamboos are being raised under it. The hardwood planted so far is mostly a hybrid of Eucalyptus which was produced by natural hybridization of various eucalypts in the Nandi Hills of Mysore State and is often known as the "Mysore hybrid". The following species are probably

Figure 1. Outlays in forestry development under National Five Year Plans in Uttar Pradesh, India. (Based on U.P. Forest Department, 1961 and 1964).

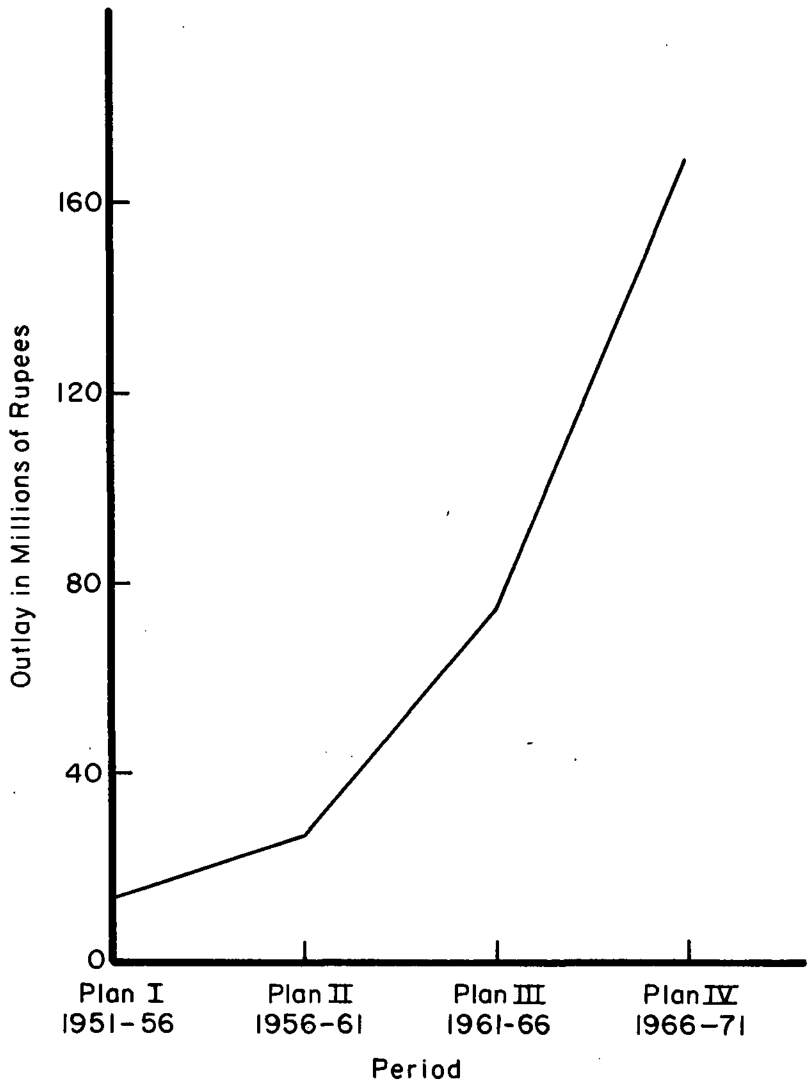
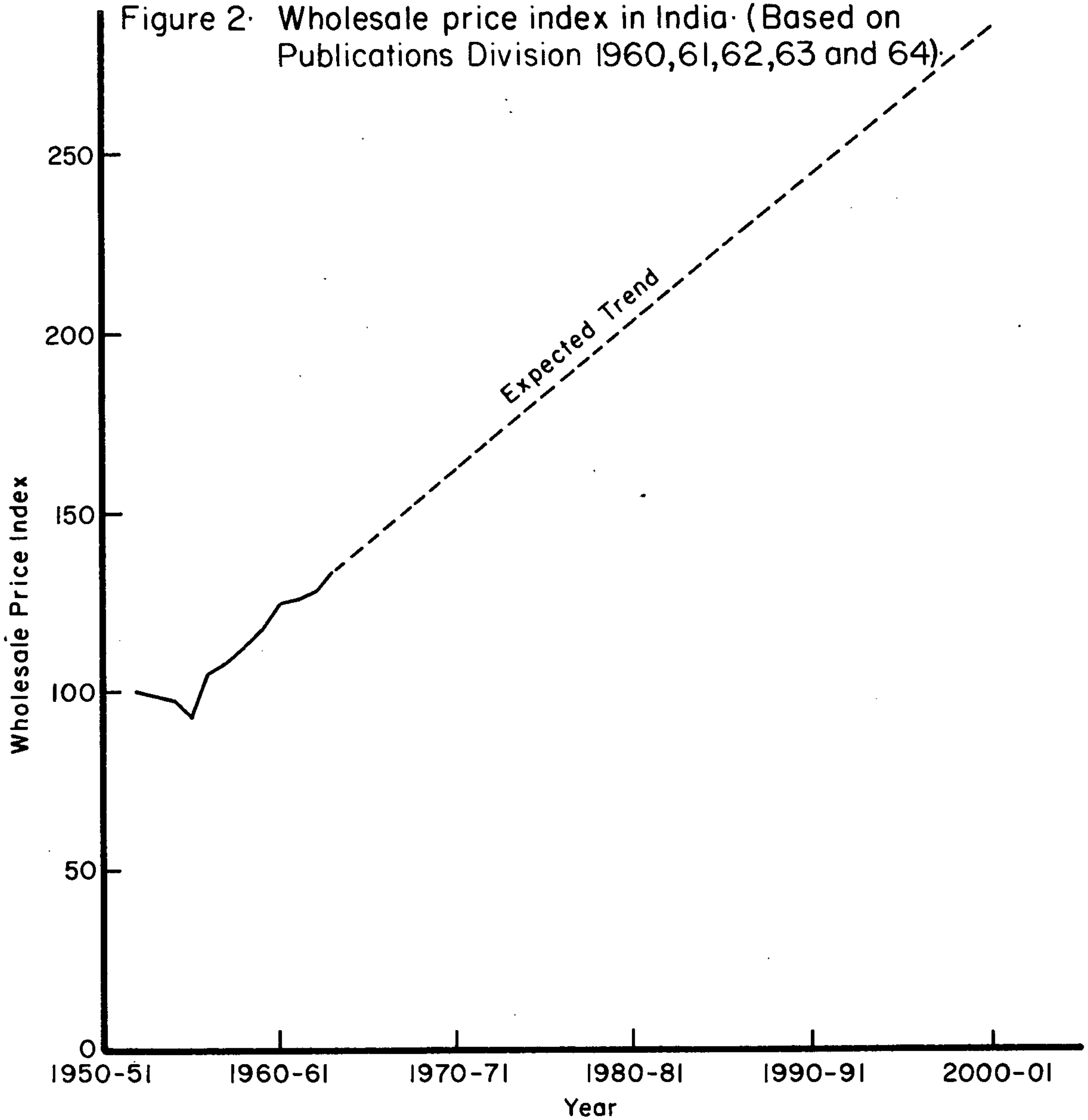


Figure 2. Wholesale price index in India. (Based on Publications Division 1960, 61, 62, 63 and 64).



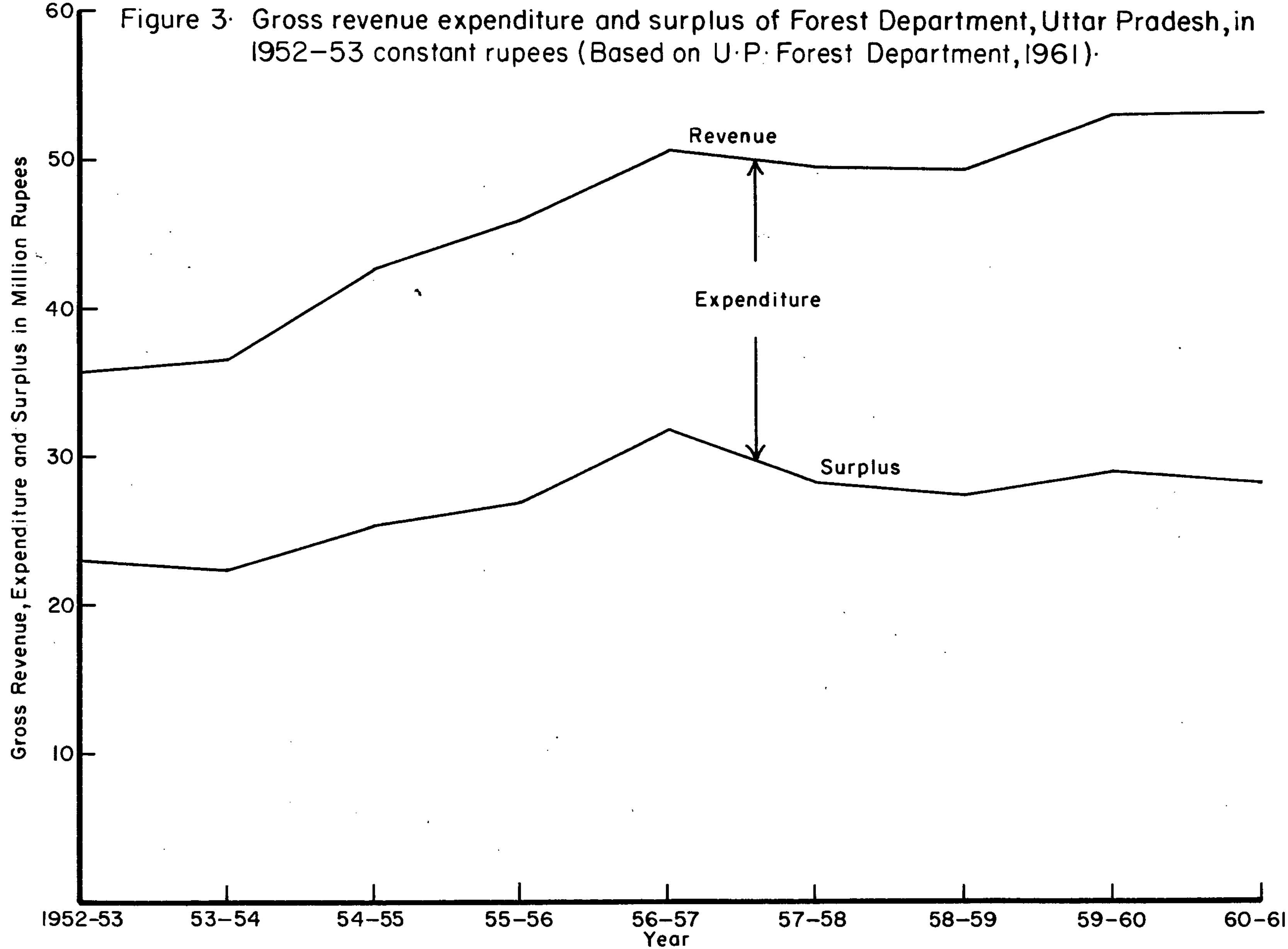
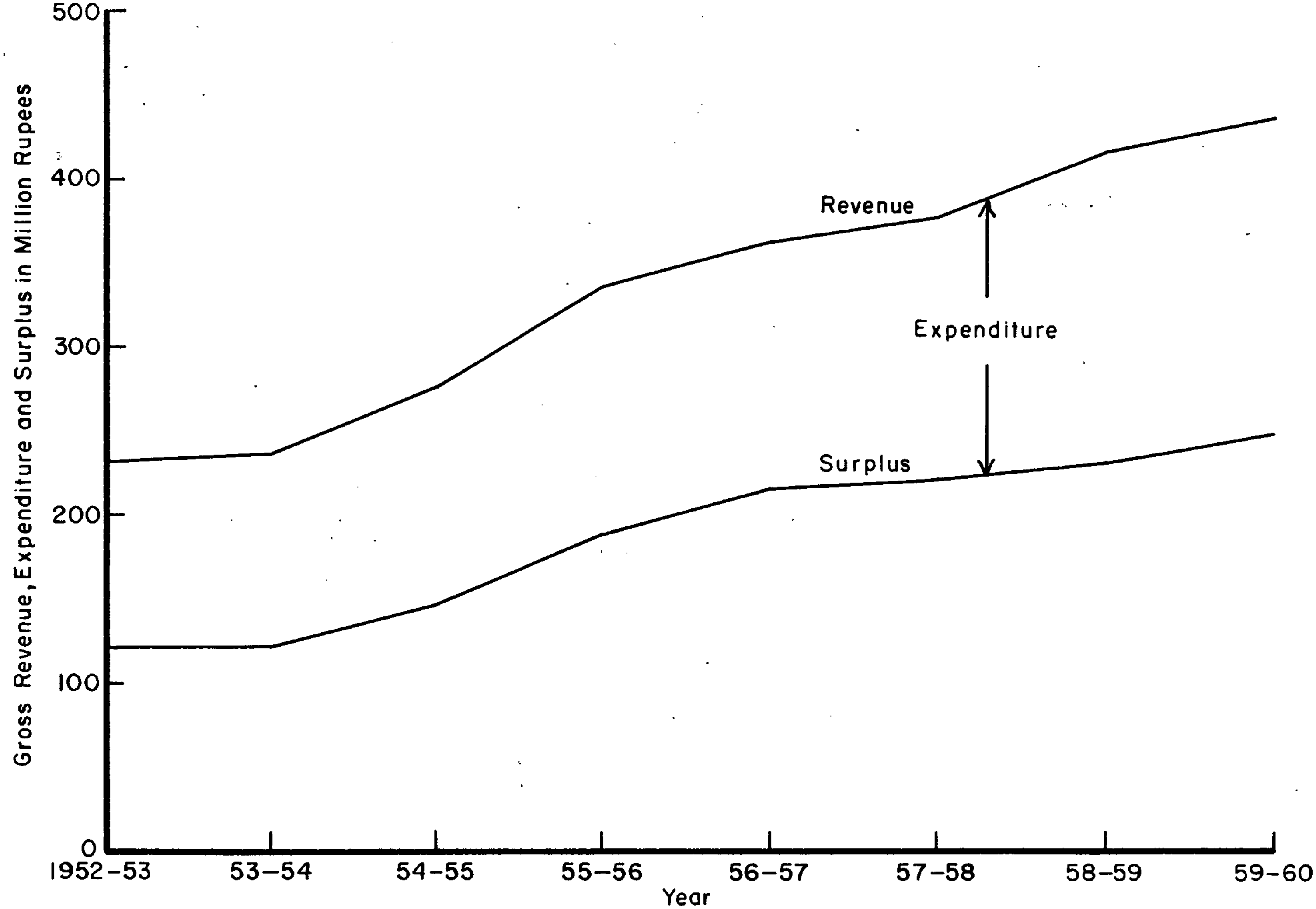


Figure 3. Gross revenue expenditure and surplus of Forest Department, Uttar Pradesh, in 1952–53 constant rupees (Based on U.P. Forest Department, 1961).

Figure 4· Gross revenue, expenditure and surplus of the Forest Departments in India in 1952–53 constant rupees (Based on Forest Research Institute, 1961)·



related to the hybrid (Kaikini 1963? Qureshi 1964).

E. tereticornis

E. camaldulensis

E. robusta

E. botryoides

E. citriodora

The largest plantations of this hybrid were raised in the *tarai* where 1,253; 2,028 and 3,265 acres respectively were planted in 1962, 1963 and 1964 (Western Circle U. P. 1964).

The bamboo used most has been *Dendrocalamus strictus*.

The area where most of these plantings have been and will be done is in the *Bhabar* and *Tarai* tract in the mixed miscellaneous forests or the open badly treated ex-*Zamindari* forests which have been under the control of the Government for a little more than a decade now.

The plantations of fast growing species for production of raw materials for pulping are being raised according to the programme (U. P. Forest Department 1964) given in Table 2.

It has been anticipated that all suitable land for the planting of fast grown species will be planted by the end of the Fifth Five-Year Plan in 1975.

From the figures given in Table 2 it can be assumed that more than 500,000 acres of suitable land are available in the State of Uttar Pradesh for raising various fast-growing species for the production of pulp. More than 30,000 of these will have been planted till the end of 1965.

Table 2. Planting programme for fast growing species in U. P.

Plan III	Area in acres		
Year	Hardwoods	Bamboos	Total
1962	3,150	300	3,450
1963	5,350	1,500	6,850
1964	8,300	4,250	12,550
1965	9,990	4,250	14,150
Total for Plan III	26,700	10,300	37,000
Plan IV			
1966	28,400	9,900	38,300
1967	32,350	10,850	43,200
1968	41,250	11,850	53,100
1969	45,200	12,850	58,050
1970	50,400	13,850	64,250
Total for Plan IV	197,600	59,300	256,900
Total for Plan V	197,600	74,100	271,700
Grand total for plans III, IV, and V	421,900	143,700	565,600

Plantations of suitable fast-growing species in optimum quantity on this area can play a very significant role in the development of forest industries in U. P.

CHAPTER II

PRESENT AND FUTURE CONSUMPTION AND PRODUCTION OF PAPER IN INDIA

Relative demand for various classes of forest products

Forest products can be broadly divided into two categories:

(i) Fuel wood, and (ii) Industrial wood

The Fuel wood may be used either for burning as such or for conversion into charcoal. In either case it is mainly used for cooking of food and heating. To a smaller extent it is also used in various industries. It has been estimated by von Monroy (Forest Research Institute 1961a) that in India 95 per cent of the fuel wood produced is used for cooking. The outturn figures for U. P. given in Table 1 show that about 81 per cent of the total wood harvest is fuel wood and thus it can be assumed that about 77 per cent of the total harvest every year is used for cooking purposes.

The 'industrial wood' which has been called 'timber' in Chapter I may be subdivided into:

(a) Timber - for house building mainly

(b) Plywood and Boards, and the following uses:

(c) Mining

(d) Transport and communication - for railway ties and bridges mainly

(e) Woodworking industry - for furniture, sports goods, etc.

(f) Packaging (g) Pulp and paper

(h) Rayon (i) Matches

The requirements for these uses in India, from 1960 to 1975, have been given by von Monroy (Forest Research Institute 1961a) and are shown in Figure 5. The projections to the year 2000 have also been drawn on the basis of these figures.

These projections are not made by sophisticated econometric methods because so little data are available now on the factors that may determine the requirements of various uses in India. Moreover, it is impossible to predict the future with any high degree of precision. For these reasons the projections of Figure 5 as well as other projections given hereafter, should be taken as indicating only the general shape of future expectations. They should be refined by much further study.

The estimates of requirements for various uses by percentages of the total requirement of industrial wood have been obtained from Figure 5 and are given in Figure 6.

Fuel-wood has not been accounted for anywhere in Figures 5 and 6 but it is expected that gradually its requirements will decrease as cheaper and more efficient fuels become available to the people and as the physical availability of these fuels also increases. It is possible that in future much of the increased demand for pulpwoods may be met from the wood that is used as fuel presently.

From the data given in Table 2 it is apparent that the role of U. P. Forest Department in meeting the future demands of raw materials for producing pulp (Figures 5 and 6), is limited by the availability of only about 500,000 acres of plantable area.

Special demands that could be met by fast-growing species

The planting of the above mentioned area, of 500,000 acres with fast-growing species, will naturally meet part of the general requirements of raw materials for production of pulp. But it is also possible to

Figure 5. Expected requirements of industrial wood. (Based on von Monroy as given in Forest Research Institute, 1961 a).

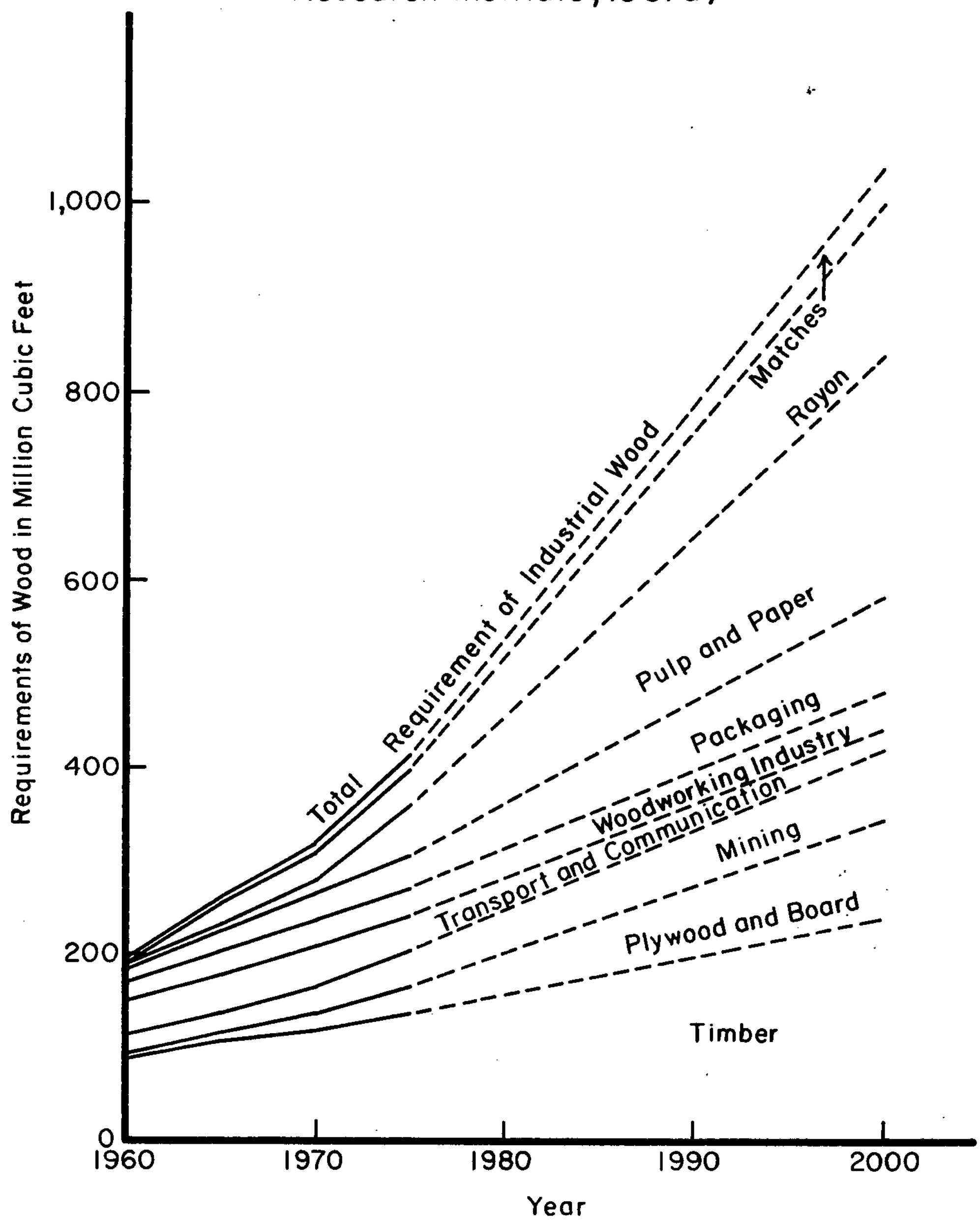
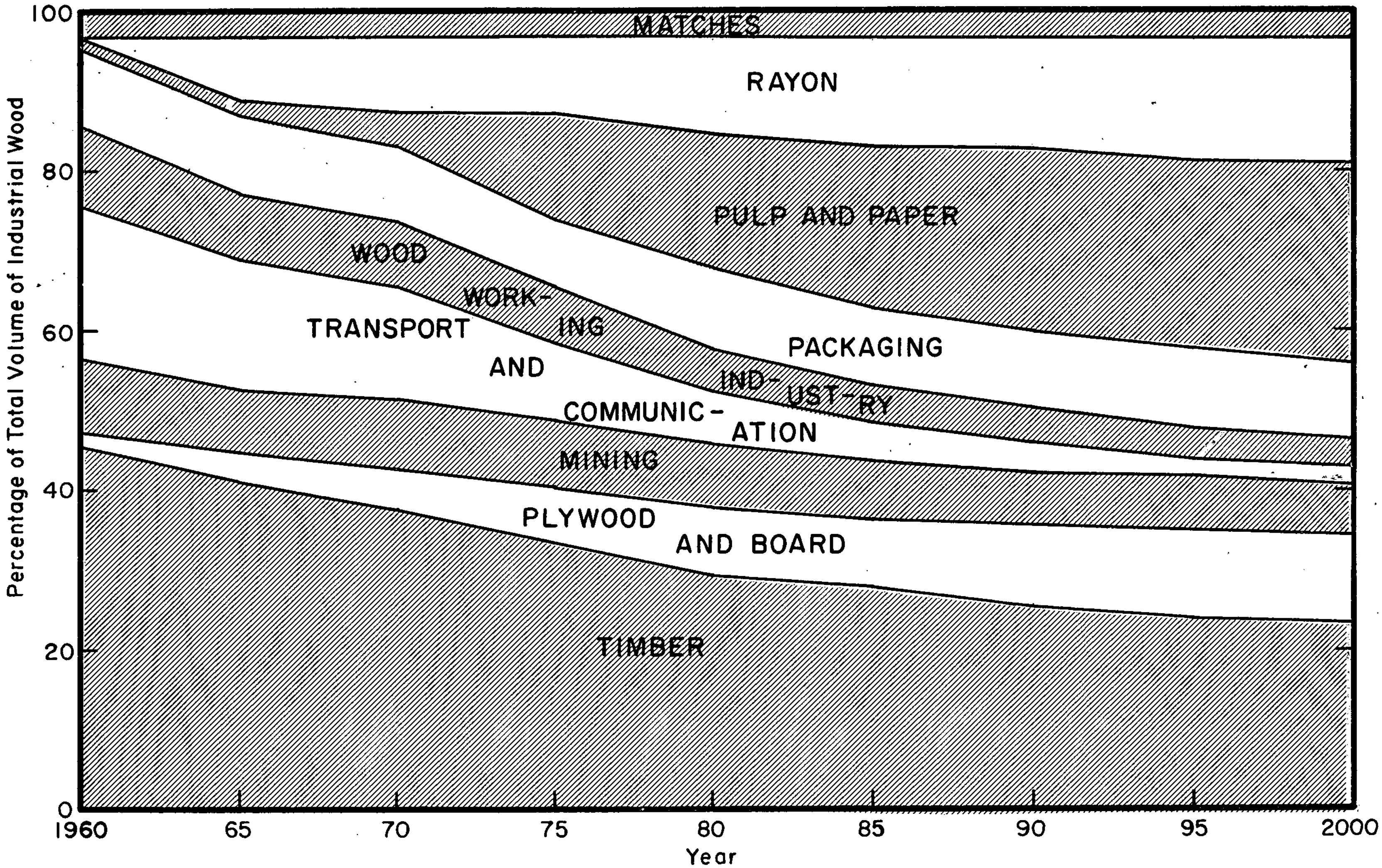


Figure 6· Estimated requirements for various uses of industrial wood in India on percentage basis·



establish specific pulp or paper plants which can be run from a given area out of the 500,000 acres. As shown in 'Pulping of Eucalypts' (Nautiyal 1965a) a newsprint mill of 300 metric tons per day capacity can draw all its requirements of short-fibred pulp from a 30,000 acre plantation of eucalypt. Similarly other types of plants can be established at suitable locations and all or most of the raw material obtained from this area. If necessary it might even be possible to feed a veneer and plywood factory from fast growing poplars or eucalypts. In addition to production of pulpwood or veneer logs the area could also produce substantial quantities of matchwood by planting Semal at wide spacings of 35' x 35' or 50' x 50' in the same plantations. This could meet part of the requirements of the match factory at Bareilly.

Economic, political and strategic reasons for concentrating on pulp and paper industry

A study of Figures 5 and 6 clearly brings out the dominant position of pulp producing species in the management of forests in the future. In the year 2000 about 415 million cubic feet or 8.3 million tons (1 ton = 50 cubic feet) of pulpwood will be required for the rayon and paper industries. This will be about 40 per cent of the total requirement of industrial wood in that year. It is therefore necessary that steps be taken now to ensure that the forests can play their proper part in the future development of the economy. With the lack of paper, the development of any young industry can be seriously held up.

