SECTION A

INTRODUCTION

REVIEW OF LITERATURE

STUDY AREA

MATERIALS AND METHODS
Man and forest have never been separable. To begin with the life of human species, forests have been providing food, shelter and clothes to him. Only the way of utilisation has been changing. At present, man is not eating much of forest products directly, but it is still vital as food for aboriginal tribal people and food for its cattle. The building construction, ship-building or any transport vehicle still utilize major produce of forests. It continues to be source of fuel, in shape of firewood or charcoal to 90% of Indian population. The mineral coal is also a product of ages old vegetation. The synthetic cloth and paper are product of wood pulp. Timber continues to be major raw material for furniture and decoration. The wealth of medicinal plants is bountiful and yet to be explored fully. The limitation of agricultural land and mineral resources have no go but to look forward towards inexhaustible resources of forests for food and energy in not too distant future. There shall be no surprise if we start manufacturing synthetic protein rich diets from wood within few decades. A device may be found to convert wood into energy fluids to replace petroleum products.
But the million rupee question is if the forest resources are inexhaustible. Probably not! And definitely not in the way the forests are being exploited in our country. To day we have 350 cities in our country. Within next 24 years we are likely to have 3500 cities having population over 1,00,000 each. All these will utilize timber heavily for building construction. The present population of 600 million is bound to cross 1000 million by the end of century. That will mean much more need for the wood, pulp wood and all the forest products.

Before the population explosion, until beginning