Within the sphere of forest economy it is only the pulp and paper industry (and to a slightly lesser degree plywood industry) which is able to keep in step with the increasing trends in productivity in the manufacturing industries and thus can afford to produce more at lower costs. In almost all other forest industries (mainly in woods, mills and yards) there is the sickness of low productivity and instead of producing more abundantly at lower costs less is produced at higher costs (Duerr 1960). This fact is seen in the steadily increasing prices of sawn timber at a rate faster than the increase in general price index. The increase in prices of paper usually remains in tune with increases in general price index. Therefore if the productivity in other sectors of forest economy does not improve it will become more and more difficult to produce increasing quantities of forest products other than mainly pulp and paper or plywood at reasonable costs. For this reason it appears that the future of forestry depends to a very great extent on the pulp and paper industry.

Rankin (1963) considered that manufacture of sawn timber (lumber) provided the greatest return on invested capital, but Nicholson (1964) estimated that manufacture of pulp and paper adds four or five times as much to the basic wood value. Smith (1965) has therefore reasoned that in British Columbia higher priority should be given to the manufacture of pulp and paper. A similar reasoning can be assumed for India also.

For these economic reasons it is considered that only those species should be planted under the scheme for 'Plantation of fast-growing species' which can yield fibrous raw material for the production of pulp.

Committed to the evolution of a 'socialistic pattern of society', everything in India has to be done by keeping in view the vast majority of the poverty stricken and largely ignorant masses. Poverty is a cause of ignorance and also a result (Galbraith 1964). Therefore one of the most important ways of tackling poverty is the spread of education. In the Third Plan (1961-66) the allocation of money for education was $1,200 million, as against $250 million for public housing and $620 million for health, sanitation and water supplies (Ward 1964). The high priority given to education can only bear fruits if enough paper is available to back it up. Without paper education will not spread, and without education the new frontiers of life promised to the Indian people will not arrive. In order that paper, especially writing and printing paper, may be within the reach of the poor man the prices are fixed by the government and are revised from time to time. This action, taken for social reasons, may some times interfere with the expansion of the industry as the price system is not allowed to work. Nevertheless, the importance of the pulp and paper industry for the social and political reasons in India is evident.

An underdeveloped country is in need of almost everything from the developed countries. Yet it has to decide which items to produce at home and which to import. To make itself reasonably self-sufficient in respect of major strategic materials, India must not plan to spend any of its resources in buying pulp and paper. These resources may instead be used for acquiring heavy machinery. It might be more advisable to import paper making machinery into India and increase the indigenous producing capacity than to import paper. Such a step will not only help to make the country self-sufficient in its paper needs, but also provide industrialization in many parts of northern India along the foot-hills of the Himalayas, and thus consolidate the Indian position <u>vis-a-vis</u> that of the

Chinese by diversifying and strengthening economy in these border areas. To make all this happen more pulpwood must first be produced from the forests in the Indian States bordering China's Tibet.

<u>Factors that influence consumption of paper</u>

There are two very important factors that influence the total, regional and per capita consumption of paper in an economy:

(i) Total number of literate persons or percentage of population that is literate

(ii) The per capita income of the people

The total consumption will increase even if the literacy percentage does not increase but remains constant in an increasing population. The per capita consumption might, however, not increase in such a case. If, however, the literacy percentage also increases progressively the per capita consumption of paper will increase as a greater section of the population uses more paper for writing and reading. An educated person is almost invariably interested in knowing what is happening around him and so causes increase in the consumption of newsprint also. Because of coming in contact with outsiders he may come to know of various other uses of paper and paper products and thus continues to push up the level of consumption. On reaching higher levels of education he increases his consumption of writing and printing paper to a very considerable extent.

Due to these reasons those regions of India willl show highest consumption of paper where literacy is highest.

The old pattern of reading, writing and other scholarly activities being the exclusive domains of certain castes in India has long since disappeared. The maximum consumption of paper now probably takes place in the ever-increasing middle class. The use of paper by the peasantry is still low due to their low incomes but the number of literate children of the peasant is increasing rapidly. It is not unusual to see a peasant, especially one from an area where agricultural productivity is very low, sending all his savings to his son whom he is determined to give college education.

Population and literacy

India is the second largest nation in the world on the basis of its population which was estimated at 439.1 million in 1961 (Publications Division 1964). This fact might lead one to expect that the total consumption of forest products, particularly pulp and paper products, would be high in this country. However, due to the low percentage of literacy and the very low per capita income the consumption actually is far lower than in most other parts of the world.

The growth of population and literacy in India and U. P. and the future trends are given in Figures 7 and 8.

If growth of population in India is assumed to remain the same as during 1951-61 then the population at the end of the 20th century will be about 740 million. Because the government of India is expected to take some significant measures for introducing family planning on a large scale it is possible that the rate of population growth may slow down. On the basis of a lower rate of growth an estimate of 670 million has been made in this thesis.

The figures for literacy show that if the same growth rate as existed between 1951-61 is assumed for the next 35 years then 285 million Indians, or 42.6% of the population, will be classed as 'literate'. In

Figure 7· Growth of population and literacy in India (Based on Publications Division, 1964 and Times of India, 1942)·

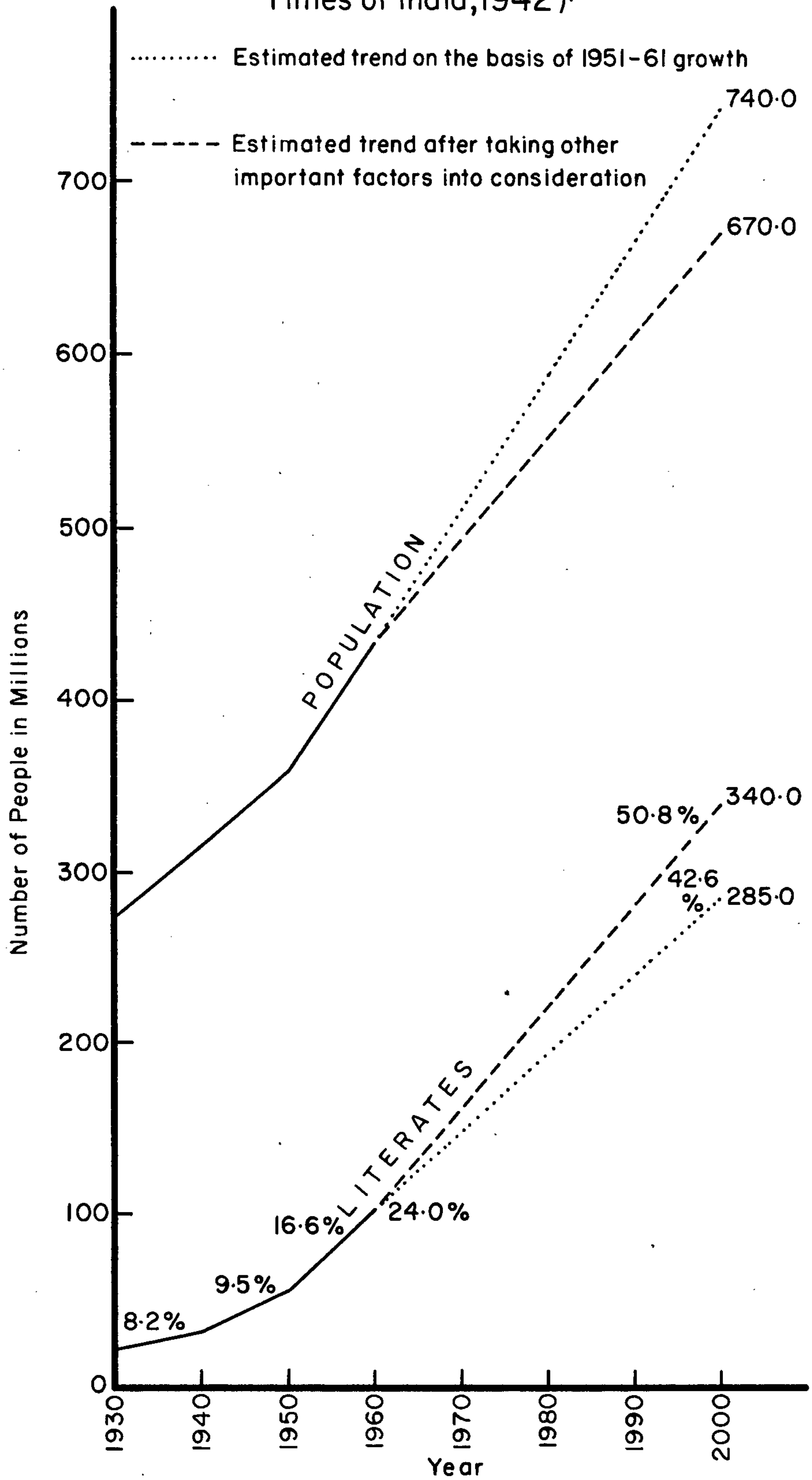
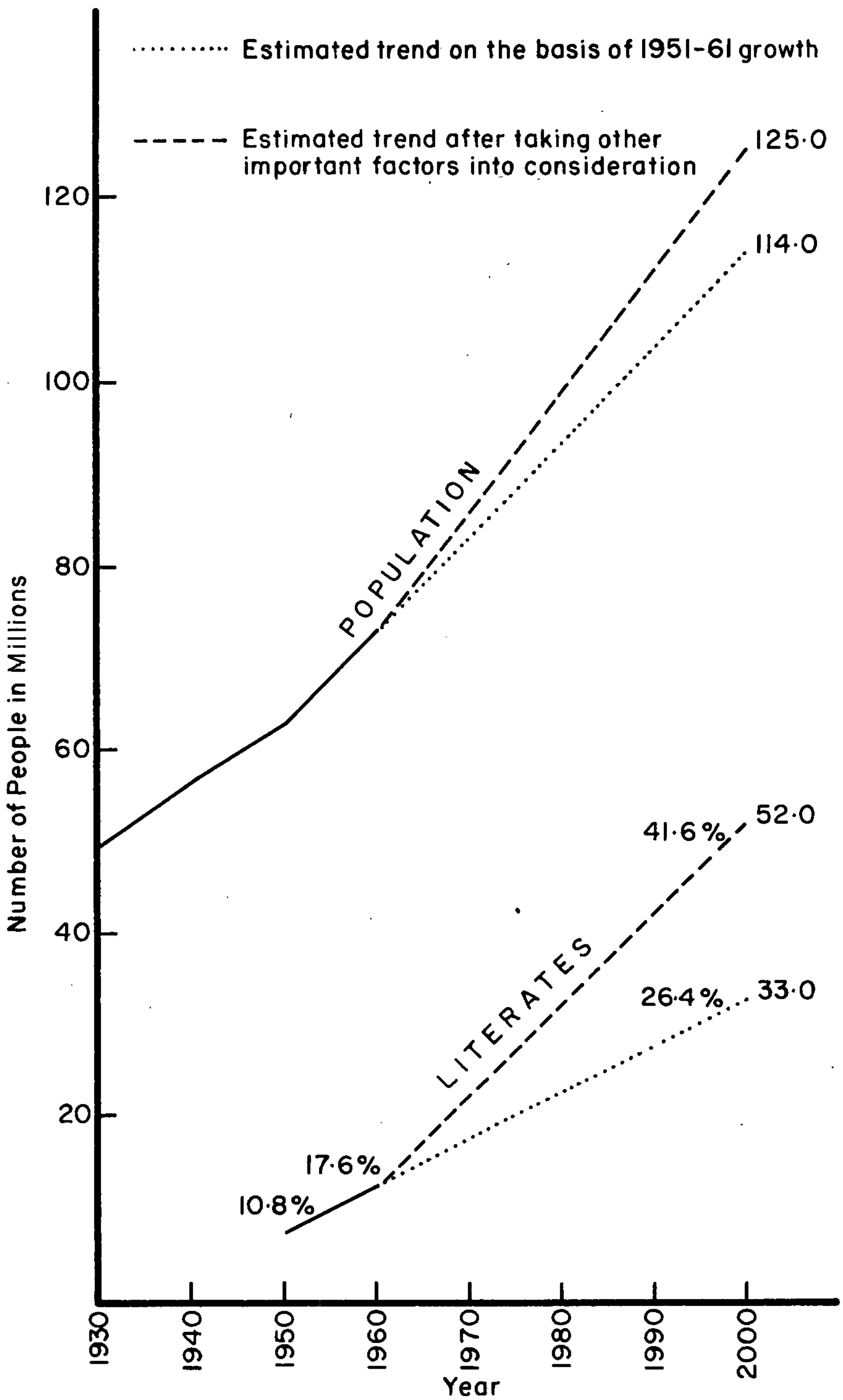


Figure 8· Growth of population and literacy in Uttar Pradesh (Based on Publications Division, 1964)·



view of the fact that education is one of the most important fields emphasised in the Five-Year Plans and also because even the most ignorant peasant in India is now very keen to send his children to school, it is estimated that about 340 million persons (50.8% of the population) will be literate at the end of this century.

The projections for the future in respect of the State of Uttar Pradesh are slightly different in reasoning. This is due to the fact that U. P. is comparatively more backward than India as a whole. The literacy figure for U. P. was only 17.6% in 1961 whereas the corresponding figure for India as a whole was 24.0%. The peasant in U. P. is probably more tradition bound than in the more advanced states. The family planning measures are therefore expected to have less effect in U. P. than in India as a whole. It is on the basis of this reasoning that the rate of population growth after 1961 has been assumed to be higher than that during 1951-61 and a population of 125 million has been estimated at the end of the 20th century. Because of the present backwardness of U. P. and the knowledge of this fact by the National Government, it is also expected that education will receive high priority in future Five-Year Plans and so 52 million persons or 41.6% of the population in U. P. may be literate in the year 2000.

<u>Gross national product and per capita income</u>

The growth of the gross national product (GNP) of India from 1948-49 to 1962-63 is given in Figure 9 in terms of 1948-49 constant rupees. The future values in various years up to the end of the 20th century can be shown by projecting the trend of 1960-63 and estimating the GNP as 285 billion rupees. This is, however, highly improbable. As

Figure 9. Growth of the gross national product in India in 1948-49 constant rupees. (Based on Publications Division 1962, 1963 and 1964.)

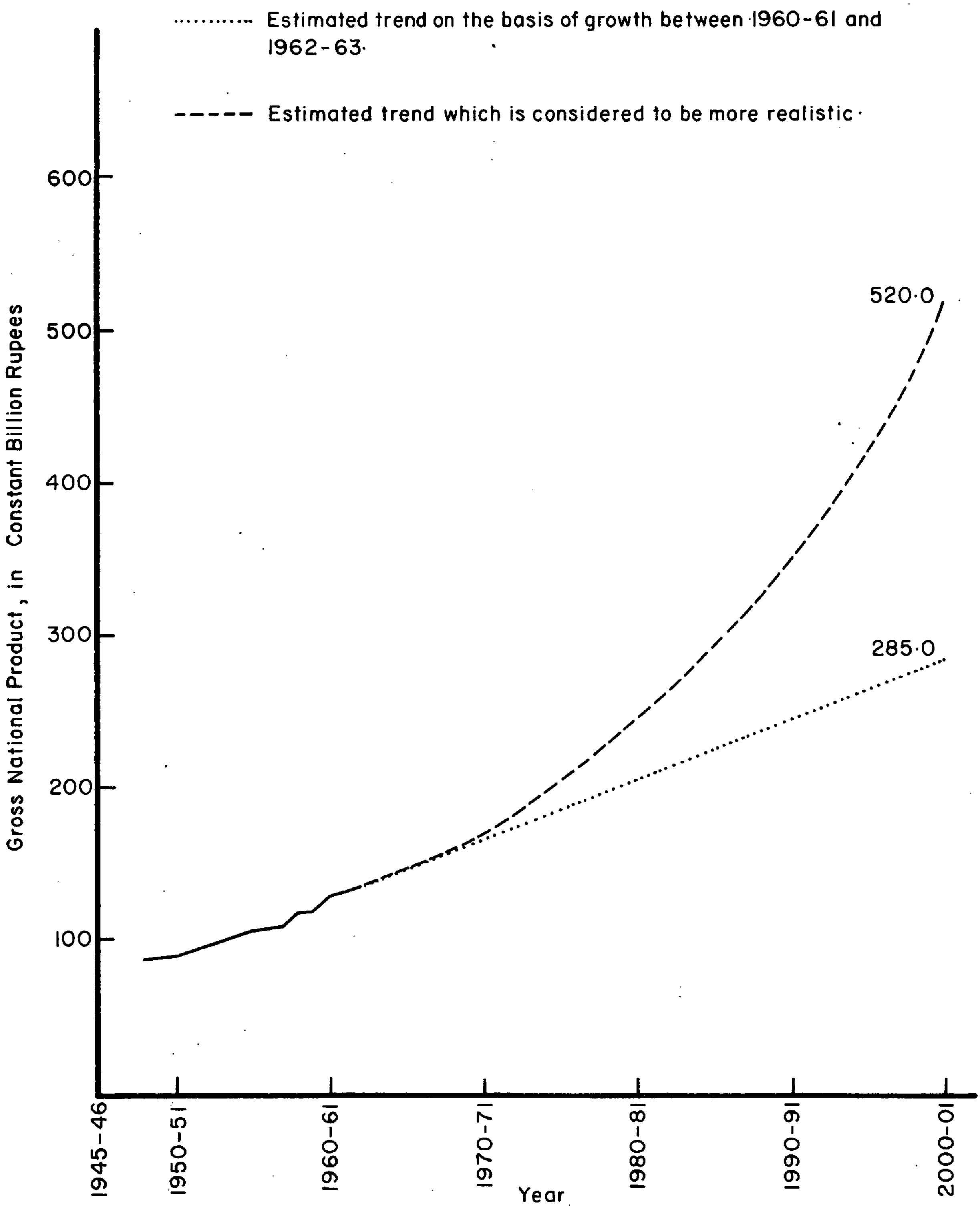
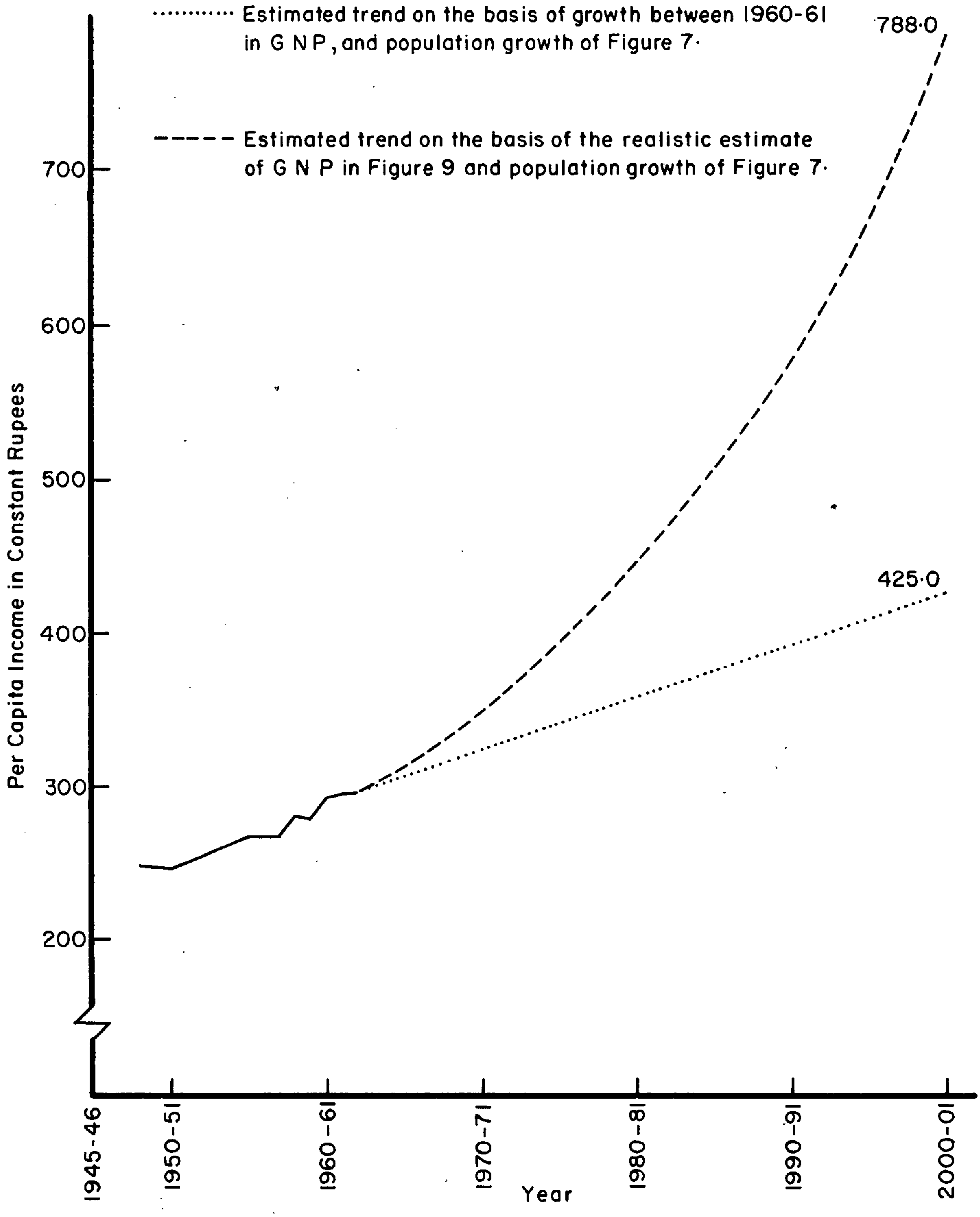


Figure 10· Growth of per capita income in India in constant 1948-49 rupees (Based on Publications Division, 1962, 1963 and 1964)·



the different segments of Indian economy are strengthened, the growth of GNP will increase at an accelerating rate. It is estimated that in the year 2000-01 GNP will be 520 billion rupees in terms of the 1948-49 value of the rupee.

Due to the high rate of growth of population in India, increases in GNP between 1948-49 and 1962-63 failed to show up in any substantial way in the per capita income as is seen from Figure 10.

On the assumption that the GNP will grow at a rate so that in the year 2000-01 it will be only 285 billion rupees, the projected growth of the per capita income on the basis of the estimated population growth of Figure 7, is given in Figure 10. With these assumptions the estimated per capita income at the end of the century is Rs 425. With the more optimistic estimate of Figure 9 for the growth of GNP the per capita income will be Rs 788 in the year 2000-01 as shown in Figure 10.

Apparent consumption

The apparent consumption of paper and paper board from 1957 to 1963 has been estimated by adding imports to indigenous production and subtracting exports from it (Indian Pulp and Paper 1960, 1961, 1963, 1964). Consumption, production, imports and exports during the years are shown in Figures 11, 12, 13 and 14.

The analyses for this thesis suggest the trends for future shown in these figures. It will be noticed that the projected consumption in the year 2000 is 2.0 million metric tons if it is assumed that the growth of consumption will take place at the same rate as the average growth rate between 1957 and 1963. This means an increase in per capita consumption from 1.1 Kg in 1963 to 3.0 Kg in 2000. Due to the accelerating rate of

Figure 11· Consumption of paper and paperboard in India (Based on Indian Pulp and Paper, 1960, 1961, 1963 and 1964)·

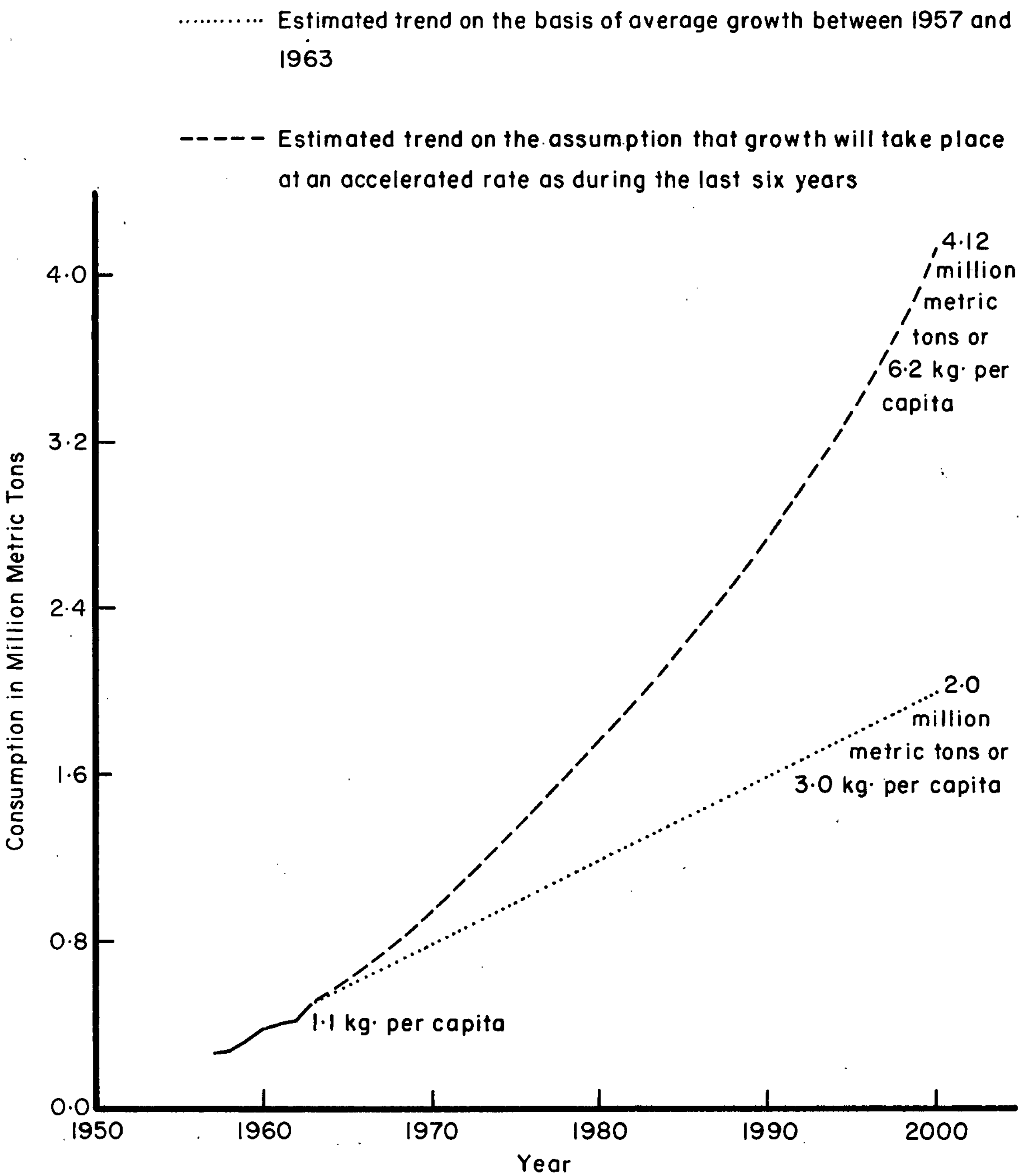
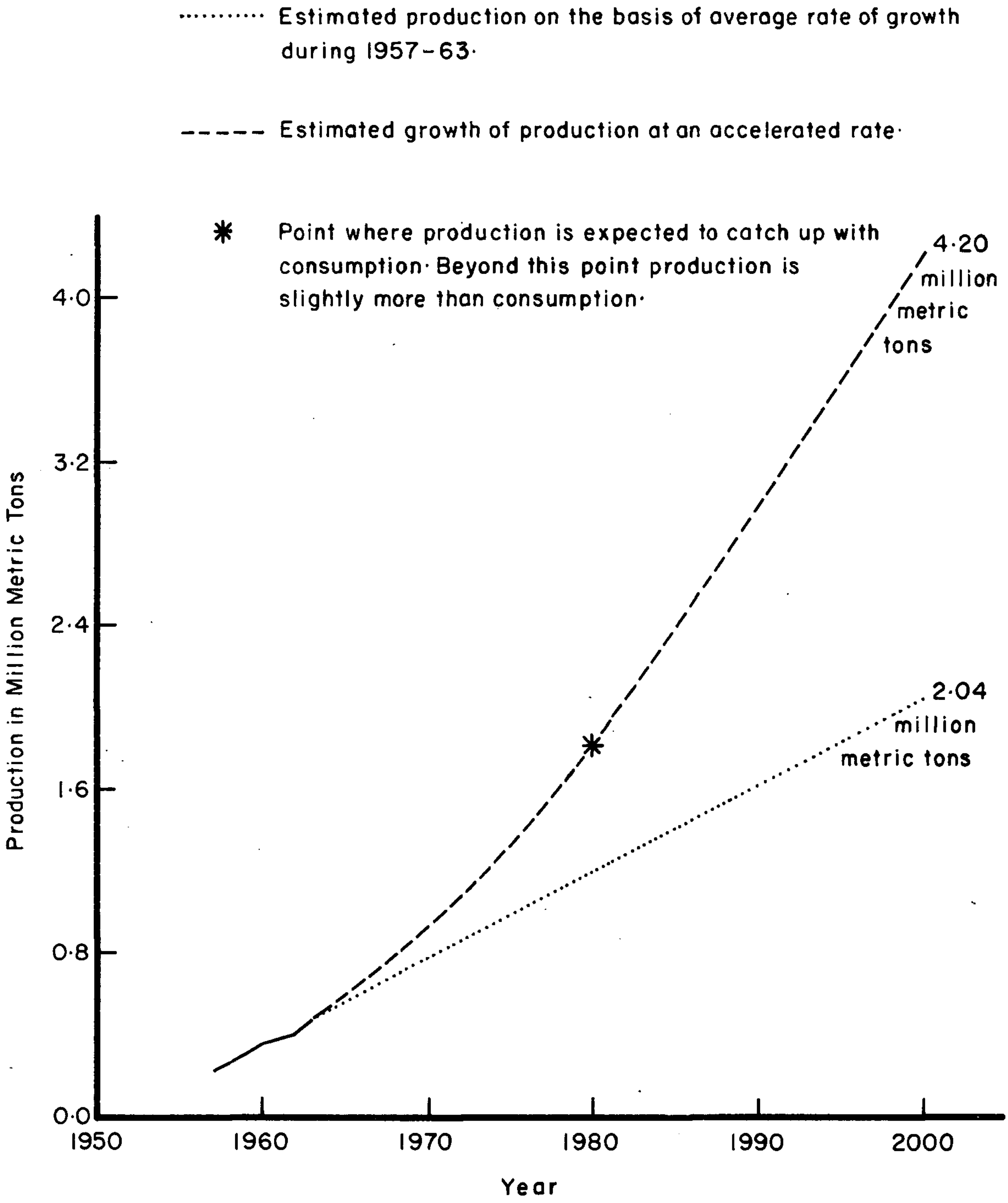


Figure 12· Production of paper and paperboard in India (Based on Indian Pulp and Paper, 1960, 1961, 1963 and 1964)·



increase in literacy it is assumed that the consumption figure at the turn of the century will be 4.12 million metric tons or 6.2 Kg per capita. The projections drawn by Podder and referred on page 110 of Forest Research Institute (1961a) are more optimistic than those given in Figure 11. It appears to the writer that the achievement of a figure of 7 Kg per capita consumption in 1980-81 as referred in the Indian Pulp and Paper (1964) is almost impossible. When the literacy percentage increases from 24.0 per cent to 50.8 per cent between 1963 and 2000 and the per capita income rises from Rs 295 to Rs 788 the per capita consumption of paper can not be expected to go far above $\frac{50.8}{24.0} \times \frac{788}{295}$ or 5.5 times the 1963 per capita consumption of 1.1 Kg. This puts the estimate per capita consumption in the year 2000 as $5.5 \times 1.1 = 6.05$ Kg which is not very different from the estimate of Figure 11.

A comparison of Figures 11 and 12 shows that production in India is a little short of the consumption at present. The projected production and consumption figures show that around 1980 the production will be almost equal to consumption and thereafter more will be produced than can be consumed locally in India.

It is estimated that imports of paper and paper board will rise very gradually during the next 35 years (Figure 13). The papers imported will mostly be of special kinds such as high quality document paper, parchment paper or papers with very high burst factor.

The prospects of exports to Asian and African countries during the next 5 years at least, are poor. The projected rise in exports thereafter (Figure 14) may or may not take place. The high cost of production in India and the comparatively poorer quality of paper and paper

Figure 13. Imports of paper and paperboard into India (Based on Indian Pulp and Paper 1960, 1961, 1963 and 1964).

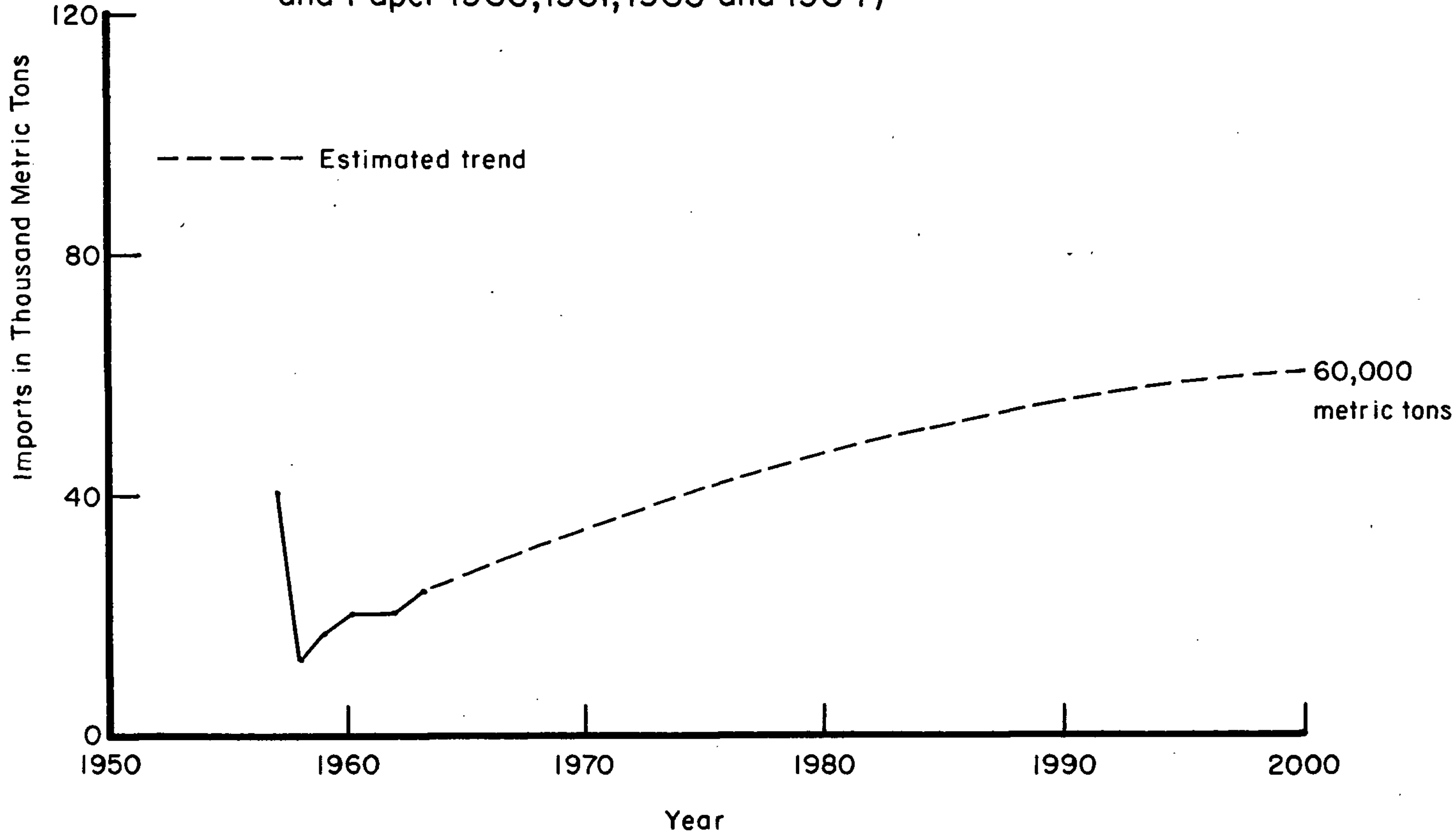
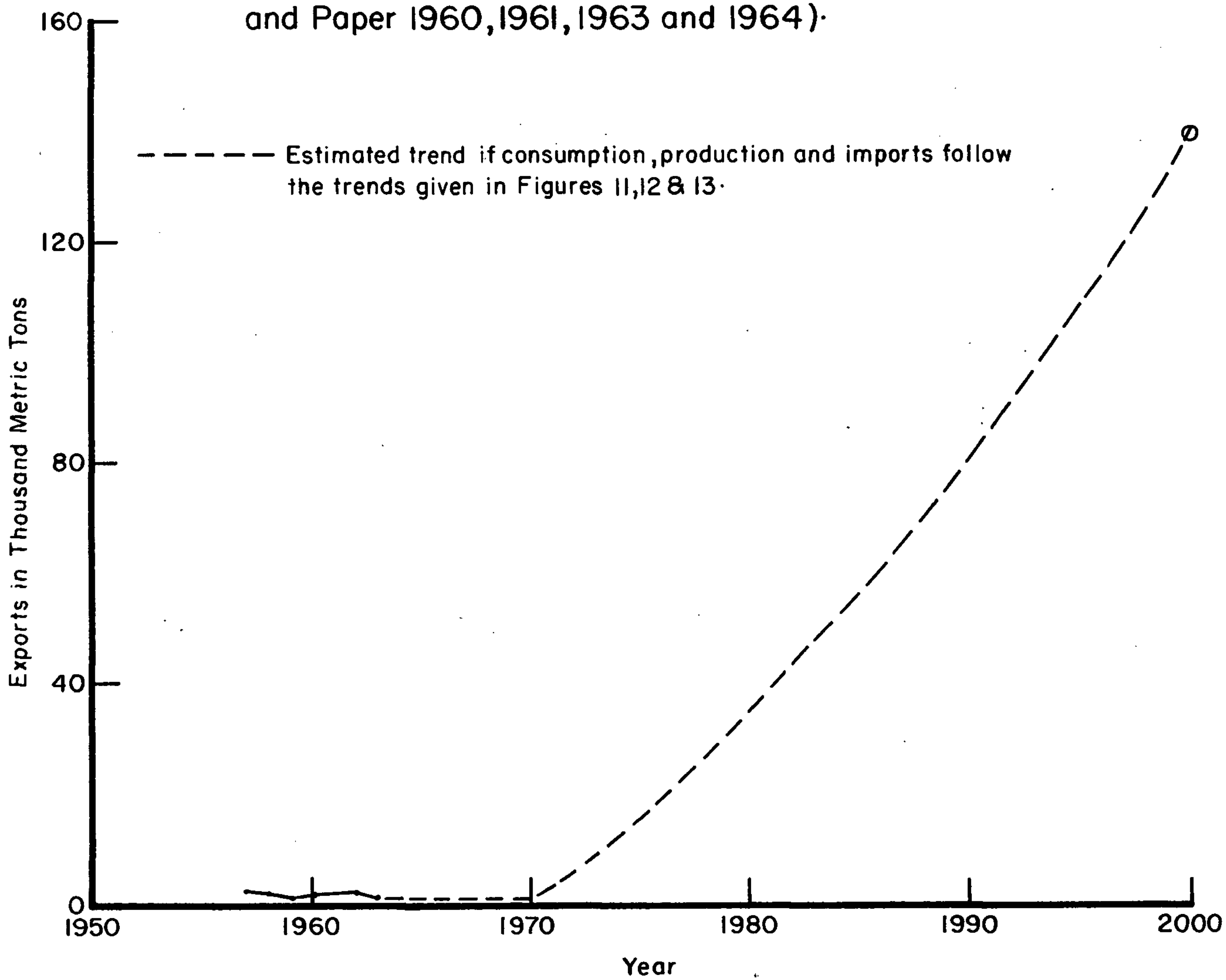


Figure 14. Exports of paper and paperboard from India (Based on Indian Pulp and Paper 1960, 1961, 1963 and 1964).



products will be the main reason for the failure of increase in exports. If the exports fail to rise it may be assumed that the imports shown in Figure 13 may also not materialise. It is most likely that imports will increase only if exports increase, because of strict government control of imports.

<u>The pattern of consumption</u>

The large variety of papers and boards in use may be grouped into two categories (Bhargava 1964) <u>viz</u>:

(a) Cultural papers, which include writing and printing papers of all kinds and newsprint,

and (b) Industrial papers, which include wrapping and packing papers, other special papers, and all kinds of boards.

In technically and industrially advanced countries, demand for industrial papers is, as a rule, higher than that for cultural papers and the trend is towards continued increase of the former. In India, due principally to the low level of literacy and industrial production, percentage of cultural papers has been higher than that of industrial papers as seen in Table 3.

Roughly speaking the pattern of consumption at present is as follows:

Cultural papers - 60% Industrial papers - 40%

The data in Table 3 might suggest that the ratio of cultural to industrial papers has been increasing slightly between 1957 and 1963. But data for such a short period cannot be treated as a reliable guide. It is likely that in the long run as India becomes more industrialized the proportion will fall. Bhargava's (1964) estimate of the change has been graphically shown in Figure 15. Then the pattern of consumption in the year 2000 might be: Cultural papers - 39% Industrial papers - 61%

Table 3. Pattern of paper and board consumption in India from 1957 to 1963.

(Based on Indian Pulp and Paper 1960, 1961, 1963 and 1964)

Year	Consumption of paper and board										
	Cultural papers				Industrial papers						
	Writing & printing		Kraft wrapping		Specialties		Boards		Total		Grand Total Metric Tons
	In Metric Tons	As % of grand total	In Metric Tons	As % of grand total	In Metric Tons	As % of grand total	In Metric Tons	As % of grand total	In Metric Tons	As % of grand total	
1957	141,013	56.97	52,049	21.03	12,778	5.17	41,667	16.83	106,494	43.3	247,507
1958	157,841	59.17	44,625	16.73	10,026	3.76	54,262	20.34	108,913	40.83	266,754
1959	181,310	58.85	61,301	19.90	8,295	2.68	57,206	18.57	126,802	41.15	308,112
1960	218,891	60.17	73,742	20.27	13,146	3.61	58,037	15.95	144,925	39.83	363,816
1962	240,046	59.19	86,326	21.28	7,670	1.89	71,526	17.64	165,522	40.81	405,568
1963	308,320	63.19	83,620	17.14	15,107	3.10	80,876	16.57	179,603	36.81	487,923
Average		59.59		19.39		3.37		17.65		40.41	

Figure 15. Change in the pattern of paper and board consumption in India (Based on Bhargava, 1964).

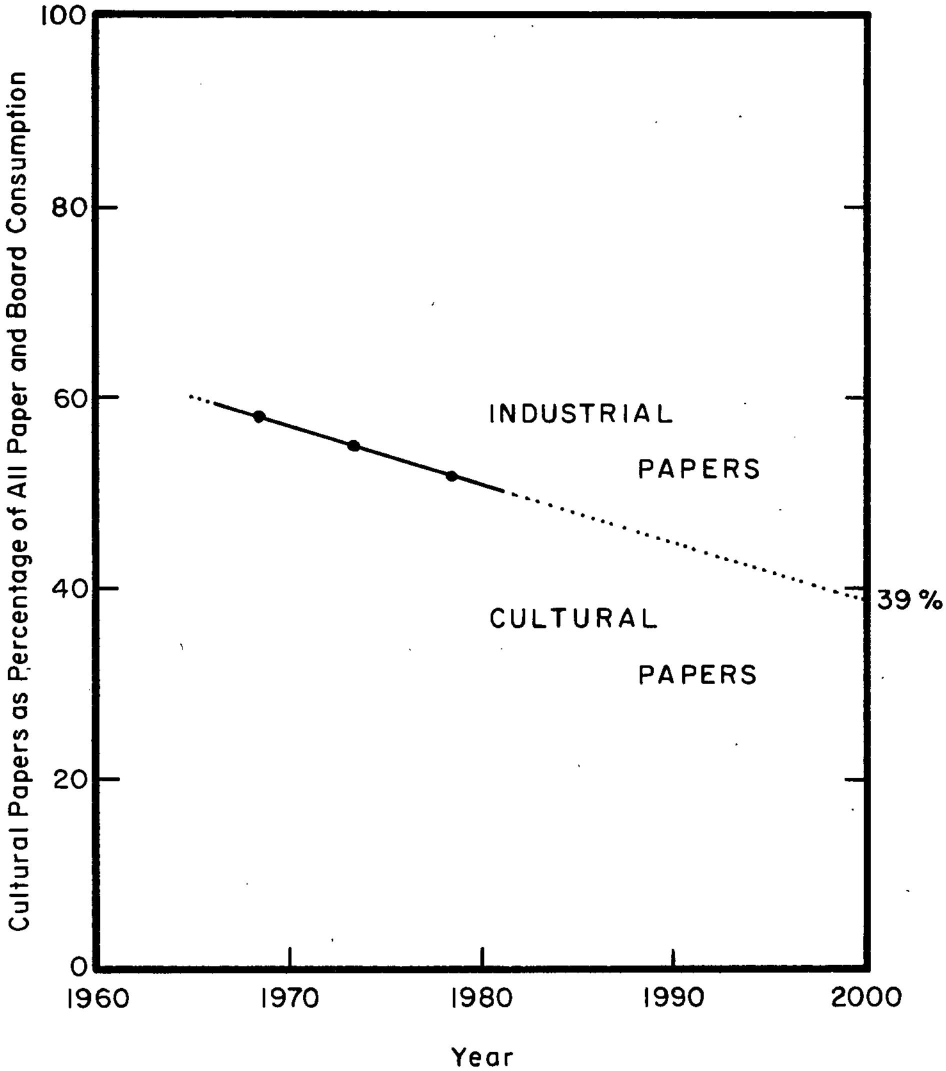
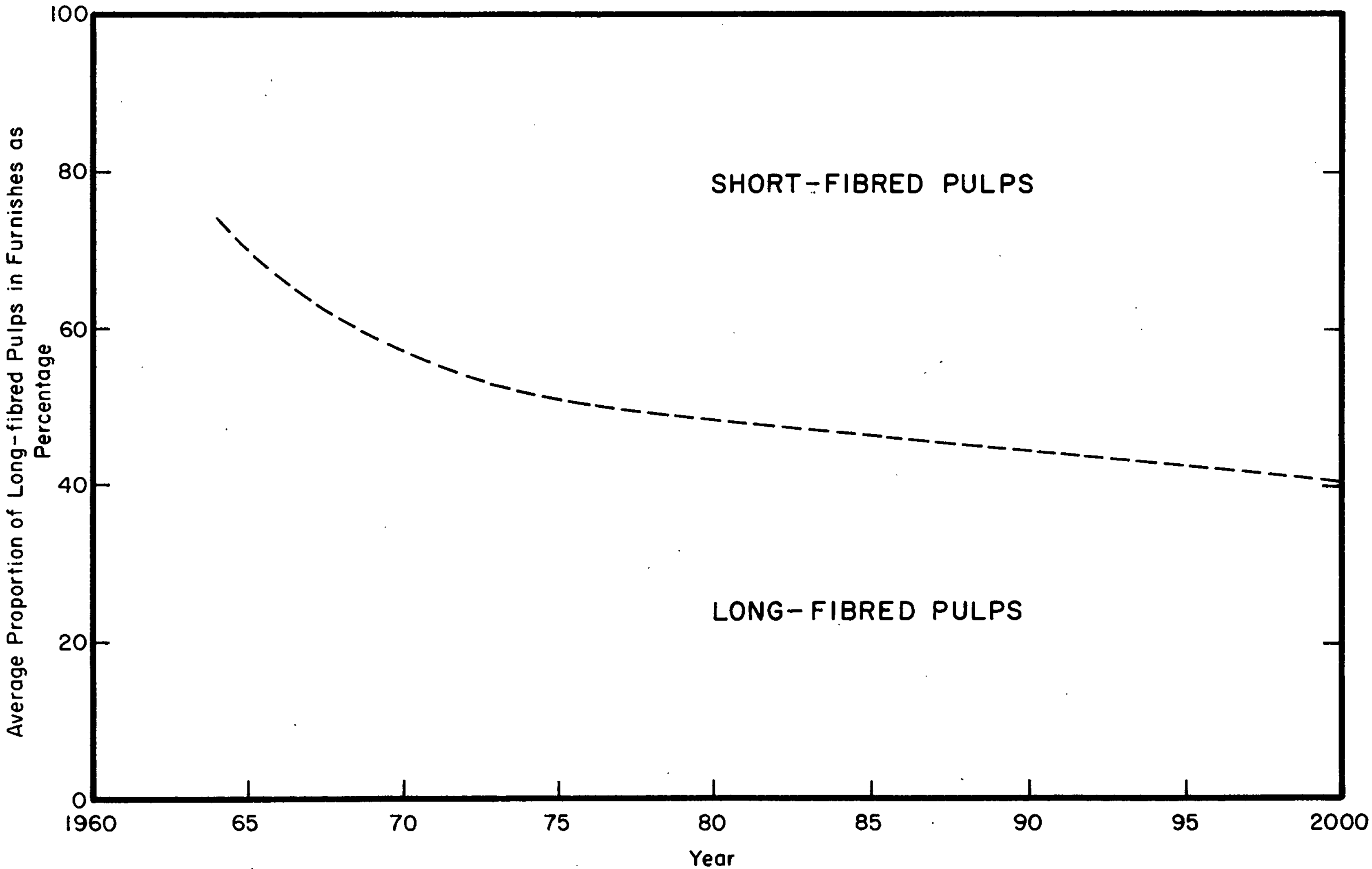


Figure 16· Changes in the proportion of long-fibred pulps in Indian paper and paperboard industry (Based on Bhargava, 1964)·



CHAPTER III

POSSIBILITY OF INDIA BECOMING SELF-SUFFICIENT IN PULP AND PAPER PRODUCTION

The determining factors

The question whether a country can become self-sufficient in respect of a product or group of products must be asked in relation to time. It may be possible for a society to be self-sufficient for a few years when its demands are limited, but later it may not be possible. Also due to lack of knowledge, development of resources and technical skill, a country may have to depend on outside sources of supply for some time but may be able to become self-sufficient and even a supplier of other countries in due course of time. For the purposes of this thesis an attempt will be made to answer the question for India, for the period 1965-2000.

The factors that determine whether self-sufficiency is possible or not, are:

(1) Availability of technical skill

(2) Availability of capital

(3) Availability of labour

(4) Availability of managerial talent

and (5) Availability of raw materials.

At present there is a shortage in India of all the factors except labour. Even in labour there is a shortage of the trained or skilled labour. Thus, unless the educational programmes are carried out to a sufficient extend India cannot be self-sufficient. There is, however, a reasonable chance that the standards and levels of technical and other education will continue to improve and in the next 15 years sufficient numbers of technicians, engineers, skilled labourers and managers will be available for running the pulp and paper industry.

Though the growth of industry and technical knowledge in other sectors has been encouraging it will not be realistic to assume that by 1980 India can produce enough capital to expand its pulp and paper industry. It is possible that in the last decade of the 20th century the country may be self-sufficient in its need for capital.

The remaining factor to be considered is 'raw materials', and this will be dealt with in more detail.

<u>Fibrous raw materials in India</u>

Although theoretically any material capable of yielding cellulose could probably be used for making pulp, the principal factors which determine the commercial utility of a given plant for pulp and paper making are (Nautiyal 1965a):

(i) Suitability of fibres for conversion into pulp

(ii) Fibre yield per unit volume of raw material

(iii) Quality of the resulting pulp for paper making purposes

(iv) Dependability of supply

(v) Cost of collection, transportation and conversion

and (vi) Degree of deterioration in storage

The morphological and chemical properties of the fibres have a considerable effect on the properties of paper that is produced from them (FAO 1953).

Fibre length influences tear resistance. In general, longer fibre gives higher tear. However, it is less the absolute value of the fibre length than the ratio of fibre length to fibre diameter that is of importance. The higher this ratio is the greater the tear resistance becomes.

Fibre length has practically no influence on such properties as tensile strength and burst, provided the fibre length is above 0.8 mm. Folding strength also seems to be little affected by fibre length. The sheet formation properties are better for short fibre pulps than for long fibre pulps.

The ratio of cavity diameter to fibre diameter determines the flexibility of the fibre. Fibres with walls thin in relation to the diameter collapse on drying to form flat flexible ribbons which give a denser sheet than the stiffer thick wall fibres. The denser the paper, the higher, in general, are such strength properties as burst and tensile strength and the lower is the opacity. For coniferous woods, papers obtained from thick wall fibres have higher tear resistance than those obtained from thin wall fibres. For broad leaved woods, however, this statement does not seem to have the same general value.

The flexibility of fibres also influences the folding resistance of the paper. The more flexible the fibre the higher, generally, is the folding strength. However, the internal structure of the fibre wall interferes at least to the same degree.

Among the chemical properties of the fibres, the hemicellulose content is the most important from the paper making point of view. Such information is, however, not often available and a rough estimation has to be made by assuming that all but cellulose, lignin, extractives and ash is hemicellulose. For tropical broad leaved woods and agricultural residues, the hemicellulose content may be the same as the pentosan content. In coniferous wood pulps, the hemicellulose faction largely consists of mannan and xylan.

In general, fibres with high hemicellulose content swell more rapidly on beating than those of low hemicellulose content. The drop in freeness of easily hydrated pulps is usually so rapid that little fibrillation takes place during beating.

The higher the hemicellulose content the denser the sheet, and the higher the burst, tensile and folding strength factors and lower the opacity.

The hemicellulose content in pulp depends on the pulping process also as some processes dissolve more of it than others (FAO 1953).

Fibres which have an average length of about 1.0 mm are called 'short' and those having an average length of about 3.0 mm are called 'long'. The long fibred pulp has to be addedin varying proportions to short fibred pulps for making different kinds of papers with different tear and other strength factors.

The fibrous raw materials used in India at present in paper and paper board mills are (Bhargava 1964):

(i) Bamboo

(ii) Sabai grass (Eulaliopsis binata)

(iii) Twisted Chir pine (Pinus roxburghii)

(iv) Rags and hemp

(v) Other coniferous wood (Abies pindrow and Picea smithiana)

(vi) Hardwoods (A few in small quantities)

(vii) Sugar cane bagasse

(viii) Jute sticks

About 72 per cent of the present production capacity of Indian mills is based on bamboo as the staple raw material (Bhargava 1964). It has also been estimated that in 1965 the production capacity of mills based on bamboo will be about 550,000 metric tons per annum and annual requirements of bamboo pulp as 350,000 metric tons. This estimate puts the annual requirement of bamboo as roughly 0.9 million metric tons. In addition about 200,000 metric tons of bamboo is required for production of rayon grade pulp. Thus the total requirement in 1965 will be roughly 1.1 million metric tons. Though information about forest areas under bamboo growing stock and potential yields is limited, Bhargava (1964) has given the estimated annual supplies in different states of India based on various references. He pointed out that the known total annual supplies of bamboo in India amount to about 2.45 million metric tons, of which the contribution by Uttar Pradesh in 1959 was only about 6,500 metric tons. As already mentioned 1.1 million metric tons, or 45%, of the supplies are already being used. Sizeable quantities for the establishment of new economic pulp or paper mill units are at present available only in Assam, Kerala, Madhya Pradesh, Mysore and Orissa States.

Information about the actual consumption of each of the other seven raw materials in the mills is not to hand. But on a rough calculation it has been estimated that about 100,000 metric tons of pulps are produced per annum at present from these raw materials in both the bamboo and non-bamboo mills (Bhargava 1964). As far as information is available, additional supplies of Sabai grass, twisted Chir, and rags and hemp etc. for future increased production of papers and boards are not likely to be available.

The coniferous woods other than chir pine occur in the rugged mountainous Himalayan region in the states of Kashmir, Himachal Pradesh, Punjab and Uttar Pradesh. The species that can be considered for pulping are the Himalayan spruce (Picea smithiana) and silver fir (Abies pindrow). They mostly occur at elevations higher than 8,000 feet above sea level in localities where communications are poor. In addition a sizeable part of the crop is overmature so that the trees are too big to be easily handled, on steep slopes where they grow, and also are often heavily attacked by fungi due to their old age. The regeneration of these forests, especially of silver fir, is also a problem and the establishment of the second growth may pose serious difficulties if the old growth is harvested without devising economic and reasonably successful means of obtaining regeneration.

The data regarding the availability of these species for pulping are meagre and unreliable. It is possible that up to 0.4 million metric tons may be available annually in about 5 or 10 years time from now (Bhargava 1964).

India abounds in hardwoods, about 97% of the forest area being covered by them. About 60% of the area is presently exploitable and from this nearly 530 million cubic feet of industrial and fuel woods are extracted per annum. The quantity, however, is a minor fraction of the total available supplies. Plentiful supplies of pulpwoods can, therefore, be available from the forests.

These supplies, however, may not prove to be technically suitable raw materials for pulp and paper production, principally for the following reasons:

(i) The supplies would be an extremely heterogeneous mixture of a large number of species, differing fairly widely in physical properties, such as density, colour, etc. and also in their chemical characteristics.

(ii) The species are very widely scattered over long distances and the cost of collection and transport of selected species may prove to be quite uneconomical.

(iii) No regular or systematic surveys have been carried out so far and practically no information exists about the different species with regard to their sustained annual supplies and other relevant matters.

Hence the major part of Indian hardwoods cannot be relied on unless and until the Indian pulp and paper industry overcomes these technological and economic hurdles. The vast hardwood resources may, at a future date, provide the suitable raw material and vigorous research should be conducted in the matter.

The information available on the supplies of sugar cane bagasse and jute sticks is fairly definite.

About 4.5 million metric tons of dry bagasse is currently produced per annum in sugar factories. Most of this quantity is consumed in factories, as fuel for steam and power generation. It can therefore be used for pulping only if an alternative fuel is made available to the sugar factories. The alternative fuels are coal and fuel oil.

The following difficulties arise in the switch-over from bagasse fuel to other fuels in sugar factories and the procurement of bagasse by pulp and paper mills:

(i) Reluctance of sugar factories to use coal or fuel oil, particularly because of uncertaintly with regard to regular, adequate and assured supplies of the alternative fuel due to bottlenecks in railway transport. Building up stocks of fuel in off-season would involve locking up of large capital and provision of large storage space.

(ii) Lack of adequate space in most factories for storage of bagasse bales, coal or oil.

(iii) Fairly large initial capital expenditure necessary for installing, depithing and boiling equipment and also multi-fuel boilers in place of the existing bagasse burning boilers.

(iv) Present high prices of fuel oil and rising prices of coal, coupled with additional expenditure involved, in depithing, boiling and transporting to pulp or paper mill site and in its storage in mill yards, result in prices of bagasse, which are not attractive or competitive.

Therefore, in view of the fact that coal was (and is) a good foreign exchange earner, Bhargava (1964) thought that it would be in national interests to avoid its use as substitute fuel for bagasse. He also argued that this would also serve to release railway transport, needed for haulage of coal and bagasse, for other equally good or better purposes. He suggested that some bagasse could be used for manufacture of pulp and paper without its replacement by coal or fuel oil in sugar factories if the steam economy in the latter could be brought up to optimum. This being at a low level, he estimated that about 15-20% of bagasse produced in each factory would be available as surplus after fully meeting all the requirements for steam and power. To utilize the 'surplus' bagasse the sugar factories would necessarily install depithing and baling equipment and arrange for transport of bales to pulp mill sites.

Bhargava (1964), however, suspected that the price of bagasse due to these expenditures and those to effect heat economy may rise above a level that is uncompetitive for paper and board manufacture in view of the fact that the price of paper is fixed by the government. He however considered that it would still be competitive for production of dissolving pulp, and estimated that about 0.6 million metric tons of bagasse may be available annually for the purpose within the next 5 years.

The method suggested for getting this supply by effecting heat economy in the sugar factories is interesting but it is doubtful if these factories can be easily persuaded into achieving the economy. Achieving the best physical efficiency may not necessarily coincide with economic efficiency for the sugar producer and so the suggestion made may not materialise at all. Even if it does materialise, the costs may or may not be competitive even for dissolving pulp, and therefore only little reliance on bagasse as a raw material for pulp on a large scale is possible in the next few years. There is, however, a reasonable certainty that better means of using bagasse in India will be found during the next 15 or 20 years. Already some mills in South India are planning expansion of their capacity based on bagasse.

It is estimated that more than 4 million metric tons of jute sticks are produced per annum in Assam, Bengal, Bihar, Orissa and Uttar

Pradesh and a good part of it can be made available for paper and paper board production for which its use has recently been established (Bhargava 1964). Cultivation of jute being concentrated in a few localities, collection of the material is expected to be easier than that of bagasse. However it is very bulky and so cost of its transportation would be high. Two existing paper mills in West Bengal are maturing plans for its use for their expansion programmes. Its use for dissolving pulp production also is under active investigation. Assuming that only about 50% of total supplies can be collected for pulp and paper production, Bhargava (1964) has estimated that about 2 million metric tons of raw material per annum should be available for the industry. The present position with regard to the annual availability of fibrous raw materials for the pulp and paper industry has therefore been summarized by him as follows:

(i) Long fibred raw materials		
(a) Bamboos		2.45 million metric tons
(b) Coniferous woods		0.40 " " "
(c) Rags, hemp etc.		0.05 " " "
	Total	2.90 " " "
(ii) Short fibred raw materials		
(a) Grasses		0.16 million metric tons
(b) Bagasse "surplus"		0.60 " " "
(c) Jute sticks		2.00 " " "
	Total	2.76 " " "

Requirements of raw materials

For achieving the projected production figures given in Figure 12, an estimate of raw material requirements up to the year 2000 must be made.

If enough raw material for this estimate can be produced then it can be said that India can be self-sufficient in its paper and paper board requirements from 1980 to 2000. As production is not expected to catch up with demand till 1980 there can be no self-sufficiency till then even if enough raw material is available in the country. The position after the year 2000 is not the subject of this thesis, but some general idea can be had about it from the discussions in this chapter.

As mentioned earlier 72% of the present paper and board production is based on bamboo and the overall percentage ratio of long-fibred to short-fibred pulp in India is 74 to 26. This percentage is very different from other countries. In France the overall average of long-fibred chemical pulps used by the whole industry was only 33% in 1957 and was expected to be reduced to 28% by 1965. In Japan, estimates for the use of long-fibred chemical pulps by the whole industry are 28% in 1965 and 24% in 1975. In the U. S. A., where qualities of industrial papers and boards are comparatively much superior to those in other countries, the percentage of long-fibred pulps was 43.9% in 1954 and since then is has been reduced further (Bhargava 1964).

In view of the fact that supplies of long-fibred raw materials are very limited in India and are very likely to remain so in the foreseeable future it appears absolutely essential to progressively reduce the percentage of long-fibred pulps and correspondingly increase that of short-fibred pulps in the furnish of the different categories of papers without appreciably affecting the desired characteristics in the finished product.

On the basis of Bhargava (1964) the progressive decrease in the proportion of long-fibred pulps which can practically be effected in Indian pulp and paper industry is given in Figure 16. The corresponding progressive decrease in the proportion of long-fibred raw materials to the total requirement of raw materials is given in Figure 18.

The average long-fibred material yields about 45% pulp (chemical pulping) and the short-fibred material may yield from 95% (mechanical pulping) to 45% (chemical pulping). For the purposes of calculations here, however, yield figures of 35% for long-fibred material and 50% for short-fibred material are taken so that the estimates are conservative. With the proportions of Figure 16 the requirements of raw material for achieving the production levels of Figure 12 have been calculated and are given in Figure 17. The proportion of total requirement that will be required in the form of long-fibred raw material has been calculated from Figure 17 and is given in Figure 18.

With the present state of development of resources and the assumption that "surplus" bagasse will be available for pulping the annual availability of raw materials, as already mentioned, is:

Long-fibred	2.90 million metric tons
Short-fibred	2.76 million metric tons

These supplies and the requirements are shown together for long-fibred and short-fibred raw materials on Figures 19 and 20. The requirements of the rayon industry have also been included in these figures from the estimates of Bhargava (1964).

From these figures it is apparent that India is likely to experience increasing shortages in the supplies of long-fibred as well as short-fibred raw materials from 1975 onwards.

The magnitude of the shortages is given in Table 4.

Figure 17· Estimated requirements of long-fibred and short-fibred raw materials for Indian pulp and paper industry·

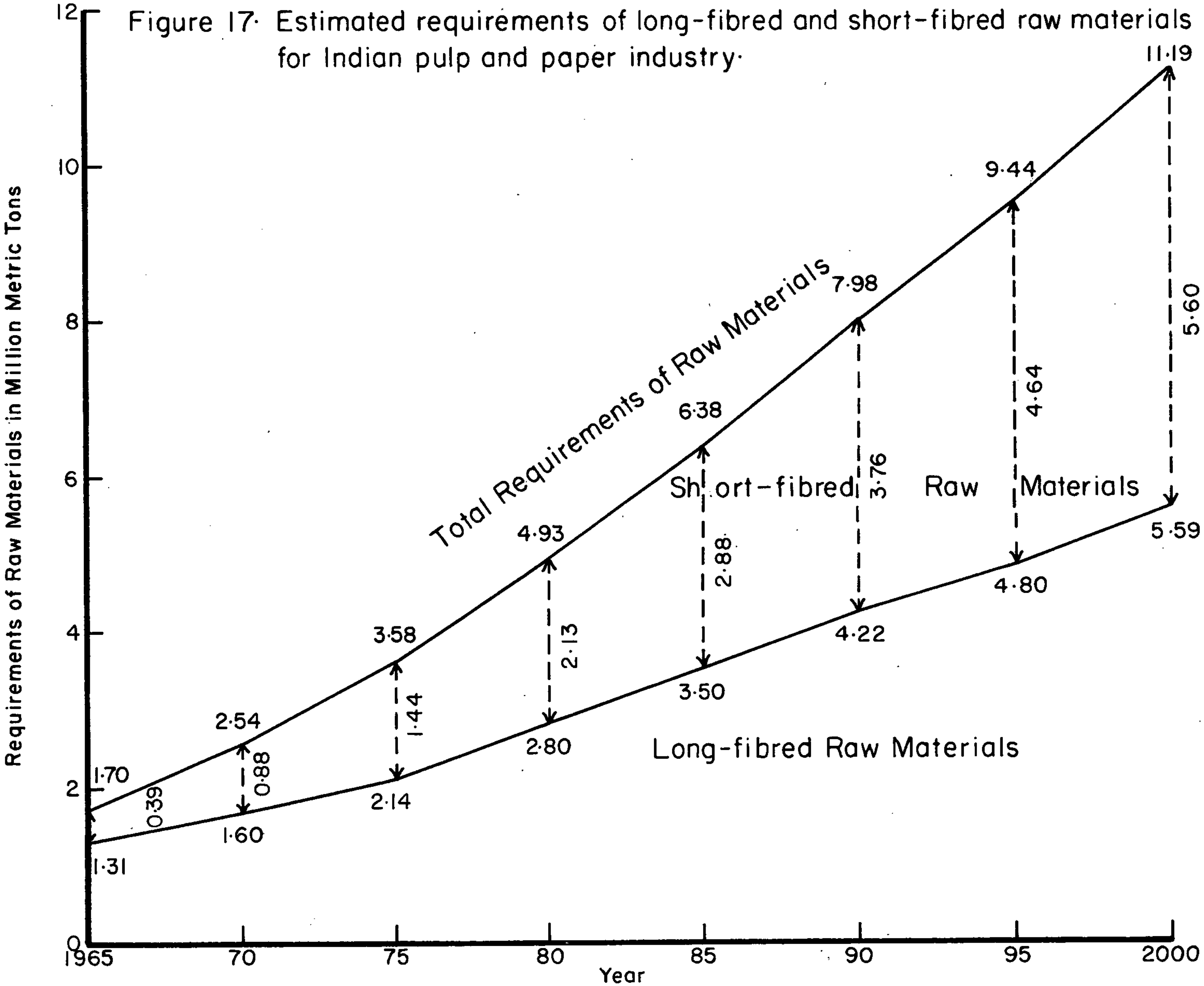


Figure 18· Changes in the proportion of long-fibred raw materials required in Indian paper and paperboard industry·

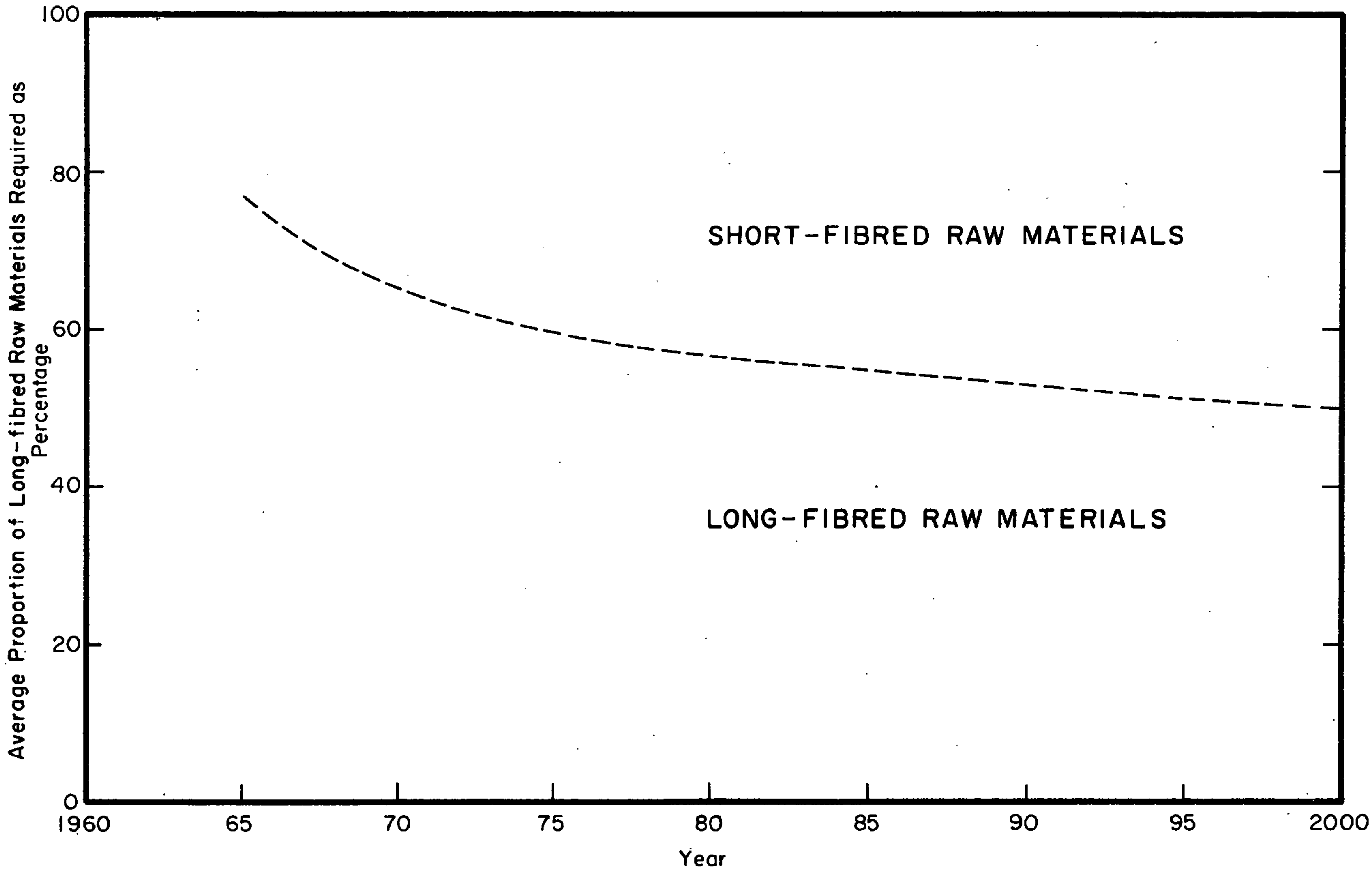


Figure 19· Estimated requirements and supplies of long-fibred raw materials for pulping in India·

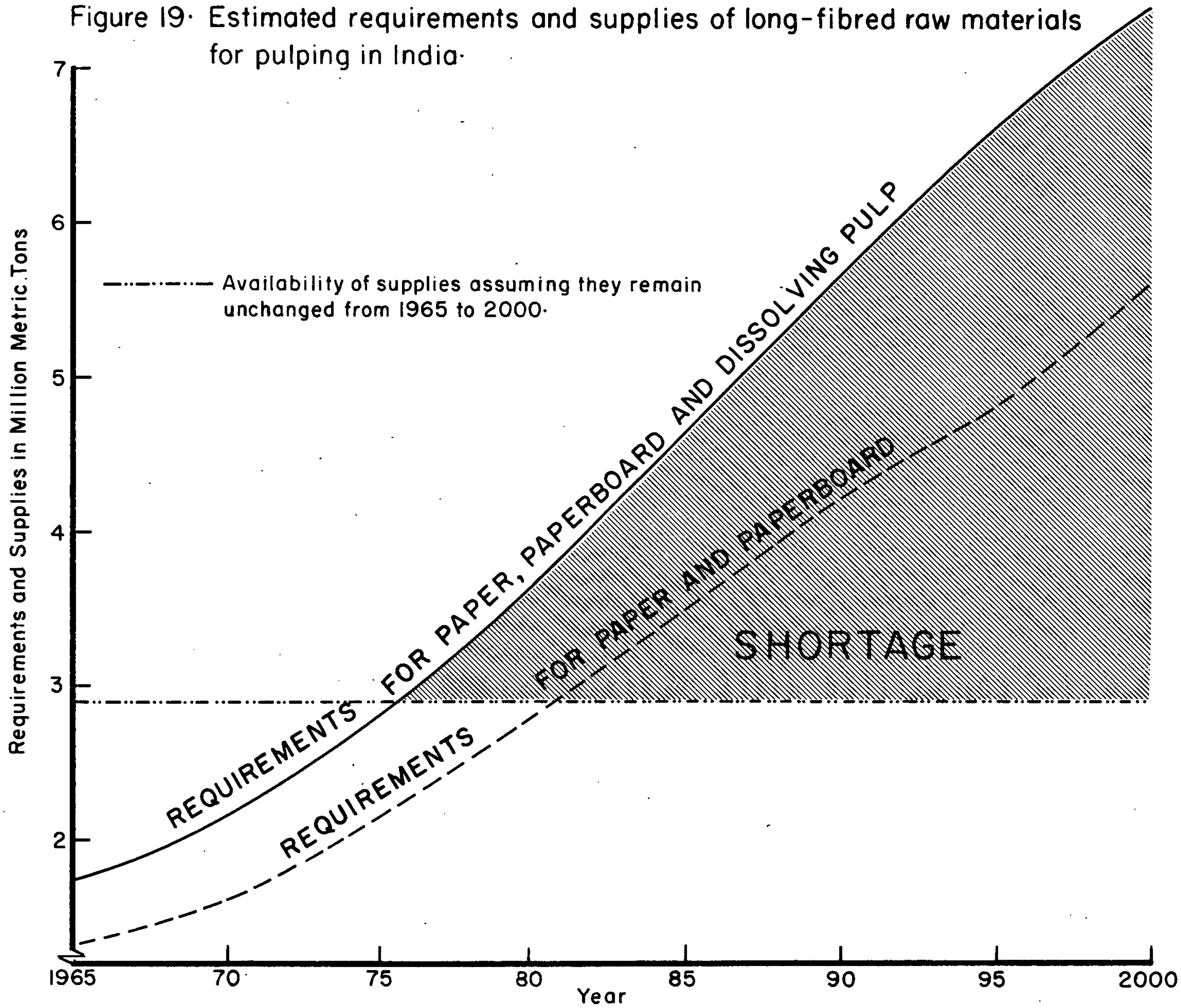


Figure 20· Estimated requirements and supplies of short-fibred raw materials for pulping in India·

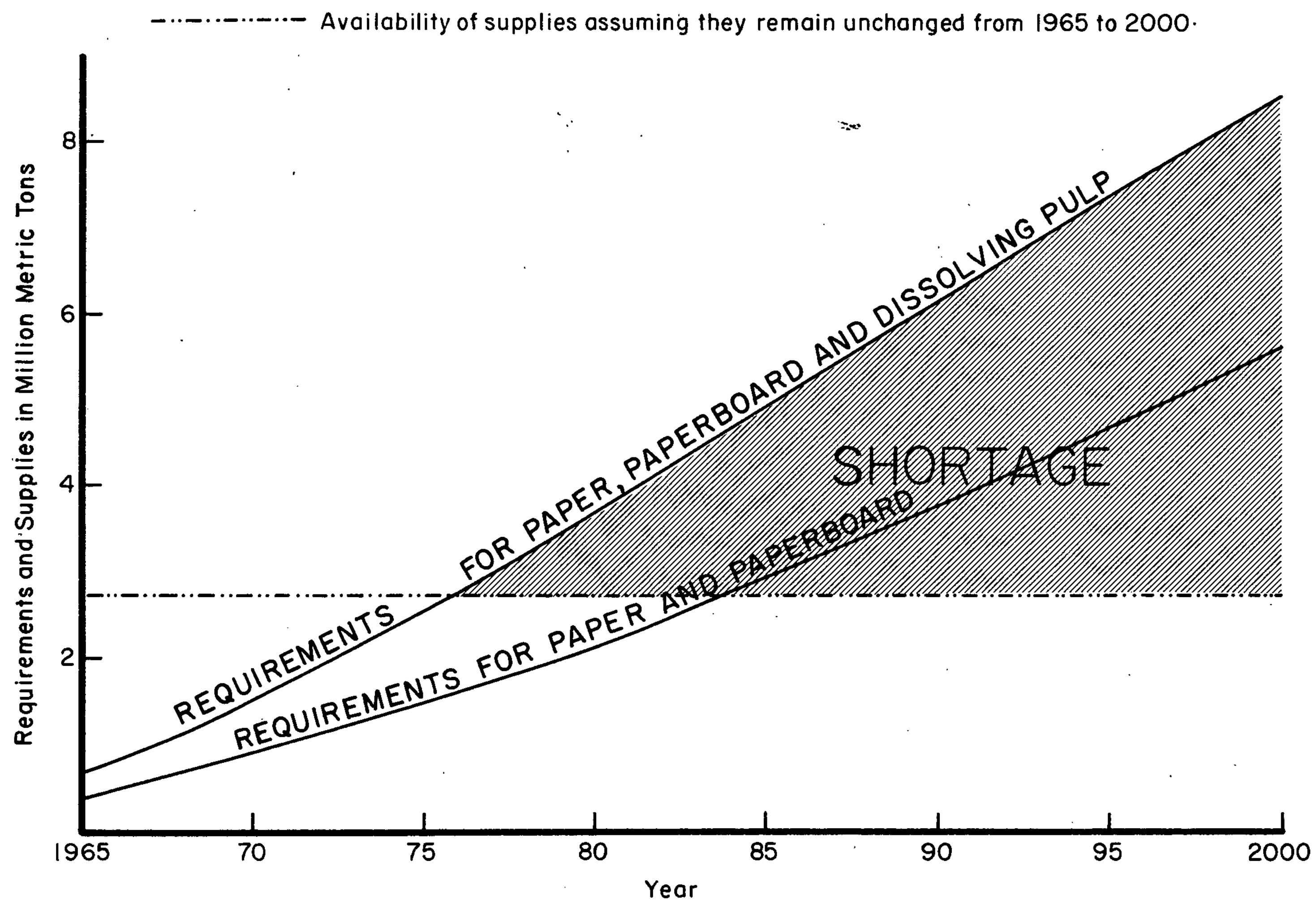


Table 4. Expected shortages of raw materials in India for pulping if the resources are not developed.

Year	Shortage of raw materials in million metric tons	
	Long-fibred	Short-fibred
1975	nil	nil
1976	0.06	nil
1977	0.21	0.24
1978	0.39	0.46
1979	0.57	0.71
1980	0.76	0.95
1981	0.96	1.20
1982	1.14	1.45
1983	1.34	1.70
1984	1.53	1.93
1985	1.75	2.15
1986	1.95	2.42
1987	2.15	2.66
1988	2.36	2.90
1989	2.55	3.15
1990	2.75	3.39
1991	2.95	3.64
1992	3.14	3.86
1993	3.34	4.13
1994	3.52	4.36
1995	3.70	4.60
1996	3.88	4.84
1997	4.04	5.07
1998	4.20	5.33
1999	4.35	5.55
2000	4.50	5.80

Note: If the "surplus" bagasse, spruce and silver fir are not made available the shortages in both kinds of material will start in 1973.

The answer to the question "Can India be self-sufficient in its paper and paper board requirements between 1980 and 2000" depends almost entirely on its ability to produce the raw materials shown in Table 4.

If the spruce and silver fir forests are exploited by modern techniques; methods of using bagasse economically are developed and even a small fraction of the large number of hardwoods and coarse grasses are utilized, there does not seem to be any reason why self-sufficiency cannot be attained. Economic solutions to the use of bagasse and the technical and economic solutions to the use of hardwoods and coarse grasses cannot be found quickly. But if these problems can be solved by the early nineties there is a reasonable hope of India being able to produce as much as is shown in Figure 12.

The more immediate problems are almost entirely within the sphere of activities of the various State Forest Departments of India. For production of long-fibred material they are:

(i) Developing modern means of exploiting spruce and silver-fir forests in the Himalayas with the help of advanced countries

and (ii) Developing new resources of bamboos and exotic pines all over India and planting exotics like Douglas fir in the Himalayas.

For the production of short-fibred material the Forest Departments must start plantings of fast growing exotics like eucalypts and poplars and other indigenous or naturalized fast growing species which are suitable for production of pulp.

Due to the promises offered by bagasse and hardwoods in meeting the needs of short-fibred materials it is evident that the real problem in

India, in the long run, will arise from the shortage of long-fibred raw materials.

CHAPTER IV

POSSIBLE CONTRIBUTIONS OF THE UTTAR PRADESH FORESTS IN DEVELOPING RAW MATERIALS FOR INDIAN PULPING

The share of Uttar Pradesh

As shown in Table 1, U. P. occupies 9.0% of the geographical area but supports 16.8% of India's population. Also its forest area is only 5.8% of the total forest area but its total annual outturn of wood is 13.9% of the corresponding figure for India. This is due to the higher productivity of land in U. P. than in India as a whole. This point is also illustrated by the fact that the outturn of wood per acre of forest in U. P. is 183.1% of the all-India average.

It is therefore logical to expect this state to share the burden of meeting the national shortages of raw materials not merely on the basis of its geographical size but on the basis of its population and productivity. U. P. is also one of the four states in India which grow coniferous forests and therefore it should pay more attention to production of long-fibred raw materials than many other states can do. U. P. is the largest producer of sugar in India and has 71 factories which yield about 1.9 million metric tons of dry bagasse (Bhargava 1963). It has been suggested that from about 1980 this raw material will be used on a large scale and so U. P. would be contributing to an extent of at least 30% of the short-fibred raw material requirements of India from 1980 to 2000.

Availability of the long-fibred resources of U. P. is limited and almost entirely under the Forest Department. In 1959 only about 6,500 metric tons of bamboos were produced as mentioned earlier and in 1963 about 12,000 metric tons were available (Working Plans Circle U. P. 1963). Also only about 40,000 metric tons of twisted chir were available in 1963 (Working Plans Circle U. P. 1963) for the paper industry.

Thus the U. P. Forest Department should try to raise more long-fibred raw materials than it seems to be planning (Table 2). Due to the limitations of total area available for planting it may be necessary to cut down its programme of planting hardwoods so that pulp, paper and paper board mills may be set up in the state. With only large quantities of short-fibred material it is doubtful if the industry can be expanded without importing long-fibred pulps from abroad.

In view of the above arguments it is suggested that not more than one-sixth (ratio of the population of U. P. to population of India) of the shortages in short-fibred raw materials shown in Table 4, be made up by the U. P. Forest Department. All other land available for planting fast growing species should be dedicated to production of long-fibred raw materials.

Areas available for planting fast growing species in U. P. forests

The areas that are to be planted with fast growing species by the U. P. Forest Department for production of pulpwood are given in Table 2. An area of more than 500,000 acres is available for planting and about 30,000 acres will presumably have been planted by the end of 1965.

The broad distribution of this area on the basis of Table 1 given in Working Plans Circle (1963) is as under:

Vindhyan region	100,000 acres

Erstwhile *Zamindari* forests in

Western parts of the state

Bijnore division	70,000 acres
Rohilkhand division	30,000 acres

Areas in eastern parts of the state

Pilibhit division	30,000 acres
North Kheri division	30,000 acres
Gonda (north and south) divisions	30,000 acres
Bahraich division	30,000 acres
South Kheri division	20,000 acres

Areas in sub-montane zone in western parts of the state

Tarai and Bhabar division	100,000 acres
Haldwani division	15,000 acres
Ramnagar division	15,000 acres
Saharanpur division	10,000 acres
Dehra Dun division	20,000 acres

Total for the state	500,000 acres

All the localities mentioned above are within the forest area shown in Map 3.

The Vindhyan region has poor soil and is not suitable for growing tree species for economic purposes. It can, however, support bamboo crops. Bamboo (*Dendrocalamus strictus*) grows naturally in the sub-montane zone in the western parts of U. P. and so this region is also suitable for its cultivation.

In the western sub-montane region *Chir* pine or exotic tropical pines can also be tried. Though *Chir* does not grow naturally in this region it has done well when planted as in New Forest and at Lachchiwala. This region is also generally very suitable for growing eucalypts and other hardwoods.

Some of the areas classified as erstwhile *Zamindari* forests in western districts (Bijnore division) are close to the sub-montane region and suitable for growing bamboo. The rest of the areas in this region as well as the eastern districts are suitable for growing eucalypts and other hardwoods.

Rough allocation of areas for planting

The choice of species to be planted is discussed in detail in Chapter V. At the present stage the Mysore hybrid of Eucalyptus Nautiyal 1965b) seems to be the most promising short-fibred raw material and bamboo is the best long-fibred raw material. The allocation of areas for planting will therefore be done here for these two species only.

The tentative rotation for the eucalypt hybrid is 10 years and its estimated yield about 40 metric tons per acre at the age of 10 years (Nautiyal 1965a). The cutting cycle for bamboo has been estimated as 4 years commencing 10 years after initial planting (Working Plans Circle 1963) and the yield as 4 metric tons per acre.

With the assumption that after once planting the eucalypt it can be relied on to produce adequate coppice regeneration for three successive (coppice) rotations the planting programme given in Table 5 is able to meet about one-sixth of the all-India shortages in short-fibred raw material from 1977 to 2000. A total area of 240,000 acres should be planted from 1967 to 1997.

If bamboo is planted in the remaining 260,000 acres for the production of long-fibred raw material then the planting programme given in Table 6 can result in the U. P. Forest Department meeting one-sixth of the all-India shortages up to the year 1984. Within the limitations of the area of 500,000 acres available for planting fast growing species, it is not

Table 5. A hypothetical planting programme for hybrid eucalypt in U. P. for meeting one-sixth of the expected shortages of short-fibred pulping materials up to 2000.

Year	Area to be planted (acres)	Area available for harvesting (acres)				Expected yield (million metric tons)
		Of planting origin (1st rotation)	Of 1st generation coppice (2nd rotation)	Of 2nd generation coppice (3rd rotation)	Total	
1965	-	-	-	-	-	-
1966	-	-	-	-	-	-
1967	1,000	-	-	-	-	-
1968	2,000	-	-	-	-	-
1969	3,000	-	-	-	-	-
1970	4,000	-	-	-	-	-
1971	5,000	-	-	-	-	-
1972	6,000	-	-	-	-	-
1973	7,000	-	-	-	-	-
1974	8,000	-	-	-	-	-
1975	9,000	-	-	-	-	-
1976	10,000	-	-	-	-	-
1977	10,000	1,000	-	-	1,000	0.04
1978	10,000	2,000	-	-	2,000	0.08
1979	10,000	3,000	-	-	3,000	0.12
1980	10,000	4,000	-	-	4,000	0.16
1981	10,000	5,000	-	-	5,000	0.20
1982	10,000	6,000	-	-	6,000	0.24
1983	10,000	7,000	-	-	7,000	0.28
1984	10,000	8,000	-	-	8,000	0.32
1985	10,000	9,000	-	-	9,000	0.36
1986	10,000	10,000	-	-	10,000	0.40
1987	10,000	10,000	1,000	-	11,000	0.44
1988	10,000	10,000	2,000	-	12,000	0.48
1989	10,000	10,000	3,000	-	13,000	0.52
1990	10,000	10,000	4,000	-	14,000	0.56
1991	9,000	10,000	5,000	-	15,000	0.60
1992	8,000	10,000	6,000	-	16,000	0.64
1993	7,000	10,000	7,000	-	17,000	0.68
1994	6,000	10,000	8,000	-	18,000	0.72
1995	5,000	10,000	9,000	-	19,000	0.76
1996	4,000	10,000	10,000	-	20,000	0.80
1997	3,000	10,000	10,000	1,000	21,000	0.84
1998	2,000	10,000	10,000	2,000	22,000	0.88
1999	1,000	10,000	10,000	3,000	23,000	0.92
2000	-	10,000	10,000	4,000	24,000	0.96
Total	240,000	-	-	-	-	-

possible to significantly increase this contribution. The only increase can come from the coniferous forests in the Himalayas, which should be exploited by modern techniques at the earliest opportunity. In view of the unsuitability for planting of areas covered by hardwoods other than Sal it might not be able to convert such areas to eucalypts. The possibility of converting these areas to bamboo forests must be very seriously considered so that more long-fibred material may be had. Sal is still too valuable as structural timber to be converted to pulp producing plantations.

A comparison of Table 2 with Tables 5 and 6 shows that for proper growth of the pulp and paper industry in U. P. it is imperative that attention be paid to production of long-fibred raw materials. With the planting programme of Table 2 it is very likely that there may be no market for all the short-fibred material being grown, because in the event of non-availability of the long-fibred pulp in India no industry can be set up. The alternative of importing long-fibred pulp from abroad must be rejected as it is most unlikely that any sizeable quantity of foreign exchange will be allocated by the government for this purpose.

Table 6. A hypothetical planting programme for bamboo in U. P. for meeting one sixth of the expected shortages of long-fibred pulping materials up to 1984.

Year	Area to be planted (acres)	Area available for harvesting (acres)								Expected yield (million metric tons)
		1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	Total	
1965	-	-	-	-	-	-	-	-	-	-
1966	9,000	-	-	-	-	-	-	-	-	-
1967	9,000	-	-	-	-	-	-	-	-	-
1968	9,000	-	-	-	-	-	-	-	-	-
1969	9,000	-	-	-	-	-	-	-	-	-
1970	24,000	-	-	-	-	-	-	-	-	-
1971	32,000	-	-	-	-	-	-	-	-	-
1972	40,000	-	-	-	-	-	-	-	-	-
1973	48,000	-	-	-	-	-	-	-	-	-
1974	32,000	-	-	-	-	-	-	-	-	-
1975	24,000	-	-	-	-	-	-	-	-	-
1976	16,000	9,000	-	-	-	-	-	-	9,000	0.036
1977	8,000	9,000	-	-	-	-	-	-	9,000	0.036
1978	-	9,000	-	-	-	-	-	-	9,000	0.036
1979	-	9,000	-	-	-	-	-	-	9,000	0.036
1980	-	24,000	9,000	-	-	-	-	-	33,000	0.132
1981	-	32,000	9,000	-	-	-	-	-	41,000	0.164
1982	-	40,000	9,000	-	-	-	-	-	49,000	0.196
1983	-	48,000	9,000	-	-	-	-	-	57,000	0.228
1984	-	32,000	24,000	9,000	-	-	-	-	65,000	0.260
1985	-	24,000	32,000	9,000	-	-	-	-	65,000	0.260
1986	-	16,000	40,000	9,000	-	-	-	-	65,000	0.260
1987	-	8,000	48,000	9,000	-	-	-	-	65,000	0.260

Year	Area to be planted (acres)	Area available for harvesting (acres)								Expected yield (million metric tons)
		1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	1st cutting cycle	Total	
1988	-	-	32,000	24,000	9,000	-	-	-	65,000	0.260
1989	-	-	24,000	32,000	9,000	-	-	-	65,000	0.260
1990	-	-	16,000	40,000	9,000	-	-	-	65,000	0.260
1991	-	-	8,000	48,000	9,000	-	-	-	65,000	0.260
1992	-	-	-	32,000	24,000	9,000	-	-	65,000	0.260
1993	-	-	-	24,000	32,000	9,000	-	-	65,000	0.260
1994	-	-	-	16,000	40,000	9,000	-	-	65,000	0.260
1995	-	-	-	8,000	48,000	9,000	-	-	65,000	0.260
1996	-	-	-	-	32,000	24,000	9,000	-	65,000	0.260
1997	-	-	-	-	24,000	32,000	9,000	-	65,000	0.260
1998	-	-	-	-	16,000	40,000	9,000	-	65,000	0.260
1999	-	-	-	-	8,000	48,000	9,000	-	65,000	0.260
2000	-	-	-	-	-	32,000	24,000	9,000	65,000	0.260
Total	260,000	-	-	-	-	-	-	-	-	-

CHAPTER V

SPECIES SUITABLE FOR PLANTING IN U. P.

Necessary characteristics

The most important characteristics of species that may be recommended for planting in U. P. for producing pulping materials are:

(i) They should be able to grow in the climate and soil of U. P.

(ii) They should be suitable for making pulp by known economic processes and the pulp produced should be of qualities which can make suitable end products.

(iii) The species should be 'fast grown', which term will be taken to mean that they reach exploitable sizes within 2 to 25 years.

(iv) The costs of raising and harvesting the species should be commensurate with the values obtained.

The other requirements are:

(i) Hardiness to vagaries of nature, insects, fire and fungal attacks.

(ii) Ease of handling in nursery and planting.

(iii) Fitness for being used for other purposes if another more economic raw material for pulping is developed.

(iv) Should not be too exacting as regards requirements of soil.

(v) Should not deteriorate the site.

It is evident that without very detailed studies and trials the optimum species cannot be determined. In this thesis only some of the important species will be reviewed in general.

Possible species

The following groups of species are some of the 'fast growing' ones as they are ready for harvesting within a period of about 25 years.

Eucalypts (for short-fibred pulp)

Pines (for long-fibred pulp)

Poplars (for short-fibred pulp)

Bamboos (for long-fibred pulp)

Other species which are fast grown, suitable for pulping and can grow in U. P. (Seth 1963) are:

Broussonetia papyrifera

Kydia calycina

Ailanthus excelsa

Albizzia procera

Albizzia chinensis (A. stipulata)

Boswellia serrata

Lannea coromendelica

Platanus orientalis

Morus alba

Trema orientalis

and Helicteris isora

Possibly Canadian Douglas fir (Pseudotsuga menziesii) can also be included in this list as a few trees planted in Kulu forests in the state of Punjab by some British foresters showed good growth. However, due to some reason which is not known to the writer, interest was lost completely in later years. It might be worthwhile to investigate whether Douglas fir can be used to replace silver fir and spruce in the Himalayan forests where the regeneration (natural as well as artificial) of these species is very problematic.

Apart from making this suggestion, this thesis does not deal with

Douglas fir due to non-availability of data on the introduction of the species in India.

At present the composition of fast growing plantations for pulpwood in U. P. is: Eucalyptus hybrid - 85 per cent of area, Broussonetia papyrifera - 5 per cent of area, and Kydia calycina - 10 per cent of area (Western Circle 1964). It is apparent that almost all the species given by Seth (1963) and mentioned above have been eclipsed by the Mysore hybrid. This thesis therefore does not discuss these species. At a later date, if more efficient methods for the growing of these species are developed, the study may be more rewarding. At present it seems that large scale plantations of these species are not likely to be raised though they may continue to be tried on areas where mechanized plantations are not possible.

The two shrubby species in this list, Trema orientalis and Helicteris isora, are capable of growing under moderate shade and yield bark which gives strong fibre. The leaves of Trema orientalis are in addition used as fodder by cattle (Gupta 1928). It may therefore be interesting to try to raise them under the canopy of trees like pines, eucalypts, poplars or others.

Whatever species are grown, it is likely to be more economic for the Forest Department as well as the local population if an integrated industry is fed from them. The use of some of the really better quality logs for plywood industry, the branches as fuel, leaves (of some eucalypts) for extraction of oil or fodder etc., should be carefully considered. With limited areas left for use under forestry and very high demands for forest products such an approach is essential.

The eucalypts, pines, poplars and bamboos will be dealt with in subsequent chapters in slightly greater detail.

CHAPTER VI

THE EUCALYPTS

Main sources of information

Some useful information about the eucalypts has been compiled by Nautiyal (1965a, 1965b and 1965c) dealing with their silvics, yield, value, growth and pulping. A summary of the more important information will be given here.

Natural habitat

Eucalyptus is one of the nearly 90 genera of family *Myrtaceae* and has about 700 different species and varieties in it (Penfold and Willis 1961; Cromer 1956). It occurs naturally in Australia, New Guinea and Celebes (Nautiyal 1965b) but is confined mainly to Australia where it ranges from 10 degrees south to 43 degrees south latitude and from sea level to nearly 7,000 feet elevation. Eucalypts grow in areas of varying annual rainfalls from 10 inches to 120 inches per annum. The soils encountered in natural eucalypt forests are also very variable (Cromer 1956).

The distribution of rainfall in different eucalypt forest types in Australia is different. The central desert sector has scanty uncertain rains. The tropical sector in the north has moderate summer rainfall. The subtropical sector just south of the central desert has dry summers and infrequent, irregular and scanty winter rainfall. The temperate Mediterranean type sector has dry summers and moderate but regular rainfall. It occurs in the extreme south as a belt running from west to east. The moderate and uniform rainfall sector along the eastern coast has at least

8 months with more than one inch of rainfall. The maximum amount falls in northern parts of this sector during summer and in southern parts during winter. In between the two, the distribution of rainfall is precisely uniform near Sydney and in eastern Victoria. The mountainous regions in this sector have higher rainfall with a little more precipitation in winters than in summers. The Tasmanian sector is very damp on the western side where much of the rain falls during winter. In the eastern part, which is protected from the moisture laden winds of the Indian Ocean by mountain ranges, the rainfall is much less and fairly equally distributed (Metro 1955).

Comparison with U. P.

The most important eucalypt forests (dry and wet sclerophyllous) occur in the temperate Mediterranean type, the moderate and uniform rainfall and the Tasmanian sectors of Australia, where by and large much of the rainfall comes during winters (except in north-eastern parts of Australia). The mean maximum temperature in these three sectors does not go above 90°F and the mean minimum does not drop below 35°F except in high mountains (Nautiyal 1965b). The temperature variations in these sectors are not very much different from those in U. P. though the rainfall pattern is significantly different except in case of north-eastern Australia.

The temperature pattern and rainfall distribution of the semi-arid south-western U. P. and the tropical sector in northern Australia are not very much different. In both the localities the annual rainfall is nearly the same and most of it occurs during summer. The forest type occurring in the tropical sector of Australia is open woodland with some mallee formation.

Forest types

A general description of the eucalypt forest types of Australia mentioned above is given (Metro 1955):

Woodland:

This is an essentially open formation, a kind of meadow woodland composed of isolated trees and more or less permanent grasslands. The important species in the plains are E. microcarpa, E. largiflorens and E. populnea. On the plateau of the Dividing Range in eastern Australia the important species found in this type of forest are E. melliodora, E. blakelyi, E. rubida and E. pauciflora. On higher hills where woodlands become a kind of wooded mountain pasture E. stellulata and E. niphophila are found.

Dry Sclerophyllous Forest:

In this type the crowns of the dominant eucalypts, although generally not very dense and not exceeding 90 to 130 feet in height, form a fairly continuous cover. There is frequently plentiful undergrowth of shrubs less than 6 or 7 feet, while the herbaceous cover is sparse and patchy.

The important species occurring in different parts of Australia under this type are E. marginata, E. rossii, E. macrorrhyncha, E. obliqua and E. sideroxylon. In the intermediate type between woodland and dry sclerophyllous forest species like E. salmonophloia, E. salubris, E. brockwayi and E. transcontinentalis are found.

Mallee:

The mallee is a kind of extreme type of the dry sclerophyllous forest - a scrub 20 to 25 feet in height, of varying density composed of species of eucalypts with natural bushy habitat, with voluminous root systems which include lignotubers. This formation covers a large area on the southern edge of the central desert and some in the north. Many of its component species when cultivated in zones less arid than those of their origin may develop into small trees such as E. behriana, E. fruitectorum and E. transcontinentalis.

Wet Sclerophyllous Forest:

Where rainfall is fairly abundant and the dry season is short, the sclerophyllous forest cover becomes taller, remains unbroken but light, while the undergrowth includes fairly numerous tall shrubs. The usually abundant herbaceous cover may become continuous. This is an extremely vigorous formation on very deep soils often more than 10 feet in depth and may include trees reaching 200 to 260 feet or more in height. E. diversicolor, E. delegatensis, E. regnans, E. dalrympleana and E. pauciflora exemplify this type.

Adaptability

Though it is quite possible that Eucalyptus species from any part of Australia may be found to thrive very well in U. P. it is likely that those from the tropical sector may be better adapted. The species from temperate Mediterranean type sector, moderate and uniform rainfall sector and Tasmanian sector are also likely to do well. The species from central desert sector and the subtropical sector of Australia may not find much use in U. P. except in the semi-arid south-western parts.

Eucalypts have adapted themselves to very variable environments. The change in climate, soil etc. is accompanied by similar variations in size, form, rate of growth, silvicultural requirements and timber characteristics. Many species are extremely sensitive to changes in micro-habitat. Consequently the dominant species frequently changes rapidly from point to point, with mixtures of species a common feature and each one dominant over certain small areas (Cromer 1956). Thus from a genus which has specialized species for specialized environments it is not difficult to find species suitable to meet a wide range of climatic conditions in countries outside Australia, provided the moisture required is adequate and the conditions are not too cold. The remarkable adaptability (Metro 1955) of eucalypts makes them still the most sought after group of trees for planting overseas. They have been found to acclimatize so well to new environments in many instances that they have put on better growth than in their natural habitat (Metro 1955).

Coppicing

In Australia eucalypts regenerate naturally from seed and coppice (Jacobs 1955). In other countries where they have been planted regeneration from seed may occur but is of little silvicultural value and for practical purposes the old crop is replaced by the new one either by coppicing or planting (Cromer 1956).

Coppicing, however, is not a universal phenomenon in eucalypts. Some species like E. regnans, E. gigantea and E. fraxinoides do not coppice at all whereas E. nitens and E. astringens coppice only rarely. The coppicing power of eucalypts is associated with the bulbous sub-terranean lignotubers. The non-coppicing species do not have lignotubers, but all coppicing species do not necessarily have them. E. fastigata, E. grandis and E. camaldulensis produce coppice shoots without any lignotubers (Jacobs 1955)

The coppicing species may recover from the scorching of a heavy fire or defoliation by insects but the non-coppicers rarely recover from fires though they may survive defoliations.

Size

There is a very great variation in size shown by eucalypts at maturity. The mallees of deserts may be less than 10 feet tall and the giants in mountains may be over 325 feet with boles clear for more than 100 feet. The smallest sizes are seen in E. erythrandra, E. burdettiana and E. mitrata and the tallest in E. regnans, E. diversicolor, E. obliqua, E. gigantea, E. ovata and E. marginata. In spite of very impressive heights the girths of eucalypts are not as remarkable. The boles taper very quickly to tall slim trunks. The greatest recorded girth is 110.5 feet at ground level and 78 feet at 6.5 feet above ground level on a E. regnans (Hardy 1918).

Eucalypts outside Australia

Due to their (i) rapid growth (ii) high yield (iii) ease of handling (iv) ability to grow under low rainfall conditions (v) ability to grow well under irrigation and (vi) adaptability to poor lands unsuited to agriculture as well as to new environments, eucalypts have been planted in a very large number of countries since the early nineteenth century (Cromer 1956). The genus has mostly been planted for firewood, poles, posts, mining timber and charcoal. Some countries have grown eucalypts for sleepers, sawn timber and pulpwood. A more limited role has been for windbreaks, reclamation, soil fixation, woodlots, and oil production. Except in a few cases the countries which planted eucalypts on a large scale have achieved the objectives for which the genus was introduced.

It was estimated in 1961 (FAO 1961) that there are about 109 million acres of eucalypt forests in Australia, and about 4.2 million acres of plantations in other countries. The species most commonly found in plantations in the different regions of the globe are E. saligna, E. tereticornis, E. globulus, E. camaldulensis, E. citriodora, E. pilularis, E. robusta, E. grandis, E. viminalis, E. deglupta, E. regnans and E. rudis.

The most impressive results of planting eucalypts have so far been in two groups of countries (Thirawat 1956).

(i) Countries of Southern Hemisphere where the latitudes are similar to those of Australia. For example, Brazil, Peru, Ecuador, Argentina, Chile, South Africa, Malagasy, Tanzania, Kenya, New Zealand and others.

(ii) Countries in the Mediterranean Region and California where most of the rainfall occurs during winter as is the case with the sclerophyllous forests in Australia. For example Spain, Portugal, France, Italy, Greece, Turkey, Cyprus, Israel, Libya and Morocco.

In India, eucalypts were probably introduced in the last quarter of the eighteenth century by Tipu Sultan in Mysore (Kaikini 1963?), as avenue trees. The region was taken over by the British in 1799 and it was only in 1843 that a few trees, most probably of E. globulus, were planted in the Nilgiri hills for the purpose of finding some species capable of yielding regular and plentiful supplies of fuel (Penfold and Willis 1961). Plantations of E. globulus were subsequently established in the Nilgiri hills in 1856. Small plantations of other species have been in existence in the same hills since 1911. These are mainly of E. eugenioides, E.

pilularis, E. punctata, E. hemiphloia, E. propinqua, E. acmenioides, E. paniculata and E. crebra.

E. globulus was also planted to a small extent in the Simla hills together with E. citriodora, E. tereticornis, E. viminalis and E. rudis but principally as avenue trees in the larger towns. Attempts to establish plantations of E. citriodora in West Punjab (now in Pakistan) irrigated plantations did not produce encouraging results.

Many species were introduced in different arboreta or cultivated as avenue trees in larger towns of India. The most commonly cultivated species however remained E. globulus. It was felt that the climate over the major part of India did not suit eucalypts. A chance hybrid formed probably by free hybridization of a number of species introduced in the earlier parts of the present century in the Nandi hills of Mysore, has attracted attention since the middle fifties. This hybrid may be related to E. tereticornis, E. botryoides, E. camaldulensis, E. citriodora and E. robusta (Kaikini 1963?; Qureshi 1964) and is probably a hybrid between hybrids. It resembles E. tereticornis very considerably in its morphological characters (Qureshi 1964) and has admirably adjusted itself to a variety of soils and climatic conditions (Kaikini 1963?). It has thrived very well from sea coast to an altitude of 4,000 feet in South India and from areas with annual rainfall of 10 inches to 200 inches. It was tried in the coastal afforestation works on the west coast of India along with the well tried Casuarina equisetifolia and found to be faster growing than it (Kaikini 1963?). This indicates that the hybrid, commonly called 'Mysore hybrid', can stand salinity in soil. It has been found to produce profuse coppice shoots and is fire resistant. The resistance to termite attack, however, is poor.

The interest in eucalypts has been revived in India for the last ten years and a large number of species are being tried in different regions. In addition to the trials, fairly large scale plantations of the Mysore hybrid have been initiated in the state of U. P. since 1962. Similar developments are taking place in the other states also.

Use in pulping

Eucalypts as a group can be put to a very large number of end uses like building and construction, railway sleepers, ship-building, mining props, tool handles, bridges, plywood and veneers, cases and casks, furniture, matches, agricultural implements, wagon and vehicle body building, sports goods, boat building, fence posts, pulp and paper, dissolving pulp, fibre-board, tanning material, fodder, firewood, ornamental plants, shade and shelter trees, trees for soil conservation purposes and oil production (Nautiyal 1965b). Due to the limited scope of this thesis only the pulpwood producing species will be discussed here.

Pulpwood producing eucalypts must necessarily possess the following qualities (Sagreiya and Khan 1962).

(i) The colour of the wood should be pale and not dark.

(ii) Basic density of the wood should be low (around 30 pounds per cubic foot)

(iii) Percentage of extractives from wood should not be large.

(iv) The trees should be young, as they yield better pulp than older trees due to low percentage of extraneous materials and high cellulose and pentosan contents.

(v) The trees should be fast grown and tall as they give higher percentage of long fibres (the mean fibre length in eucalypts usually varies from 0.75 to 1.3 mm) and taller trees have higher pentosan contents.

According to Jeffreys (1955), fast grown eucalypt wood gives the best chemical pulp with very high bursting and tensile strength and suitable for producing the best mechanical pulp. The tear factor of pulp made from young fast grown trees is, however, low and satisfactory pulp, for newsprint, from many eucalypts can be produced only from mature and overmature trees.

The eucalypts that have given best results in pulping in various parts of the world are *E. regnans*, *E. gigantea*, *E. obliqua*, *E. viminalis*, *E. sieberiana*, *E. globulus* and *E. grandis*. The suitability of various species to different pulping processes is as follows (Sagreiya and Khan 1962; FAO 1955; Guha *et al* 1962; Guha and Madan 1963):

(i) for mechanical pulps

In Australia about 200 year old *E. regnans*, *E. gigantea* and *E. obliqua* are pulped by this process. The quality is not very good but newsprint is made containing 80 per cent groundwood pulp. The mechanical pulp obtained from *E. tereticornis* in India has been found to be of satisfactory strength properties but the brightness is not good enough for making newsprint. Even an addition of 20 per cent bleach (as available chlorine in pulp) fails to raise the brightness above 50.

The mechanical pulp from the Mysore hybrid has been found to be a little inferior to *E. tereticornis* in strength properties but the brightness can be raised to 60 from 43 by adding 10 per cent bleach. The hybrid is thus suitable for being pulped by mechanical means for the manufacture of newsprint.

(ii) For semi-chemical pulps

These pulps have been made in Australia on laboratory and semicommercial and commercial scale. They can be used as greater part of furnish for corrugating paper and liner boards.

Low grade pulp is produced in Australia by cooking chips with lime at 90 pounds per square inch pressure, followed by disc refining. This pulp is used only for low grade boards as part of furnish.

It has also been shown by the Forest Products Laboratory, Madison that newsprint can be made from the cold soda process.

The species most amenable to semi-chemical processes are E. globulus, E. saligna, E. regnans, E. obliqua, E. gigantea and E. camaldulensis.

(iii) For sulphite pulps

The sulphite process is used for production of paper and rayon pulps. The species used are E. globulus, E. saligna and E. umbellata. Unbleached pulp yields of 47 to 57 per cent, with bleached yields 2 to 3 per cent lower, are obtained. Commercial yields rarely exceed 50 per cent.

(iv) For soda pulps

Commercial yields averaging about 45 per cent are obtained from E. gigantea, E. viminalis, E. obliqua and E. salicifolia, by using single stage and two stage cooking processes.

(v) For sulphate pulps

Sulphate pulping is the best chemical pulping process for the eucalypts and has been used for the pulping of E. regnans, E. gigantea, E. obliqua, E. siberiana, E. eugenioides, E. capitellata, E. radiata, E. viminalis, E. goniocalyx and many others in Australia. In South Africa E. saligna and E. grandis are being pulped by the process and in Latin America E. saligna, E. grandis and E. globulus may be pulped.

This process is also reported to have been used on E. camaldulensis, E. umbellata, E. lindleyana, E. muelleriana, E. nitens and E. scabra in addition to those already named (Sagreiya and Khan 1962). The yields vary from 45 to 55 per cent and are 3 to 5 per cent lower for bleached pulps. Commercial yields are about 48 per cent.

The Mysore hybrid has been found to be suitable for pulping by this process (Guha 1963). The preliminary results of experimental pulping show that the average fibre length is 0.65 mm which is less than most eucalypts, and the average fibre diameter is 0.09 mm (also less than most eucalypts), but the important ratio of length to diameter (Cohen 1948) is 7.2 against 5.0 to 6.5 for most eucalypts. The results of pulping with 20 per cent chemicals ($NaOH:Na_2S = 3:1$) at 162°C for 4 hours are given below:

Unbleached yield (% on r.m.)	44.5
Bleached yield (% on r.m.)	43.6
Bleach consumption as available chlorine, % on pulp	9.3
Tensile strength	7710 metres
Burst factor	53.3
Tear factor	90.3

(vi) For dissolving pulps

The common species used for the production of rayon pulp are E. globulus, E. camaldulensis (10 year old), E. maideni, E. botryoides and E. saligna. When young clean eucalypts of even quality are available the sulphite process is better than others for making dissolving pulp.

Growth and yield

Australia:

On small selected areas of some giant eucalypts in their natural habitat, very high volume of growing stock and yield per acre may be carried. An assessment of virgin forests of E. regnans disclosed an average merchantable volume of approximately 10,000 cubic feet per acre on a compartment of 213 acres which carried 21.5 trees per acre. On small selected areas of this species volumes exceeding 20,000 cubic feet per acre have been reported. A height curve constructed from a stem analysis during the above assessment indicated that a height of 200 feet was attained in about 135 years (Cromer 1956).

In Western Australia and Tasmania the average height of the forest belt is about 150 feet and the average volume per acre in areas of high rainfall would probably be in the region of 1,000 cubic feet (Cromer 1956). In areas where the rainfall is less than 40 inches per annum volume per acre is much less.

Even within Australia the habitats and rates of growth of eucalypts vary considerably. It is therefore difficult to generalize but the average annual increment has been estimated at about 17 cubic feet per acre over the whole eucalypt forest area under present conditions in that country.

Brazil:

Flinta (1956) has mentioned that an overall average yearly growth for E. camaldulensis, E. tereticornis, E. saligna, E. longifolia, E. robusta, E. botryoides, E. globulus, E. resinifera and E. viminalis in fuelwood is 380 cubic feet per acre. The figure is based on 2,500 acres of plantations cut at ages of 8 to 12 years.

It can therefore be assumed that at the age of 10 years, roughly 3,800 cubic feet of wood can be obtained. If it is used as pulpwood it can be assumed to be about 76 metric tons per acre.

Ceylon:

From the figures given by Perera (1962) for the eucalypt plantations in central Ceylon at elevations between 4,100 feet and 6,500 feet with annual rainfall from 70 inches to 115 inches which comes mostly during summers. A rough volume table for E. saligna and E. microcorys has been prepared (Nautiyal 1965c), which is given in Table 7.

Table 7. Rough volume table for two species of eucalypt in central Ceylon

Age (years)	Diameter (inches)	Volume of tree (cubic feet)
	Eucalyptus saligna	
5	3.9	2.4
10	7.5	9.5
15	11.4	20.0
20	15.0	35.8
25	18.1	55.8
30	21.1	75.5
	Eucalyptus microcorys	
5	3.6	1.0
10	7.0	5.0
15	10.3	11.0
20	13.4	21.0
25	16.8	33.7
30	19.7	47.8

With the assumption that at the age of 10 years the stocking density will be 400 trees per acre and 50 cubic feet of wood is equivalent to one metric ton the following yields of pulpwood can be obtained from these plantations at the age of 10 years:

E. saligna	76 metric tons per acre
E. microcorys	40 metric tons per acre

India:

The growth data for the *E. globulus* and other plantations in the Nilgiri hills are not readily available, but a few estimates of the yield from the Mysore hybrid of *Eucalyptus* are given. Pande (1963) has estimated that a yield of 30 tons per acre at the age of 10 years can be expected. In Mysore the same hybrid has been found to put on increment at the rate of 7 tons per acre and could yield up to 70 tons per acre at 10 years (Qureshi 1964).

The U. P. Forest Department (1964) has estimated the rate of growth as 4 tons per acre and a yield of 40 tons per acre at the age of 10 years, for the Mysore hybrid plantations in that state. Seth (1964) has estimated that a yield of at least 80 to 100 tons per acre can be obtained from eucalypt plantations on rotations of 10 to 15 years.

In view of the fact that the hybrid plantations in the *tarai* of U. P. have reached a maximum height of 40 feet and average height of 25 feet and attained a maximum diameter of 8 inches and average diameter of 3 inches after three years of planting (Joshi 1965), it seems that the estimate of the yield as 30 tons per acre is too conservative. At least 40 metric tons of pulpwood per acre may be safely expected to be harvested at the age of 10 years from these plantations.

Israel:

From the data given by Karschon (1960) and reproduced in Nautiyal

(1965c) it can be calculated that *E. camaldulensis* planted at 2 metres x 2 metres produces a mean tree of volume 2.6 cubic feet at the age of 8 years. With the spacing of 3 metres x 3 metres the volume of mean tree is 2.7 cubic feet at only 6 years. This suggests that with an initial spacing of 3 metres x 3 metres (about 10 feet x 10 feet) a pulpwood yield of about 21.6 metric tons per acre can be obtained at 6 years.

If the plantations are irrigated the yield may be expected to be much higher.

Kenya:

The eucalypt plantings in Kenya are done mostly between 4,000 and 9,000 feet elevation. The growth is very rapid and at 10 years the average crop is 75 feet tall. The plantations are raised mostly for fuelwood and the yields are as given in Table 8 (Griffith 1956).

Table 8. Fuelwood yields from eucalypts in Kenya

Species	Rotation (years)	Height (feet)	Diameter (inches)	Yield per acre (stacked cu.ft)	Spacing (ft.xft.)
E. globulus	1st-10	80-100	7-8	3-4,000	9x9
	2nd-10	80-100	7-8	8-10,000	9x9
E. saligna	1st-12	80-100	7-8	3-4,000	10x10
	2nd-12	80-100	7-8	5-6,000	10x10
E. maideni	Comparable to *E. globulus*				

If these plantations were used for pulpwood and with the assumption that the solid volume is half of stacked volume the following yields may be expected:

E. globulus and E. maideni	1,750 cubic feet or 35 metric tons per acre at 10 years in first rotation and 180 metric tons in second rotation.
E. saligna	1,750 cubic feet or 35 metric tons per acre at 12 years in first rotation and 110 metric tons in second rotation.

South Africa:

Eucalypts play a very important role in the forestry of South Africa. Of the total area afforested with exotic species in South Africa about 361,300 acres or 13 per cent is under eucalypts. The most important eucalypt in the country is E. saligna which occupied 241,516 acres in 1955. Detailed growth data for this species is available (van Laar 1961) and part of it for Transvaal and Zululand has been reproduced by Nautiyal (1965c). The climate of Zululand has been classified as 'subtropical' and that of Transvaal either as 'warm temperate' or 'humid colder', and therefore it may be possible to treat U. P. as more akin to Zululand than to Transvaal. In both the localities the major part of precipitation takes place during summer, as in U. P., but the distribution of rainfall is more uniform in Zululand than in Transvaal. Therefore on the whole the yield tables of less productive Transvaal are considered to be more applicable to conditions in U. P.

Seven site indices are recognized for E. saligna in South Africa on the basis of top height at the standard age of 25 years. The site indices are:

Site Index	Top height in feet at 25 years
I	200
II	180
III	160

IV	140
V	120
VI	100
VII	80

Yield tables are not available for Site Indices I and VII in Transvaal and for Site Indices I, II, and VII in Zululand. All the tables are based on 445 stems per acre.

With the assumption that 50 cubic feet of wood is equivalent to one metric ton the approximate pulpwood yields (volume to 3 inch top diameter) of unthinned stands at the age of 9 or 10 years are given in Table 9.

Table 9. Pulpwood yields from E. saligna in South Africa

Age Years	Site Index	Yield in metric tons per acre in	
		Transvaal	Zululand
9	II	117	-
10	III	103	108
10	IV	78	87
10	V	56	66
10	VI	37	43

A comparison with Ceylon shows that the yield in that country is roughly equal to that on Site Index IV in Transvaal.

The yield of E. saligna in Kenya for the first rotation is much less than that on Site Index VI in Transvaal, but in the subsequent coppice rotation is almost equal to that from Site Index III in Zululand.

U. S. A.:

Eucalypts were introduced into California in the middle 1850's. They have since then been planted in Arizona, Florida, New Mexico and along the Gulf Coast (Metcalf 1956). The common species in the country are:

E. globulus	*E. citriodora*
E. camaldulensis	*E. viminalis*
E. tereticornis	*E. robusta*
E. saligna	*E. rudis*
E. botryoides	*E. polyanthemos*
E. sideroxylon	

Metcalf (1924) gave detailed figures for growth of plantations of many species in California. On the basis of these data he prepared the yield table given in Table 10 for *E. globulus*.

Table 10. Yield table for *E. globulus* in California

Age Years	Volume in solid cubic feet including bark per acre		
	Site I	Site II	Site III
2	300	100	-
4	1,050	600	250
6	2,150	1,350	750
8	4,400	2,400	1,400
10	6,100	3,400	2,050
12	7,450	4,350	2,550
14	8,550	5,150	2,900
16	9,600	5,900	3,250
18	10,500	6,500	3,500
20	11,450	7,100	3,800

The three site indices were classified on the basis of age and top height (as given in Table 11).

Table 11. Site indices for *E. globulus* in California

Age Years	Top height in feet in site classes		
	I	II	III
5	Above 53	41-53	Below 41
10	Above 90	70-90	Below 70
15	Above 119	92-119	Below 92
20	Above 133	102-133	Below 102
25	Above 139	108-139	Below 108
30	Above 145	112-145	Below 112

Data on bark volume of *E. globulus* are not available, but in the case of *E. saligna* in South Africa, van Laar (1961) has shown that in trees from 2 inches to 12 inches in diameter bark volume forms 12.0 to 10.7 per cent of the total overbark volume. The proportion of bark decreases as diameter of tree increases. Assuming that the bark of *E. globulus* is thicker than that of *E. saligna*, the volume of the bark of the former may be taken as 15 per cent of the total overbark volume.

At the age of 10 years, therefore, the following underbark volumes may be produced:

Site index I	Site index II	Site index III
5,185 cubic feet	2,550 cubic feet	1,743 cubic feet

If 50 cubic feet of wood makes a metric ton, the pulpwood yield may be put as:

Site index I	104 metric tons at	10 years age
Site index II	51 metric tons at	10 years age
Site index III	35 metric tons at	10 years age

From the data given by Metcalf (1924) for E. globulus, E. camaldulensis and E. tereticornis, Nautiyal (1965c) did a number of regression analyses on the volume produced per acre, volume of single tree, average mortality per year, diameter of single tree, and height of single tree. The analyses were done on I.B.M. 7040 electronic computer at the University of British Columbia, separately for the three species and also for the combined figures for E. camaldulensis and E. tereticornis as the results of analyses for the two, done separately, were very close to each other.

Due to the possible relationship of the Mysore hybrid eucalypt with E. camaldulensis and E. tereticornis the results of the regression analysis done on the combined data of these two species are reproduced here from Nautiyal (1965c).

There were in all 10 variable in the analysis of which six (x_1 to x_6) were obtained direct from Metcalf's tables and the other four (x_7 to x_{10}) were derived from them. The ten variables were:

x_1 Age of plantation in years

x_2 Number of trees planted per acre

x_3 Diameter of single tree at breast height in inches

x_4 Height of single tree in feet

x_5 Volume of single tree in cubic feet

x_6 Volume of plantation per acre at age x_1

x_7 x_6/x_5 Number of trees per acre at age x_1

x_8 x_4/x_1 Average height growth per year in feet

x_9 $(x_3)^2(x_4)$ Product of $(\text{diameter})^2$ and height of single tree. The diameter measured in inches and height in feet

x_{10} $(x_2-x_7)/x_1$ Average mortality of trees per acre per year

The analysis was based on 28 plots of E. camaldulensis and 24 plots of E. tereticornis. The mean values of the ten variables, their standard deviations and maximum and minimum values are given in Table 12.

Table 12. Some basic data on the regression analysis for E. camaldulensis and E. tereitcornis

Number of plots: 52

Variable	Units	Mean values	S.D.	Minimum	Maximum
x_1	Years	8.6923	3.46	1.5	16.0
x_2	No./acre	856.4420	522.29	303.0	2720.0
x_3	Inches	4.4673	1.60	1.8	8.3
x_4	Feet	30.9615	9.28	16.0	47.0
x_5	Cubic feet	2.0308	1.99	0.1	5.4
x_6	Cubic feet per acre	834.4420	696.99	53.0	2923.0
x_7	No. per acre	533.5650	267.03		
x_8	Feet per year	4.1933	2.23		
x_9	Square inch x feet	809.9790	756.38		
x_{10}	No. per year	25.7243	109.53		

The simple co-relation co-efficients between the ten variables and x_3, x_4, x_5 and x_6 are given in Table 13.

Table 13. Simple correlation co-efficients

	x_3	x_4	x_5	x_6
x_1	0.583**	0.632**	0.509**	0.498**
x_2	-0.004	0.044	0.054	-0.133
x_3	1.000	0.830 **	0.907 **	0.725**
x_4	0.830 **	1.000	0.866	0.825**
x_5	0.907 **	0.866 **	1.000	0.782**
x_6	0.725 **	0.825 **	0.782 **	1.000
x_7	-0.575 **	-0.376 **	-0.478 **	-0.099
x_8	-0.271	-0.171	-0.128	-0.135
x_9	0.928 **	0.879 **	0.988**	0.769**
x_{10}	0.149	0.102	0.131	-0.047

The various regression equations are given in Table 14. The least significant variables from the multiple regression equation have been dropped on the basis of the smallest 'F' value. The first equation with all 'F' values significant has been called 'Type 1' equation and the equation with only one variable left at the end has been called 'Type 2' equation. The standard error of the estimate is the square root of the residual variance and the R^2 is the co-efficient of determination showing the percentage of variation explained by the regression equation.

** Significant at 1 per cent level

Table 14. Regression equations

Regression of	Type of Eqn.	Equation	Standard error of estimate: In units	Standard error of estimate: As % of mean value	R^2 %	Eqn. No.
x_3 on x_1 and x_2	2	$x_3 = 2.12 + 0.27x_1$	1.3	29%	34.04	1
x_4 on x_1 and x_2	2	$x_4 = 16.21 + 1.70x_1$	7.0	23%	39.94	2
x_5 on x_3, x_4 and x_9	2	$x_5 = -0.07 + 0.0026x_9$	0.3	15%	97.7	3
x_6 on x_1 and x_3	2	$x_6 = -576.94+315.94x_3$	484.0	58%	52.60	4
x_6 on x_1, x_3 and x_4	2	$x_6 = -1083.95+61.96x_4$	398.0	48%	68.02	5
x_6 on x_1, x_3, x_4 and x_7	1	$x_6 = -1966.07+198.92x_3 +44.39x_4+1.01x_7$	337.0	40%	78.02	6
	2	$x_6 = -1083.95+61.96x_4$	398.0	48%	68.02	7
x_6 on x_1, x_2, x_3, x_4, x_5, x_7 and x_8	1	$x_6 = -779.44-0.31x_2 +37.39x_4+184.92x_5 +0.99x_7-43.52x_8$	298.0	36%	83.50	8
	2	$x_6 = -1083.95+61.96x_4$	398.0	48%	68.02	9
x_6 on x_1 and x_8	1	$x_6 = -1287.25+171.26x_1 +150.98x_8$	569.0	68%	35.79	10
	2	$x_6 = -39.35+100.52x_1$	610.0	73%	24.84	11
x_6 on x_1, x_3, x_4 and x_5	2	$x_6 = -1083.95+61.96x_4$	398.0	48%	68.02	12
x_6 on x_7 and x_9	1	$x_6 = -376.29+0.95x_7 +0.87x_9$	395.0	47%	69.20	13
	2	$x_6 = 260.18+0.71x_9$	450.0	54%	59.20	14

No equation between x_6 and x_2 was possible due to poor correlation.

Regression of x_{10} on x_1 and x_8 gave equations with standard error of estimate (S.E.) as about $3\frac{1}{2}$ times the mean value of x_{10} and so have not been included in the table above. It will be seen that in each of the equations the S.E. has been very high. Probably the reason is because of extreme variation in the number of trees planted per acre in various plots and the extreme light demanding nature of eucalypts which reduce the number of trees very quickly in the first few years.

The following conclusions can be drawn from the regression analysis.

(i) As the number of trees planted per acre (x_2) has not found a place in any of the equations with x_3, x_4, or x_6, it seems reasonable to conclude that the initial number planted (within the range tested) does not have any effect on the diameter, height or volume of these two species. It may be because of the fact that these are strong light demanders and the initial number quickly falls down to an optimum level.

(ii) Equation number 3 is a good relationship for determining the volume of a single tree of E. camaldulensis or E. tereticornis. It can be written as:

$$V = -0.07 + 0.0026\ D^2H \pm 0.30 \qquad R^2 = 97.7\%$$

where 'V' is the volume of a tree in cubic feet, 'D' is its diameter in inches and 'H' is its height in feet, and the $\pm$ value is the S.E. of estimate.

It is possible that this equation might prove to be useful even in India in the case of the Mysore hybrid of Eucalyptus.

(iii) The best equation based on a single variable for determining the volume of crop per acre is based on height of trees. This equation number 5 can be written as

$$v = -1083.95 + 61.96\ H \pm 398.00 \qquad R^2 = 68.02\%$$

where 'v' is the volume per acre in cubic feet and 'H' is the height of the sample tree.

The dependence on height also indicates that the site index is one of the most important determinants for the yield per acre.

(iv) The diameter of E. camaldulensis and E. tereticornis increases with age as given by equation number 1 which can be re-written as:

$$D = 2.12 + 0.27\ A \pm 1.30 \qquad R^2 = 34.04\%$$

where 'D' is the diameter of a tree in inches and 'A' its age in years.

(v) The height increment with age is given by equation number 2:

$$H = 16.21 + 1.70\ A \pm 7.00 \qquad R^2 = 39.94\%$$

where 'H' is the height of a tree in feet and 'A' its age in years.

(vi) The volume per acre at various ages can be had from equation number 11:

$$v = -39.95 + 100.52\ A \pm 610.00 \qquad R^2 = 24.84\%$$

where 'v' is the volume per acre at age 'A' years. This indicates that at the age of 10 years a volume yield of 356 to 1576 cubic feet may be expected, depending probably on site. This is equivalent to 7.1 to 31.3 metric tons per acre if 50 cubic feet is equal to one metric ton.

(vii) Equation number 10 which can be written as:

$$v = -1287.25 + 171.26\ A + 150.98\ \frac{H}{A} \pm 569.00 \qquad R^2 = 35.79\%$$

(where 'v', 'A' and 'H' have the same meaning as in earlier equations) may be helpful in deciding what rotation lengths should be adopted on different site indices. This may be so because $\frac{H}{A}$ is to some extent a measure of site index.

Factors influencing growth and yield

Some important factors governing growth and yield of *Eucalyptus* plantations discussed by Penfold and Willis (1961), the effect of irrigation and spacing on growth recorded by Karschon (1960) and the findings of van Laar (1961 and Kolar (1963) have been summarized by Nautiyal (1965c).

The most important factors influencing the growth and yield of eucalypts appear to be:

1) Site Quality, which can be improved by
   (a) fertilization
   (b) irrigation, and
   (c) cultivation of soil
2) Spacing
3) Coppicing
4) Vertical mixtures, and
5) Rotation

Site quality:

Any particular site is a result of the climatic, soil and topographic factors existing there. The most dominant of these factors which influences growth of eucalypts seems to be climate, of which rainfall appears to be most important. The distribution of rainfall over the months of the year as well as the kind of precipitation are as important as the total rainfall. The periods of drought can be sometimes disastrous.

Water consumption by *E. saligna* in South Africa (van Laar 1961) is related to rainfall, temperature and soil. Evapotranspiration requirement increases with temperature and in a place characterised by high temperatures the amount of precipitation necessary to meet the water requirement of the trees is higher than in areas with a lower mean temperature. In this connection the physical properties of the soil are important and together with local variations in climate produce the complex set of conditions which are expressed as the site index of the stand.

The site quality may be improved by use of fertilizers but there is very little information available on the effect of fertilizers on the growth of eucalypts. Though some work has been carried out in this direction in Australia, no reliable experiments backed by statistical analysis have been carried out (Penfold and Willis 1961). From the scattered and rather empirical data that have been collected, it appears that while phosphate fertilizers have little or no effect, nitrogenous fertilizers show, in some cases at least, quite striking responses. It is therefore possible that the addition of nitrogen may prove beneficial to some eucalypts while the addition of phosphate fertilizers may be only of doubtful value.

Improvement of site quality may be brought about by providing irrigation to localities that experience a drought period of any length. The experiments in Israel conducted with E. robusta (Karschon 1960) show that the mean annual increment may increase as much as 7 times by providing irrigation.

Yet another way of improving site quality is by working the soil at the time of planting. Investigations carried out in Zululand by Luuckhoff (1955) show that growth is affected by soil preparation and that the best growth is obtained from the most intensive method of soil preparation. These conclusions have been verified by van Laar (1961) from measurements of sample plots in stands established on soils prepared by different methods. He also concluded that soil preparation is less effective in stands of second or third generation as compared to first generation.

Though statistically analysed experimental results are not available the experience of raising hybrid Eucalyptus plantations in Uttar Pradesh also points out that deeper soil working with caterpillar dragged ploughs gives better growth than shallow soil working.

Spacing:

Different spacings have been used for planting eucalypts. The maximum density should not be more than 1,000 trees per acre (6½ feet x 6½ feet) and the minimum used is probably 60 trees per acre (85 feet x 85 feet) in Tripolitania (Metro 1955).

In Brazil plantations are raised at 6½ feet x 6½ feet which give maximum annual yield on a seven year rotation. These plantations of E. tereticornis also give much higher net monetary return than plantations at other spacing (Penfold and Willis 1961).

For E. saligna stands of South Africa studies were made by Luckhoff (1955) and van Laar (1961). A spacing of 7 feet x 7 feet has been found to be most suitable for producing maximum volume of pulpwood. Though Luckhoff (1955) recommended wider spacing in poorer sites, van Laar (1961) did not see any reason why it should be necessary.

From these studies it appears as if very wide spacings are not suitable if firewood or pulpwood production is the aim of raising eucalypt plantations.

Coppicing:

When compared with plantations of seed origin the coppice stands have the advantage of immediate availability of a well-developed root system for the transportation of water and nutrients. This advantage is reflected in rapid early growth of coppice crops.

In the planted stands the young plants have to develop an adequate root system and particularly during the first year they are highly susceptible to the effects of drought. It is thus inevitable that in the first year after establishment the growth of planted stands should be slower than that of coppice regrowth (van Laar 1961). Apart from this difference in growth during the first year the height growth of both the types of *E. saligna* stands is almost the same in South Africa.

The data made available by Griffith (1956) and given in Table 8 of this thesis point out that the yield in the second rotation of coppice origin in Kenya is much higher than that in the first rotation of seed origin.

As regards effect of successive coppicing of stands on the yield, van Laar (1961) thought that there was no marked effect in case of *E. saligna* up to fourth generation. The results of experiments in Israel on *E. camaldulensis* also show that the mean annual increment is not much affected by successive coppicing. Only a slight decrease in it occurs in 5th or 6th generation but is attributable to other factors. In fact it is concluded (Kolar 1963) that the decisive factor is the type and quality of soil upon which vigour of growth depends.

These conclusions are interestingly different from earlier conclusions (FAO Staff 1956) when it was generally found and believed that the fourth and subsequent generations of coppice gave very poor yields.

Vertical mixtures:

When coppice with standards system is used for managing E. saligna plantations, van Laar (1961) concluded that it causes suppression of the new coppice and growth is poor. The crowns become smaller, leaves darker, heights inferior and height/diameter ratio greater. It is reasonable to believe that the yield will be adversely affected in this very way if the shade is provided by any mixture in upper canopy.

Rotation:

As in any other species the mean annual increment increases for the first few years in the life of a stand, comes to a maximum value and continually drops down thereafter. The age corresponding to the culmination of the mean annual increment is the rotation of maximum possible volume production. In South Africa such a rotation for E. saligna plantations (site indices III, IV, V and VI) varies from 10 years to 12½ years in Transvaal and 10½ years to 16½ years in Zululand (van Laar 1961).

Pests and parasites

In Australia certain destructive forces at times build up to dangerous levels causing extensive damage to valuable eucalypts, while elsewhere, the non-resistance of some species to some antagonistic organisms necessarily curtails their cultivation. While the tree flourishes, unseen diminution of leaf and penetration of trunk steadily progress and the consequent loss is significant when considered in terms of a plantation's potential total output (Penfold and Willis 1961). Some correlation of potentially destructive forces to actual economically significant damage is vital in an assessment of the eucalypts' capacity as an economic crop in a country or the world. No statistical analyses are, however, available at present. There is abundant record of possible antagonists of eucalypts but the significant damage wrought by the majority of these antagonists has not been established. Evidence suggests that critical infestation by organisms is likely to occur largely from those parasites which, evolving with the eucalypt, have mastered their host's efficient inhibiting mechanisms. *Eucalyptus* timber appears resistant to all but the most highly versatile organisms. As a genus the eucalypts have established themselves over a large part of the earth's surface. This has been possible mainly by the inherent adaptability of the genus, and by the attention paid to the silvicultural requirements of the various species.

The pests and parasites of eucalypts have been grouped into four classes by Penfold and Willis (1961):

Insects

Fungi

Marine borers and

Seed bearing parasites.

In the case of insects it has been noticed that they cause more damage in Australia than elsewhere. In some cases there have been severe losses due to insect attack on eucalypts grown elsewhere, but the majority of these attacks are due to insects which have been introduced with the eucalypts from Australia. Such introduced insects, freed from their natural enemies, have caused and continue to cause severe loss of valuable trees. For adequate quarantine or control the recognition of their nature and extent is essential.

The insect pests of eucalypts have been put in 7 categories:

1. The leaf eaters
2. The sap-suckers
3. Insects attacking the shoot system
4. Insects attacking the root system
5. Insects attacking trunk and branches
6. Termites of living trees
7. Pests of timber

When the destruction caused by insects rises above economic potential of forests or plantations, chemical control of the pests might be found useful. It must be remembered that such control aims at reduction of the number of insects to a level where they are held in check by other forces, and not to their eradication. There is a grave danger in chemical control as the beneficial insects are also destroyed with the harmful ones. The insecticides used are generally either internal poisons which kill the insect after reaching its alimentary canal or contact poisons. The internal poisons are effective against the insects with biting mouth parts. They are consumed as they kill. The contact poisons can kill even those insects which penetrate the plant surface with their mouth parts before feeding begins. These poisons are not consumed as they kill but remain effective on the leaf or other parts of the plant for some weeks afterwards.

The leaf-eaters have biting mouth parts and are susceptible to arsenical compounds. Lead arsenate and calcium arsenate are commonly used in forestry. They can be applied as a dust from the air or in dilute suspension from a conventional blower or in concentrated suspension from a mist blower. Water soluble arsenic is injurious to plant tissue even in small amounts and so its level must be controlled. For this reason, and particularly dusting seedlings in the nursery, lead arsenate with a much lower solubility (about 0.25 per cent) in water, and with a less variable content of water-soluble arsenic is to be preferred.

Contact poisons like D.D.T., aldrin and dieldrin are also effective against the leaf-eaters. Dieldrin is the most toxic and residually effective of the three. These chlorinated hydrocarbons are non-irritating to the skin, but when absorbed, are quite poisonous. D.D.T. becomes dangerous only when in oil, or other organic solutions, whilst dieldrin is most safely handled in an emulsified form.

Parathion or E.605, an organic phosphate, has also been found effective against some leaf-eaters at concentrations of 0.05 per cent. It is a liquid and only slightly soluble in water but completely soluble in acetone, ethyl ether, the alcohols and animal and vegetable oils. It has a high health hazard and its general use is not recommended. A close relative, Malathion, may prove a more generally efficient substitute (Penfold and Willis 1961).

The sap-suckers are killed only by contact poisons. It may be un-economical to use chemicals for controlling the damage in forests but one of the following contact poisons may be used:

(i) D.D.T is perhaps the most generally useful.

(ii) Parathion or E.605 and the related organic phosphate, tetra-ethyl-pyrophosphate (T.E.P.P.)

(iii) Nicotine, a plant alkaloid, sufficiently active at low vapour concentrations to be a powerful insecticide. The usual commercial form for spray is 40 per cent nicotine sulphate, which is applied at concentrations of 1:800 or 1:1,000.

(iv) Certain petroleum oils, such as white and red oil, act on the respiratory system of the insect and are most safely applied on trees during their dormant period. Emulsification of oils by water prevents plant injury by excessive oil deposits. White oil is effective at concentrations as low as 1.5 to 2 per cent.

A phase of sucking-insect control now receiving attention is the use of systematic insecticides. Such insecticides are intended for absorption by the plant and transference, through the sap-stream, to the foliage of young shoots. The application is usually as a spray on the trunk or around the roots, but so far, no data are available on the use of these systematic insecticides against the sap suckers of eucalypts.

Insects attacking the shoot system may kill the leading shoot and all those that take its place. The stem form is thus affected. Sometimes the tree may die. Such a damage by the twig-infesting chalcid Rhicnopeltella eucalypti on E. globulus has rendered the commercial possibility of planting this species in New Zealand as almost impossible. Other insects damage leaf, axillary and flower buds of many other species. Biological control may be possible in some cases.

Insects attacking the root system generally affect young trees and seedlings. Eradication of potential root-attackers is possible by soil fumigation. Carbon bisulphide has been the most widely used soil fumigant. As an undiluted liquid, it may be injected into holes in the soil or, as an aqueous emulsion, may be applied directly to the soil. Aqueous emulsions of ethylene dichloride or its substitute propylene dichloride, chlordane, solutions of methyl bromide and ethylene dibromide can also be used for direct application. Crystals of para-dichlorobenzene and napthalene can be used for mixture with top layers of the soil (Penfold and Willis 1961).

Insects attacking trunk and branches are the boring beetles. Their control is limited to individual tree treatment. Prevention of their entry is possible by treatment of exposed areas of bark or by spraying the trunk with D.D.T. Where boring has begun or is advanced, the introduction of lead arsenate dust or carbon bisulphide through the entrance hole is often successful in killing them.

Termites of living eucalypts attack both sapwood and heartwood. They confine their attention normally to dead or dying wood tissue and so predominate on the non-living bark, on dead trunks and branches, on exposed and hidden roots, and weathering timber. But living trees are also attacked frequently, particularly when there is no other readily available cellulose source. In most cases, however, invasion is initiated by way of a damaged, dead or dying limb or root, or fire-damaged trunk. Typical damage is in the form of a cylindrical 'pipe' throughout the centre of the trunk with some penetration of the surrounding wood. Sometimes concentrically arranged galleries from the 'pipe' extend farther into the heartwood. The heartwood may also be deeply encircled to the outside bark and this may result in the death of the tree.

Termites of living trees are mainly wood dwelling termites. The other kind is sub-terranean. Paradichlorobenzene, ortho-dichlorobenzene, white arsenic, paris green and sodium fluosilicate are usually effective against termites.

Pests of timber, especially <u>Lyctus</u>, can be controlled by lightly ring-barking the top of the bole six and eight months respectively before felling or basal application of hormone sprays. These treatments make the re-absorbtion of starch from the sapwood possible and thus make the timber <u>Lychus</u>-proof. Felled timber can be heat-sterilized or treated with D.D.T. or benzene hexachloride.

The growth of fungi affecting eucalypts is determined by the conditions of nutrition, respiration, moisture content of the substratum, temperature and light. The fungal attacks on the genus can be broadly put in four categories.

(i) Fungi in the nursery

Occasionally severe loss of seedlings or germinating seed occurs due to fungi. These fungi are principally either foliage parasites or soil dwellers, occasionally parasitic on seed and stem. Much work remains to be done on the identity and pathology of these fungi before adequate measures for their control are assured (Penfold and Willis 1961).

Loss can be avoided by correct nursery practice. The most successful method is to sow the seed in a well-aerated nursery bed at a time which allows completion of the tender seedling stage before the weather becomes hot and humid. Autumn and winter sowings are good and dusting of leaves of the developed seedlings with a suitable fungicide gives further protection.

The soil-dwelling fungi cause decay of the seed, collapse of the seedling before emergence through the soil, and softening and withering of that part of the stem at soil level. The disease is sporadic, most prevalent during warm, moist weather (hence called 'Damping-off'), and, once appearing, spreads rapidly. Most losses occur just before, or immediately after, the seedlings break through the soil. At this stage, no particular resistance appears to be offered by any seedling.

Complete protection from 'damping-off' is attained only by sterilization of soil, seed and equipment used in the nursery. Soil treatment may involve steam, heat, or fumigation. Heat is readily applied by burning brush above the soil. Formalin (used as a 2 per cent solution) and methyl bromide are the recommended fumigants. A number of other seed dusts or soil drenches are also used.

(2) Fungi in living eucalypts

Wood rot in living trees is caused almost exclusively by those fungi capable of secreting the enzymes essential in the breakdown of liquified tissues as well as cellulose. It is possible that fungi enter the tree through wounds caused by branch shedding.

Preventive measures are mainly silvicultural and include protection of roots from damaging forces. Wounds on trees can also be treated with fungicides like creosote mixed with tar. When infection is detected it should be removed and treated with Bordeaux paint (copper sulphate 68 gm., rock lime 450 gm. (or hydrated lime 680 gm.), to 9 litres of water).

(3) Timber staining fungi

The damage caused is not so much physical as economic when these fungi attack timber. The market value of lumber is reduced therefore when timber susceptible to staining is milled. The practice is to immerse completely the boards in tanks of preservatives within 48 hours of conversion.

(4) Fungi causing decay of seasoned timber

Decay of seasoned timber proceeds only when moisture in it is above 20 per cent. There are cases, however, where seasoned timber is liable to rot (a 'dry rot') by moisture brought to it from water-conducting mycelial strands of certain specialized fungi which, once established, are supplied with moisture by the respiratory process. The point of origin of attack is either from infected moist timber or from timber lying in contact with the soil and exposed to the weather.

Principles of wood preservation must be adopted to avoid such 'dry rot'.

Eucalypts are affected by marine borers (Crustacea and Mollusca) also but the species grown, or likely to be grown in U. P. will not mostly be used in contact with sea water and so these pests are not discussed here.

Eucalypts are subject to parasitization by mistletoe (Loranthaceae) and sandalwoods (Santalaceae). None of the species of the genus Loranthus, found commonly in India, seems to have been noticed to be parasitizing any of the eucalypts in Australia. The other mistletoes are controlled by lopping the infected branches or in extreme cases, by felling the tree.

The major sandalwood parasites of eucalypts fall under the genera Santalum and Exocarpus in Australia. Both the genera do not grow in U. P. in natural state and so may not present any problems.

Cassytha and Cuscuta are other parasites of eucalypts found in Australia. They are both twiners.

Profitability of eucalypt plantations

Examples of profit analyses, mainly for E. saligna, are available from Ceylon and South Africa. Perera (1961) has shown that the up-country plantations in Ceylon, mainly of E. saligna with mixture of E. microcorys, E. pilularis, E. robusta, E. globulus, E. citriodora, E. maculata, E. paniculata, E. regnans and Acacia dealbata, yield an annual return of 6.8 per cent with a rotation of 40 years.

van Laar (1963) has shown that for the E. saligna plantations in Transvaal, which have a rotation of 8 years, an annual profit of at least R[1] 8.30 per acre is earned.

van Laar (1961) has also concluded that when land is available in plenty, for planting *E. saligna* for pulpwood, the financial rotation of highest rate of interest be adopted. When there is a shortage of lands, as in India, the financial rotation of highest soil expectation value should be adopted. On site indices III to VI such rotations vary from 9.0 to 11.5 years in Transvaal, and from 9.1 to 14.0 years in Zululand.

Planting technique

The planting techniques for different eucalypts in various parts of the world have been given by Metro (1955). The usual technique adopted in U. P. for planting the Mysore hybrid eucalypt has been described by Nautiyal (1965b) and is summarized here.

No direct seeding is done in the forest, but bagged plants - usually more than 18 inches tall - are planted. The plants are raised by sowing the seed either in the container bags themselves or raised nursery beds or germination boxes. The best time of sowing is in September - October, just after the end of the rainy season. The container bags are made of polythene and are 7 inches x 10 inches (flat) in size. Soil used for germination is sterilized and enriched with organic manure and fertilizers. Frequent but sparing watering with fine sprays is done till the plants are 6 inches tall. Protection from sun, frost and heavy rain is also necessary till this stage. Afterwards the plants are kept in full sunlight. One kilogram of seed gives about 40,000 bagged plants after about 9 months from sowing.

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[1]Rate of exchange for South African Rand and Canadian Dollar on June 22, 1965 was: R 100.00 = C $152.25
and C $1,086.26 = U.S. $1,000.00

Planting is done during the rainy season from July to September in soil that has been ploughed and harrowed - usually with D4 caterpillar tractors - after clear felling of the poor quality forest on it. Planting is done in lines 12 feet apart, the distance from plant to plant in a line being 6 feet. The entire area is fenced against porcupines and semi-wild cattle.

The planted lines are weeded manually between July and September. The strips between the planted lines are harrowed at least once during this period to deep down the grasses. At the end of the rainy season usually mustard is sown in the strips to keep away the grasses till next March when it is harvested. After that harrowing has to be done again and again till the grasses are suppressed by the eucalypt canopy. Growing of mustard is not usually possible in the second year due to development of Eucalyptus plants.

About 70 to 90 per cent of the plants put in survive at the end of one year from planting.

Cost of planting and the minimum stumpage price that must be realized

The actual first year per acre cost of planting the hybrid eucalypt in 1962 came out to R_s[2] 230.07 in U. P. The breakup of the cost (Chief Conservator of Forests U. P. 1964) is given in Table 15.

A further amount of R_s 20.00 to R_s 30.00 per acre may be spent on raising the mustard crop in between the lines, but it also yields a return of R_s 50.00 to R_s 60.00 per acre. The net financial effect of raising such a crop may thus be a reduction of about R_s 30.00 per acre

[2]Rate of exchange for Indian Rupee and Canadian Dollar on June 22, 1965 was: R_s 100.00 = C $22.79; and C $1086.25 = U.S. $1000.00

Table 15. Break-up of cost of planting eucalypt in U.P.

Item	Amount
1. Survey and demarcation	0.35
2. Site clearance	0.25
3. Soil working	
A. By hired tractor	34.50
B. By departmental tractor	
(i) Ploughing	12.00
(ii) Harrowing	4.00
(iii) Ridging	4.00
4. Fencing	
(i) Cost of porcupine-cum-cattle proof fencing material	22.00
(ii) Cost of labour for erecting fence	5.00
5. Seed collection	5.00
6. Nursery cost	66.40
7. Planting including beating up of failures	16.80
8. Weeding	
(i) First weeding	6.00
(ii) Second weeding	5.00
(iii) Third weeding	4.00
9. Winter hoeing	4.70
10. Salary etc. of staff	27.00
11. Water supply, medical supplies etc. to staff	5.35
12. Making of roads and fire lines	5.55
13. Other items	2.17
Total	230.07

in the total cost of planting which can therefore be assumed to be R_s 200.00 per acre on an average.

There is expenditure involved in the remaining 9 years of the first rotation as well as in the second, third and fourth rotations. At the end of 40 years the cycle will be complete and the area will have to be re-planted. The expected expenditures in each of 40 years of a cycle of 4 rotations have been given by Western Circle (1964). These expenditures as well as their discounted or capitalized values to the year of first planting are given here. The discounting has been done at a rate of 6 per cent (p = 6).

Cost incurred during	First rotation (1st to 10th year): Item of work	Current cost (rupees)	Value of cost discounted or capitalized to 1st year (rupees)	
1st year	Initial cost of raising plantation in the first year	200.00		200.00
2nd year	(a) One hoeing in spring; 2 harrowings & weedings in rains	24.00	$\frac{24.00}{(1.op)}$ =	22.64
	(b) Fire protection and upkeep of roads etc.	7.00	$\frac{7}{(1.op)}$ =	6.60
3rd year	(a) One hoeing in spring; 2 harrowings & weedings in rains	24.00	$\frac{24}{(1.op)^2}$ =	21.35
	(b) Fire protection and upkeep of roads etc.	7.00	$\frac{7}{(1.op)^2}$ =	6.23
4th to 10th year	Fire protection and upkeep of roads etc. at the rate of R_s 5.50 per annum	5.50 per annum	$\frac{(5.50)\{(1.op)^7-(1.op)^6\}}{(1.op)^3\{(1.op)^7-1\}}$ =	0.78
		Total		257.60

Second rotation (11th to 20th year)

Cost incurred during	Item of work	Current cost (rupees)	Value of cost discounted or capitalized to 11th year (rupees)
11th year	(a) Pruning and thinning of the coppice shoots in the 11th year	25.00	25.00
	(b) One hoeing in spring; 2 harrowing and weedings in rains	24.00	24.00
	(c) Fire protection and upkeep of roads etc.	6.00	6.00
12th year	(a) One hoeing in spring; 2 harrowings and weedings in rains	24.00	$\frac{24}{(1.op)}$ = 22.64
	(b) Fire protection and upkeep of roads etc.	6.00	$\frac{6}{(1.op)}$ = 5.66
13th to 20th year	Fire protection and upkeep of roads etc. at the rate of Rs 5.50 per annum	5.50 per annum	$\frac{(5.50)\{(1.op)^8-(1.op)^7\}}{(1.op)^2\{(1.op)^8-1\}}$ = 0.74
		Total	84.04

The total if discounted to the 1st year becomes $\frac{84.04}{(1.op)^{10}}$ = R_s 46.92.

The year to year expenditures involved in the third and fourth rotations are the same as in the second and so the discounted or capitalized values of costs involved in these rotations are:

Third rotation - total discounted value in 21st year R_s 84.04

Fourth rotation - total discounted value in 31st year R_s 84.04

These totals if discounted to the 1st year will be equal to

$$\frac{84.04}{(1.op)^{20}} \quad \text{and} \quad \frac{84.04}{(1.op)^{30}}$$

or R_s 26.21 and R_s 14.63 respectively.

The total discounted cost for the entire 40 year cycle will be R_s 257.60 + R_s 46.92 + R_s 26.21 + R_s 14.63 or R_s 345.36 in the 1st year of the cycle.

The estimates of yield given by Western Circle (1964) are 1,400; 1,600; 1,300 and 1,300 cubic feet in first, second, third and fourth rotations respectively. These estimates appear to be too low in view of the discussion on p. 72 of the thesis and a yield of 40 metric tons (about 2,000 cu. ft.) per acre can be safely assumed. Moreover there need not be undue fear of the yields getting reduced in third and fourth rotations. A uniform yield of 40 metric tons per acre after every ten years can be considered as fairly realistic.

It is almost impossible to forecast what stumpage price will be commanded by the eucalypt pulpwood in a locality where there are no existing pulpmills based on it. Therefore instead of attempting to do so the minimum stumpage price that must be realized so that the discounted costs and discounted revenues over a 40 year period are the same, will be calculated. If the stumpage realized is lower than this figure eucalypt planting will have been unprofitable. If this stumpage price is realized the costs are just covered by revenues and the plantations would be earning a six per cent return, not considering the cost of the land.

If such a stumpage price is 'S' rupees per metric ton, then the discounted revenues in 40 years will be:

$$\frac{40S}{(1.0p)^{10}} + \frac{40S}{(1.0p)^{20}} + \frac{40S}{(1.0p)^{30}} + \frac{40S}{(1.0p)^{40}}$$

Or

$$\frac{40S\left\{1-\frac{1}{(1.op)^{10}}\right\}}{(1.op)^{10}\left\{1-\frac{1}{(1.op)^{40}}\right\}}$$

This must be equal to R_s 345.36

Therefore S = R_s 31.61 per metric ton.

It is possible that a higher stumpage price than R_s 31.61 per metric ton may be commanded by the eucalypt plantations at their maturity and Western Circle (1964) has estimated a stumpage price of R_e 1.00 per cubic foot or R_s 50.00 per metric ton. But the Forest Department should strive to keep the stumpage as low as possible so that the pulp and paper manufacturers find it attractive to expand their industry. The aim of the Forest Department, as a Public Agency responsible for the overall development of the country, should not be to make maximum profits for itself but to create circumstances under which maximum real national income or GNP in terms of constant rupees is created.

<u>Species recommended for U. P.</u>

The general suitability of species for various parts of U. P. was indicated by Gupta (1957) and some more specific recommendations have been made by Nautiyal (1965b). The names of these species are summarised here.

In temperate Himalayas (above 6,000'):

<u>E. bicostata</u>

<u>E. insizwaensis</u> from South Africa which is a natural hybrid of <u>E. globulus</u>

<u>E. biangularis</u> from New Zealand which is probably a natural hybrid between <u>E. globulus</u> and <u>E. urnigera</u>

E. unialata from Tasmania which is a hybrid of *E. globulus* and *E. viminalis*

E. antipolitensis from South France which is also a hybrid between *E. globulus* and *E. viminalis*

E. globulus	*E. dalrympleana*
E. regnans	*E. viminalis*
E. gigantea	*E. sieberiana*
E. obliqua	*E. pauciflora*

In sub-tropical hills (2,000' to 6,000'):

The Mysore hybrid	*E. saligna*
E. camaldulensis	*E. tereticornis*
E. albens	*E. grandis*
E. diversicolor	*E. astringens*
E. citriodora	*E. maculata*
E. leucoxylon	*E. microcarpa*
E. obliqua	*E. robusta*
E. rubida	*E. sideroxylon*

In *Tarai* and *Bhabar* tract:

Mysore hybrid	*E. marginata*
E. gomphocephala	*E. astringens*
E. calophylla	*E. redunca*
E. camaldulensis	*E. citriodora*
E. crebra	*E. grandis*
E. hemiphloia	*E. tereticornis*
E. maculata	*E. saligna*
E. siderophloia	

On saline and alkaline soils:

- Mysore hybrid
- *E. occidentalis*
- *E. camaldulensis*
- and some mallees
- *E. cornuta*
- *E. gomphocephala*

In the arid and semi-arid areas:

- Mysore hybrid
- *E. camaldulensis*
- *E. andreana*
- *E. macarthuri*
- *E. brockwayi*
- *E. cladocalyx*
- *E. microtheca*
- *E. gomphocephala*
- *E. dundasi*
- *E. radiata*

Along roads in the plains:

- Mysore hybrid
- *E. camaldulensis*
- *E. cladocalyx*
- *E. citriodora*
- *E. sideroxylon*
- *E. robusta*

Along roads in the hills:

- *E. bicostata*
- *E. sideroxylon*
- *E. saligna*

Needs for research

With the introduction and trial of different species of eucalypts into U. P. carefully planned study should be initiated on the following:

1. Genetics

   (a) Research should be initiated on the development of new hybrids for tree improvement so that the present needs in respect of forest tree species suitable for certain regions or certain purposes may be met.

(b) Research should also be started on the isolation of suitable characters in already existing hybrids and their selective breeding for fixing these characters and improving them in future generations.

(c) Studies on seed provenances should be started in eucalypts so that it may be possible to choose the seed from the proper place for future plantations.

(d) Methods for certification of seeds obtained from different places should be evolved at this early stage of large scale introduction of eucalypts so that there are no confusions later on.

2. Physiology

The physiology of eucalypts must be studied in detail so that they can be propagated properly and their growth controlled.

3. Effect on soils

It is necessary to study the soils on which eucalypts are being and will be introduced so that the effect of the introduction may be evaluated. It is possible that without fertilization, soils might deteriorate by growing quick short rotation crops of eucalypts.

4. Planting techniques

The most effective and economic planting techniques should be evolved by trial.

5. Effects of coppicing

As already mentioned, it has been noted in South America that yields in subsequent coppice rotations fall and this puts a restriction on use of coppice system of regeneration. The studies in South Africa and Israel, however, point out that up to 4 generations coppicing does not significantly affect the yield. Under these conflicting observations it is necessary to clearly evaluate the effects under Indian conditions and to find ways and means of arresting the possible decrease in yield in subsequent generations.

6. Control over pests and parasites

Economic methods of control must be developed as needed.

CHAPTER VII

THE PINES

General

Some 60 to 80 species of the genus Pinus belonging to the family Pinaceae are known as pines (Harlow and Harrar 1958; Scott 1960). The genus is the largest and most important of the conifers and is widely spread throughout the Northern Hemisphere. Large forests of pines occur in North America, Europe and Asia but there are much fewer species in the Eastern Hemisphere than in the Western. Only a single species of pine, namely Pinus merkusii occurs in the Southern Hemisphere in natural forests. It is found mainly in Burma, Thailand, Cambodia, Viet-Nam and the Philippines in the Northern Hemisphere and in the Indonesian islands of Sumatra, Java and Borneo in the Southern Hemisphere (Aung Din 1958).

Pine forests are considered to be mainly temperate zone forests and their occurrences in the tropics are regarded as mere extensions of temperate zone forests. It is maintained that the only true tropical pines in the whole world are P. merkusii in the Asia region and P. hondurensis in Mexico to Nicaragua and in the West Indies. Although species like P. roxburghii (Syn. P. longifolia) in India, P. khasya in Burma and neighbouring countries, P. insularis in the Philippines, P. strobus (var. chiapensis) in Central America, P. occidentalis, P. tropicalis and P. cubensis of West Indies may also be regarded as tropical, they extend their range into subtropical elevational belts of 3,000 to 6,000 feet or beyond (Aung Din 1958).

A look at any map of coniferous forests of the world reveals that there are very few such forests in the tropics (Duerr 1960). The properties and versatile uses of the conifers make them a very much desired group of trees in the tropics also. As <u>Pinus</u> is the only member of the coniferous group of trees, some species of which occur in the tropics to substantial extent, there is little wonder that the interest in pines, especially 'tropical pines', has been very widespread.

Aung Din (1958) has taken the term tropical pines to include all pines as they occur naturally in the tropical region, that is, including those to be found at high elevational belts where subtropical or temperate climatic conditions prevail. Though strictly speaking, only those areas that are bounded by the Tropic of Cancer ($23\frac{1}{2}^{\circ}$N) and the Tropic of Capricorn ($23\frac{1}{2}^{\circ}$S) constitute the tropical region of the world, he has taken the 30°N and S latitudes as the limits of this region so that the 'outer tropics', as well as the transitional zone merging imperceptibly into the subtropics may be included. This corresponds approximately to the area bounded by the zone with a mean annual temperature range of 70°-75°F. The mean annual temperature of 75°F is considered as characterizing tropical climates (Champion 1961).

A major part of India falls in this region. Even those parts of the country which lie north of the 30th parallel are considered tropical unless their elevation is higher than about 2,000 feet. Almost all the area of U. P. where plantations of fast growing species are likely to be undertaken are in this region (Map 1).

The more than 40 species of pines enumerated by Aung Din (1958) do not include many of the members of the genus from southern parts of the United States and the Mediterranean countries. His definition of 'tropical pines' is therefore not used in this thesis. Instead the term 'tropical pines' will be used in a broad sense to denote those species of the genus Pinus which either grow in the tropical parts of the world or which can grow there. The following are some of the important species that can be included in this definition (Aung Din 1958; Harlow and Harrar 1958; Scott 1960):

Region where found naturally	Scientific name	Common name
India	P. roxburghii (syn. P. longifolia)	Chir pine
India and Burma	P. khasya	
South-east Asia	P. merkusii	
Canary Islands in the north-west of Africa	P. canariensis	
Mexico & Central America down to Nicaragua, the Caribbean, the Bahamas, Cuba, the Isle of Pines	P. hondurensis	
Mexico	P. strobus Var. chiapensis	
Mexico & Central America down to Nicaragua	P. montezumae	
Mexico & Central America down to Nicaragua	P. pseudostrobus	
Mexico	P. ayacahuite	
Mexico	P. michoacana	
Mexico	P. pringlei	
Mexico	P. herrerai	
Mexico	P. douglasiana	
Mexico & Central America down to Nicaragua	P. tenuifolia	

Mexico	P. patula	
Mexico	P. durangensis	
Northern Mexico & south-western Arizona & New Mexico	P. leiophylla	Chihuahua pine
South-eastern U.S.	P. palustris	Longleaf pine
South-eastern U.S.	P. echinata	Shortleaf pine
South-eastern U.S.	P. taeda	Loblolly pine
South- eastern U.S., Cuba and Central America	P. caribaea (considered syn. for P. elliotti by some)	Slash pine
Western U.S. & Mexico	P. ponderosa	Ponderosa or western yellow pine
California & Mexico	P. jeffreyi	Jeffrey pine
Southern Arizona, New Mexico & Northern Mexico	P. arizonica	Arizona pine
California	P. radiata	Monterey pine
Spain	P. halepensis	
Mediterranean basin	P. laricio	
North-western Spain	P. pinaster (maritima)	

Value of pines

Almost all pines are suitable for pulp and paper manufacture and many produce good lumber. Several species produce turpentine, pinewood oils, wood tars and rosin. The leaf oils of several are used in the manufacture of medicines and the seeds of many are suitable for food (Harlow and Harrar 1958). The fibre length of pine woods is nearly 3 mm and that of P. radiata has been reported as 3.06 mm (Scott 1960). Most of the pines yield wood very suitable for mechanical, sulphite, or sulphate pulping.

Almost the whole of Uttar Pradesh is likely to be able to grow suitable pines. The sub-montane region where P. roxburghii has been planted (Lachchiwala) in a couple of sample plots holds promise of supporting either this indigenous pine or some other faster grown species. The sub-tropical region in the hills, below about 6,000 feet, can also support some of the fast growing pines.

Some trials in the introduction of pines in U. P. have been started during the last few years but it seems that most of the attempts are being made in the sub-tropical region in the hills. While intensifying the trials in this region, it is necessary that fairly extensive trials in the sub-montane zone be started so that some suitable fast grown pines for this region be found. Without a fast grown long-fibred pulpwood being available the economic importance of the short-fibred pulpwood like eucalypt may be very little as mentioned in Chapter IV.

Some species recommended for trial in U. P.

Of all the tropical pines, P. radiata has proved to be most successful where tried. Its success in the Southern Hemisphere has been particularly noteworthy (Scott 1960). The species is a native of California where the climate is more or less Mediterranean type with the major part of rainfall during winter. According to Scott (1960) the species is not suited for regions where there are untimely or too severe frosts in winter or when the tree is active and where damp heat or excessive dryness in summer are experienced. It therefore seems that neither the higher hills nor the plains of U. P. might be suitable for this pine. Nevertheless its trial in U. P. will be worthwhile, especially in the valleys between the Himalayas and the Siwaliks as in Dehra Dun. P. radiata is very fast growing in areas where it has been planted and in New Zealand at 25 years gives mean top height of 99 feet, mean diameter of 13.5 inches, and a total volume of 8,680 cubic feet with 270 stems per acre (Scott 1960).

In the humid summer areas of Australia P. caribaea (syn. P. elliotti) has been planted. Though this species is not fast growing (Scott 1960) it is possible that it may withstand Indian climate better.

P. patula is a very fast growing pine from Mexico which gives medium quality timber and is one of the most important timbers in Africa (Aung Din 1958). It must be tried in various parts of U. P. The longepedunculata variety of this species is more tropical than the typical P. patula (Leuchars 1961) and should also be tried.

P. palustris, P. taeda, P. pseudostrobus and P. echinata are suitable for trial in the hills as well as the sub-montane area. P. taeda may be a promising species as seen in the trials in U. P. Variety oaxacana of P. pseudostrobus is also likely to be suitable for sub-montane zone. P. palustris is not very fast grown in New Zealand (Scott 1960) but its growth in India is worth observation.

In the poor soil areas P. pinaster (maritima) has been tried in Australia (Scott 1960). This species can therefore be tried in the lower hills in soil conservation works as well as in other localities.

P. durangensis of Mexico is one of the fastest growing and most important pines. It gives light, soft, good quality constructional timber. Though it grows at elevations of 6,000 to 9,000 feet in Mexico its trial in the hills and sub-montane areas might be useful.

Other species that must be tried are P. montezumae and its form macrocarpa, P. pseudostrobus, P. michoacana, P. occidentalis, P. cubensis,

P. tropicalis, P. herrerai, P. douglasiana, P. tenuifolia, P. ayacahuite especially var. brachyptera, P. ponderosa, P. jeffreyi, and P. arizonica. For breeding experiments P. leiphylla and P. oocarpa may be useful (Leuchars 1961).

For the eastern districts, species like P. hondurensis and P. strobus var. chiapensis, which are from typical tropical climates, may be tried.

The pine from Canary Islands, P. canariensis, provides one of the best timbers among pines and should be tried in the hills.

The Mediterranean pines like P. halepensis and P. laricio may do well in the hills.

According to Aung Din (1958) successful small-scale plantations are reported of P. canariensis, P. halepensis in Kashmir; P. hondurensis, P. radiata in Assam; and P. patula, P. pinaster, P. taeda and P. laricio in the Punjab state of India.

In due course research on pines will have to be started on the same lines as suggested for eucalypts in Chapter VI.

CHAPTER VIII

THE POPLARS

General

The term 'poplars' is used to describe the genus *Populus* which includes some 35 species, their varieties and forms. *Populus*, along with the genus *Salix* and three others, forms the family *Salicaceae* (Harlow and and Harrar 1958), and has been widely cultivated in the world since early times. The cultivation of poplars began to expand in Europe in the eighteenth century when North American poplars were imported to hybridize with native European poplars (FAO 1958). Cultivation has made rapid progress since then and has gained momentum during the last 25 years.

Features distinct from other timber-producing trees

Poplars have certain features which set them distinctly apart from other timber-producing trees (FAO 1958).

1. They are propagated primarily by vegetative means and not from seed.
2. They are dioecious (with the exception of *Populus lasiocarpa* which is monoecious), that is, flowers are unisexual with male and female on separate individuals, and
3. Hybridization is common between trees of different varieties and opposite sex.

Unlike most other forest tree species, cultivated poplars are normally propagated from cuttings. Whenever any particular stem is observed to have qualities which make breeding worthwhile, it is a simple matter, by taking successive cuttings, to produce an indefinite number of trees bearing genetically identical characteristics. This is the reason for the very large number of forms to be found among cultivated poplars. As a general rule, a study of forest trees reveals species or varieties composed of a collection of stems having a large number of characters in common but perhaps differing in a few details; these are so many individuals. This is also true of poplars occurring naturally, which include male and female stems and which multiply by seeding. But in the majority of cases, and in practice the most interesting as regards cultivated poplars, a group of stems with the same characters consists of a single individual which has been split up an indefinite number of times. This group of stems with the same characters is called a clone, and is a common feature in poplars (FAO 1958).

Natural distribution and cultivation

Poplars are widely distributed throughout the Northern Hemisphere mainly between the Tropic of Cancer and the Arctic Circle. Probably the only naturally occurring poplar in India is *Populus ciliata* which has considerable distribution in the Himalayas. Other main regions of the world where the genus *Populus* is naturally found are North America, Scandinavia, Eastern Europe and U.S.S.R., North Africa, Spain, Portugal, parts of West Asia and Western China (FAO 1958).

Of the 5 sections into which poplars have been divided, only two *Aigeiros* and *Leuce* are cultivated on a large scale. Section *Tacamahaca* is cultivated to a limited extent and the other two, *Turanga* and *Leucoides*, have not received much attention (Schreiner 1959).

The cultivation of poplars has been most common in Europe, Japan, West Asia, Central Asia, New Zealand, South Africa, Chile, Uruguay and

Argentina.

Poplars have attracted attention of farmers and foresters because they have a rapid growth rate: the forms most commonly grown can be harvested within 20 to 25 years. Their wood is well suited to industries like manufacture of matches, veneers, light boxmaking materials, fibreboards and paper pulp. Moreover poplars can utilize soil which is unsuited to agriculture and in certain types of forest stands can increase productivity (FAO 1958). They also have a further advantage in that they can be cultivated in various ways in association with farm crops. They can also produce suitable hybrids for many different kinds of environment.

Site requirements

The site requirements for the two main sections of poplars, namely Aigeiros (Black poplars) and Leuce (Aspens and true white poplars) will be briefly described here.

Aigeiros - Black poplars:

This section of poplars, which includes European black poplar (*Populus nigra*), is naturally distributed in the Western Hemisphere almost exclusively in the United States. In the Eastern Hemisphere it does not occur in areas north of the latitude of London and south of the latitude of Cairo to any significant extent. These limits become narrow eastwards so that the entire Indo-Pakistan sub-continent falls outside the zone. Black poplars do not extend far to the east of Central Asia (FAO 1958).

The Aigeiros poplars are generally considered bottom-land species but their hybrids have been freely planted on upland sites in all European countries and in America. Where soil depth, fertility, pH, and moisture conditions are adequate, the growth of Aigeiros poplars on upland sites is as good as on bottom lands. Conversely, on bottom-land soils of low fertility, low pH, or very poor aeration, the poplars grow as poorly as on infertile or dry upland soils. European poplar plantatinns demonstrate that the limiting soil factors for profitable poplar culture are depth, fertility, pH, moisture and aeration (Schreiner 1959).

The minimum depth of soil, on which poplars have been grown with reasonably satisfactory growth in Europe, was approximately 18 inches. Soils 2 to 3 feet or more in depth are required for maximum growth. An accurate measure of soil fertility required for black poplars is not available but there are indications that the most profitable growth rate requires a level of soil fertility equal to that needed to grow a profitable corn crop in the United States (Schreiner 1959).

The limiting lower value of pH is about 4.5 to 5.0 as shown in Germany (Schreiner 1959) and maximum growth is obtained at about pH 6.0. The black poplars require a moist soil during the entire growing season, or a water table within reach of the roots. There are examples of good plantations on sites with light, relatively dry soil where summer water table is reported to be 12 to 15 feet deep. On upland sites, the best growth is more often on medium heavy soils, the water-holding capacity of which is better than that of light-textured soils.

Soil aeration during the active growing season is essential. The Aigeiros poplars will grow well on sites that have heavy ground water if the topography and light soil permit free water movement to provide aeration. Heavy impervious soils on wet sites, and light permeable soils with a stagnant water table that does not drop below 18 inches during the growing season, are unsuitable (Schreiner 1959).

Leuce - Aspens and true white poplars:

The section _Leuce_ is more widely distributed than the black poplars and is divided into two subsections: the aspens (_Trepidae_) and the true white poplars (_Albidae_). The _Trepidae_ include species like _Populus tremula_ (aspen) and the _Albidae_ include _Populus alba_ (true white poplars) and _Populus canescens_ (gray poplars). The gray poplars are generally thought to be the hybrids of _P. tremula_ and _P. alba_ var. _nivea_ and are also known by the name of _P._x _canescens_.

Plantation culture of aspen in Europe is still in experimental stage (Schreiner 1959). They can be grown commercially on sites that are too dry or too infertile for profitable culture of _Aigeiros_ poplars.

The gray poplars can withstand a coastal climate and its wind and salt spray better than other poplars.

True white poplars reach their best development on well-drained fertile bottom-lands. The optimum site requirements are apparently similar to those described for black poplars (Schreiner 1959).

Cultivation of poplars in forest

The success of poplar cultivation in the forest is based on the following four principles:

1. Selection of good clones
2. Cultivation on suitable sites
3. Good silvicultural practices
4. Methodical treatment

Selecting the clones for planting the section _Leucoides_ is of no importance as it does not produce any tree of economic value. The section Turanga is also not of much importance as it has not shown much promise. The species P. euphratica is, however, of local importance in the Near East where it can grow in the arid hot climate and might have to face saline soils. Little work has been done on the section Tacamahaca and so most of the new clones that are likely to be tried in a new locality may belong to sections Aigeiros or Leuce. It might however be useful to try species or clones from all the five sections.

The European black poplar (P. nigra) can reach a diameter of more than 20 inches in 25 years and is noted for its easy adaptability and capacity for fairly good growth even on soils covered with sand, gravel and pebbles.

The American black poplar (P. deltoides) attains greater dimensions but is more exacting as to soil fertility and moisture (FAO 1958).

The hybrids of the European and American black poplars are worth serious trials in U. P. as the Aigeiros are said to be particularly suited to alluvial soils (FAO 1958).

The aspens are of much less importance in temperate zones of the world but may be useful in tropical and sub-tropical regions and so deserve trial.

The drought resistant white poplars and the gray poplars must be tried in U. P. due to their capability of withstanding wind and soil salinity. It is possible that they may prove to be hardy enough in the climate of India.

Trial of clones from abroad alone can hardly solve the problem of finding suitable clones for India. Systematic study of the behaviour of these introduced forms and production of new hybrids of the acclimatized clones from foreign countries, especially with the indigenous P. ciliata may be able to produce the poplars suitable for Indian conditions (Tiwari 1965). A species can be considered as suitable to a particular site and technically satisfactory only after it has behaved well on the site for at least one generation of trees (FAO 1958).

The treatment of poplars in the forest differs from that of all other species. As selected clones are used they can generally be relied upon to produce good hereditary characteristics. Furthermore selection thinning is confined to the elimination of unsuitable clones or stems damaged in one way or another. Treatment aims at protecting the trees from damage, assisting formation of lower trunks free from knots, and ensuring a sufficient amount of light.

Cultivation of poplars in farm

Unlike most other forest trees, poplar cultivation is not confined to the forest. Poplars are cultivated outside the forest on a large scale. Here one or more poplar types carefully selected on the basis of site conditions and the products to be obtained are established in the best natural conditions, improving them if necessary by the usual agricultural techniques: preparation of the ground, application of manures, irrigation or drainage etc., and by giving the trees constant attention so as to obtain the best quality timber (FAO 1958). In this type of cultivation, the poplar is frequently combined with farm or forage crops, and is either planted among them or else the young stands are interplanted with crops. Intensive cultivation, which very often benefits from agricultural methods and manpower, depends fundamentally on the choice of clone and on efficient cultivation (FAO 1958).

As the planter has less control over poplars in the forest than in the farm the choice of the clone best suited to the site is more important in the former case than in the latter.

For either kind of cultivation efficient nurseries are required and their maintenance must be properly studied before any ideas of poplar introduction in U. P. can take definite shape. This aspect is already being studied in U. P. and trials with imported clones have been carried out since 1950 (Tiwari 1965).

<u>Dangers from pests and diseases</u>

Pure stands of any crop offer ideal conditions for the attacks by pathogenic agents to reach epidemic proportions. If the stand is composed of a single clone then the resistance of all the trees is the same and if the pest or disease kills one tree the entire stand might be wiped out in time. Moreover parasites are often virulent at one particular stage in the growth of the tree and so even-aged stands are the most vulnerable to their attack. It is therefore necessary to understand the type of damage that may occur to poplar stands. Important pests of poplars are borers, sucking insects (like woolly poplar aphis <u>Phloeomyzus</u>) and rodents. A number of fungi and bacteria also attack poplars (FAO 1958).

<u>Breeding of poplars</u>

Like all other breedings the aim of poplar breeding is also to raise strains yielding better economic returns. The aim can be realized by increase in quantity of merchantable wood produced per tree or per acre; or the improvement of the quality of wood produced. Better economic returns can be obtained by breeding strains more resistant to pathogens and environmental influences. The industrial use of the wood has also to be taken into consideration while breeding poplars. When producing wood for pulp the cellulose content and when producing wood for veneers or saw timber, the form of the trunk and the mechanical properties determine which strains to favour.

Plant breeding programs can be divided into three main operations (FAO 1958):

1. raising a greater number of different strains
2. testing these varieties in experimental plantations
3. large-scale propagation of superior varieties

The different strains can be had either by collecting seed in nature, or artificial hybridization or mutation (may be induced by X-ray or other agencies). Poplar species belonging to the same section hybridize easily and crosses between the sections Aigeiros and Tacamahaca are also highly fertile. The hybrids between these two sections are also fast growing.

Polyploid forms of poplars can be produced by the aid of colchicine and offer unlimited opportunity for selection and testing (FAO 1958).

It might also be possible to get results of practical value by inducing mutations in poplars by irradiation of seeds and shoots by X-ray, fast neutrons, by treatment of mustard gas and in other ways.

Yield from poplars

The yield of wood in the poplar plantations of Casalese in Italy (U. S. Govt. Printing Office 1954) is given in Table 16.

Table 16. Yield of wood by age and density of poplar planting.

Age Years	Volume of wood 100 trees per acre (cubic feet)	Volume of wood 160 trees per acre (cubic feet)
4	572	786
5	815	1,057
6	1,100	1,358
7	1,436	1,686
8	1,829	2,058
9	2,272	2,472
10	2,772	2,929
11	3,358	3,430
12	4,001	3,965
13	4,687	4,494
14	5,402	5,009
15	6,130	5,502
16	6,873	5,973
17	7,602	6,431
18	8,317	6,862
19	9,003	7,281
20	9,660	7,674
21	10,289	8,045
22	10,889	8,388
23	11,461	8,703
24	12,004	9,003
25	12,518	9,289

Action that should be taken in U. P.

The proposition of introducing poplars in the forests of U. P. and their cultivation in the agricultural land by the farmers have great possibilities. The vast field open to research in the breeding of poplars makes these possibilities still greater. It is therefore felt that the introduction of poplars in this state should be given far more attention than it is getting now and research should be initiated on the lines suggested for eucalypts in Chapter VI.

CHAPTER IX

THE BAMBOOS

General

The members of tribe Bambuseae belonging to family Gramineae are known as bamboos. The tribe has been divided into four sub-tribes, namely, Arundinarieae, Eubambuseae, Dendrocalameae, and Melocanneae, and comprises about 30 genera and 550 species, inhabiting the humid tropical and extra-tropical regions (Raizada and Chatterji 1956). There are 320 species in Asia, 179 in South America, only one, namely Arundinaria macrosperma in North America, north of Mexico and none in Europe. In India alone there are about 136 species, with 39 in Burma, 29 in Malaya and the Andamans, 9 in Japan, 30 in the Philippines, 8 in New Guinea and a few in South Africa and Queensland. Bamboos extend into the cold of Japan and heights of 10,000 feet or more in the Himalayas. In the South American Andes they reach the snow line.

Bamboos are shrubs or trees, very rarely herbs, culms erect or sometimes climbing, often tall, usually woody (Raizada and Chatterji 1956). They are characterized by their pointed stems, commonly called culms, arising from their rhizomes and are densely clustered so that culms grow in clumps. In a few cases they grow at intervals from a long creeping rhizome (e.g. in Melocanna) or in tufts consisting of a smaller number of culms as in Phyllostachys. The former are called 'clump forming' and the latter 'non clump forming' or 'running'.

Bamboos are found in gregarious association in moist deciduous and dry deciduous forests as well as in wet evergreen forests (Huberman

1959). They thrive best in monsoon forests where they attain their maximum development (Raizada and Chatterji 1956). In most of the species a clump bears 30-100 culms and every year at the beginning of the rainy season about 10 large culms and 30-50 smaller ones shoot up. The growth of the culms is very rapid, about 3 inches per day, but may be even 15-16 inches a day as in Dendrocalamus giganteus. Growth habits of clump forming bamboos are well illustrated by the various species of Dendrocalamus (Deogun 1936; Sen Gupta 1952).

Bamboos in India

In India bamboos form rich belts of vegetation in the well-drained parts of the monsoon region at the foot of the Himalayas and rise up to about 12,000 feet, almost to the snow line. Their distribution is quite dense in Assam, West Bengal, the north-eastern Himalayas, Western Ghats and Andamans.

The distribution of some of the important species in India follows:

Species	Localities where found
Bambusa arundiracea	Orissa, Assam, southern and western India.
Bambusa vulgaris	Assam
Bambusa tulda and B. balcooa	Bengal
Arundinaria aristata	Eastern Himalayas
Arundinaria wightiana	Nilgiris
Bambusa polymorpha	Upper mixed forests of Assam
Pseudostachyum polymorphum	Valleys of eastern Himalayas, Assam and Sikkim
Dendrocalamus strictus	Deciduous forests throughout India

Species	Localities where found
Dendrocalamus hamiltonii	Northern Bengal and Assam
Melocanna bambusoides	Assam
Cephalostachyum pergracile	Moist parts of Bengal and Assam
Oxytenanthra thwaitesii	Western Ghats
Oxytenanthra monostigma	Western Ghats from Konkan to Annamalai hills
Oxytenanthra bourdilloni	Kerala between 2-4,000 feet
Teinostachyum wightii	Western Ghats
Ochlandra rheedii	Kerala
Ochlandra travancorica	Mountains of South India

In U. P. mainly Dendrocalamus strictus is found to occur though smaller quantities of Bambusa arundinacea may also be encountered within the forests. Dendrocalamus hamiltonii and Bambusa nutans are also cultivated in some villages in north-western parts of U. P. (Gupta 1928).

Most of the bamboo used in India for manufacture of pulp and paper is Dendrocalamus strictus with small quantities of Bambusa arundinacea and Ochlandra travancorica. Other species used are Dendrocalamus hamiltonii, Bambusa balcooa, Bambusa nutans, Bambusa vulgaris, Bambusa tulda, Melocanna bambusoides and Ochlandra rheedii (FAO 1953).

As mentioned in Chapter III about 72 per cent of the present production capacity of Indian paper mills is based on bamboos as the staple raw material (Bhargava 1964). The importance of the plant in the country is thus obvious.

The length of bamboo fibres is 3.0-4.0 mm on an average (FAO 1953) which is substantially the same length as of coniferous wood. Some of the conifers like western hemlock (Tsuga heterophylla), Douglas fir (Pseudotsuga menziesii) and pines from southern United States have longer fibres with an average of 4.0 to 5.0 mm. Generally, however, the fibre length of conifers like spruce, fir and pine is between 2.0 and 3.0 mm. The average fibre length of Dendrocalamus strictus is about 3.0 mm, the minimum and maximum values being 1.0 and 5.5 mm respectively. The Indian bamboo having the longest fibre is Ochlandra travancorica; the average fibre length is 4.0 mm, the minimum and maximum values being 1.0 and 9.0 mm respectively (FAO 1953).

Site requirements

The majority of bamboos thrive at temperature ranges of 48°F to 97°F. Some species, however, grow at high altitudes where temperatures are much lower. Dendrocalamus strictus grows in areas where temperature may vary from 22°F to 116°F and the rainfall from 30 to 200 inches, though for most bamboos, 40 inches seems to be the minimum precipitation required.

Most bamboos are found on sandy loam to loamy clay soils either transported or formed in situ. Usually well drained soils are preferred but bamboos can grow on swampy or wet stream beds also. No bamboo is reported on saline soils (Huberman 1959).

Management

The natural regeneration of commercially important bamboos and their management have been described by Seth (1954). In general the mature culms are cut and regeneration obtained from new culms produced annualy from underground rhizomes. In a few cases clear felling is also done but it increases the cutting cycle as a clear cut clump takes longer to mature than a selectively cut clump. The cutting cycle may be from 2 to 6 years but usually is from 3 to 5 and in the case of Dendrocalamus strictus is usually 4 years. Worked over a long period of years, selective cutting seems to give a somewhat greater yield than clear cutting (Huberman 1959).

Artificial regeneration of bamboos was not being attempted on a large scale till about a decade ago. Considerable more attention has been given to artificial regeneration recently. Bamboos may be propagated artificially, by seed, by division, by offsets, by stem or rhizome cuttings, or by layers (Krishnaswamy 1956). Propagation is best done by seed, but this may not always be possible as bamboo seed is difficult to get every year. Direct sowings as well as transplantings of nursery seedlings have been successful.

Gregarious and sporadic flowering

Very interesting facts have been recorded about the flowering habits of bamboos. Indian bamboos in general, especially those which flower at long intervals, die after flowering and fruiting. Subsequent regeneration appears in the ensuing rainy season, but this takes some years to mature into full sized clumps. At times only some of the culms of a clump flower and die, while the remaining culms do not. This has been noticed very often in Dendrocalamus strictus (Krishnaswamy 1956). Some rare species flower annually without dying, for instance, the Arundinaria wightiana and Ochlandra rheedii of South India. Various cases have also been recorded of bamboos of different species recovering after flowering. In India the absence of new culms is generally held to be a reliable sign of prospective flowering in the following year. This has not been shown to be true in other countries (Huberman 1959). Rhizomes brought from a locality and planted elsewhere have been found to be flowering and fruiting as in the original locality (Krishnaswamy 1956). Gregarious flowering does not extend over the entire geographical distribution of a species but over tracts of varying extent. The interval from germination of seed to the next general flowering seems to be fairly constant. Such intervals for some species have been determined as follows (Huberman 1959):

Bambusa arundinacea	32 years
Dendrocalamus strictus	32 years
Bambusa tulda	35-40 years
Melocanna bambusoides	45 years
Bambusa polymorpha	60 years
Phyllostachys nigra	60 years
Arundinaria falcata	28-30 years

These figures are by no means to be considered as unalterable as in the case of Dendrocalamus strictus, Deogun (1937) has stated that "one or a few culms in one clump or a few clumps in one locality (sporadic), or all culms in one clump and all clumps in a certain area (gregarious) may flower". Mathauda (1952) concluded that the periodicity of the gregarious flowering of the bamboo Dendrocalamus strictus in some localities may be about 30 years and in others more than 65 years or possibly over a century. Krishnaswamy (1956) has mentioned that the gregarious flowering of this species occurs at intervals of 21 years in Madhya Pradesh, 28 years in Madras and 38 years in Uttar Pradesh States of India.

In order that all bamboo plantations may not die in one year after gregarious flowering, the seed for each year's planting, for the 10 years in which the clumps are expected to mature, should be obtained from a different locality.

Yield from bamboo forests

Huberman (1959) has given the yield of *Melocanna bambusoides* as about 15.0 metric tons of air dry material for the three year rotation in East Pakistan. For *Bambusa polymorpha* and *Cephalostachyum pergracile* the figure from India is given as 8.9 metric tons per acre. For *Melocanna bambusoides* it is 8.3 metric tons per acre. The yield from *Dendrocalamus strictus* in U. P. is estimated at 4.0 metric tons per acre on a four year rotation (U. P. Forest Department 1964). Hodge (1957) has estimated that bamboos in the U.S.A. yield 6 times the amount of cellulosic material yielded annually per acre by southern pines.

Pests and diseases

Few serious insect or disease problems are encountered in bamboo stands (Huberman 1959). Powder post beetles cause the most serious damage. Silvicultural and chemical control measures are easy to apply.

Fires and grazing can cause serious injury to bamboo crops.

Need for research

Bamboos grow mostly in the underdeveloped parts of the world and have not received much attention in the industrialized nations. The fast growing nature of these giant grasses and their hardiness (especially that of the clump forming ones) have lately been noticed in a country like the United States of America (Naffziger *et al* 1960). Bamboos have a potential as a raw material in the expanding pulp industry even of the United States, which has large resources of coniferous woods. The world wide interest in bamboos is evidenced by the preparation of a bibliography of 586 references on them, by the Forest Research Institute (1960) for the FAO. The values of bamboos for a country like India is thus tremendous and immediate attention must be paid to intensified research on the tribe. The only bamboo that seems to have been studied in any detail is Dendrocalamus strictus. Studies in U. P. should be undertaken on this important species as well as others that can be introduced in the state and which yield better quality and higher quantities of cellulosic material, for example, Ochlandra travancorica.

Research should be particularly directed in the following fields:

1. Phenology - records of gregarious flowering of different species in different localities should be kept and the available information collected in a central office so that it is available to all concerned. The years when flowering is expected can be anticipated one year in advance and so the planting program can be systematised. It will help in obtaining seed from different localities for planting in the same area so that the bamboo in the entire region does not die in one year. Other phenological data should also be collected.

2. The annual production of new culms, and factors affecting it, for example, age, treatment, origin of crop (seed, rhizome, etc.) should be studied carefully and systematically.

3. Methods of obtaining artificial regeneration in relation to cost involved and the time required for producing a mature clump should be undertaken.

4. Methods of harvesting the crops, selective or clear cutting, and their economics should be studied.

5. Methods of more efficient utilization of bamboos in the mills should be studied.

6. Studies on possible existence of strains which are easier to manage, grow faster and produce better pulping material should be undertaken.

7. Methods of treatments to prevent damage to cut culms should be standardized.

8. Volume and yield data should be collected and the effect of age, site quality, fertilization, number of culms in a clump etc. on them should be studied.

CHAPTER X

CONCLUSIONS

The Forest Department in the state of Uttar Pradesh in India can play a significant part in the development of forest based industries, particularly the pulp and paper industry. This fact has been realized by the administration as is clear from their increasing emphasis on the plantations of fast growing species for the production of pulp-wood.

Of all branches of forest economy pulp and paper industry is almost the only one that is able to increase productivity in step with rising prices. It is therefore the industry in forest economy that can do maximum good to the general economy. Continued increasing emphasis on it is therefore most essential. The Forest Department should gradually orient itself from a timber producing agency to a pulpwood producing or possibly pulp and paper producing agency.

What does not seem to have obtained adequate attention in U. P. is the fact that unless enough long-fibred raw materials are available in the state the plantations of short-fibred eucalypts may not be of much help in expanding the pulp and paper industry. Urgent steps to increase the long-fibred resources are therefore necessary. These include (1) adoption of modern logging techniques in the silver fir and Himalayan spruce forests of the hills; (2) plantations of tropical pines in the lower hills and the plains; and (3) plantations of bamboos in the plains and foothills.

It should also be remembered that a considerable quantity of sugar cane bagasse is produced in the state and can be utilized for manufacture of good paper if cheap long-fibred pulp is available in adequate quantities to provide greater strength.

Moreover it may be possible to induce the farmer in the plains to plant eucalypts and poplars as farm crops and thus produce short-fibred pulpwood. Probably some bamboo can also be grown in this way but is not likely to find its way to the pulpmills, primarily because it will be in great need by the farmer himself. The Forest Department in U. P. should determine the species, varieties, clones or forms that are likely to be economic propositions to the farmer and should disseminate information on them. This action will release the forest area for the production of long-fibred material.

For these reasons the suggestion made by Tiwari (1965) regarding the establishment of a research institute on fast growing species is of very great value. Such an institute must be established as early as possible.

India can become self-sufficient in its needs for paper and paper-board from 1980 till the end of the 20th century if only it can produce enough raw materials. It might not be difficult to produce short-fibred raw materials but long-fibred materials might offer difficulties if attempts to meet the shortage are not made soon in all states.

At present the need to conserve foreign exchange is far more than that for providing good quality paper to Indian consumers at rates as low as in other parts of the world. As the consumption of paper rises in India the more educated classes, which consume a major part of the paper, will not be satisfied with the quality of paper available in India today. Therefore either imports from North America and Scandinavia will have to be allowed or the quality of paper produced in India and its cost will have to be brought to the same level as foreign paper. To avoid imports and also keep the Indian consumer satisfied, requires an improvement in the technology and a reduction in the costs of production. The paper industry will have to overcome these difficulties if it does not want to face foreign producers in its home market.

The Forest departments need not judge their efficiency only from the difference between revenue and costs, for example, in plantations of fast growing species. The best yard stick would be the rate at which they contribute to the growth of industry and production of real national income.

Lack of data has prevented a more exhaustive survey of the economic implications of plantations of fast-growing species. The need for details has been felt throughout this thesis. The necessary data can be secured only by establishment of economies divisions in Indian forestry organizations. Such divisions are also needed for conducting intensive economic analyses before fixing physical targets in forestry development plans and for achieving greater co-ordination with national plans.

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GLOSSARY OF INDIAN TERMS USED IN THE THESIS

General Terms

Bhabar	Slightly elevated ground at the foot of the hills which is characterised by deep layers of boulders and very good drainage. Water table may be very deep in these areas and there are few perennial streams.
Biri	Leaf rolled cigarettes made from the leaves of *Diospyros melanoxylon*.
Cutch	An extractive of the heartwood of *Acacia catechu*, used in dyeing.
Katha	The main extractive of the heartwood of *Acacia catechu*, used for eating with betel leaves, very often after meals.
Tarai	The lower plains zone just south of Bhabar where the water that seeps down the bouldery bed of Bhabar appears at the surface in the form of many small streams. Water table is close to ground level in this zone.
Vanamahotsava	Literally translated means 'the great festival of trees'. Every year with the onset of monsoon, trees are planted in the first week of July in wastelands, house compounds, along roadsides etc.
Zamindar	Land lord.
Zamindari	Pertaining or belonging to Zamindar.

Names of Plants

Babul	*Acacia arabica* (Tree)
Chir	*Pinus roxburghii* (Tree)
Deodar	*Cedrus deodara* (Tree)
Gutel	*Trewia nudiflora* (Tree)
Haldu	*Adina cordifolia* (Tree)
Jamun	*Syzigium cumini* (Tree)

Kanju	Holoptelia integrifolia (Tree)
Khair	Acacia catechu (Tree)
Sabai	Eulaliopsis binata (Grass)
Sain	Terminalia tomentosa (Tree)
Sal	Shorea robusta (Tree)
Semal	Salmalia malabarica (Tree)
Sissoo	Dalbergia sissoo (Tree)
Tendu	Diospyros melanoxylon (Tree)
Tun	Cedrela toona (Tree)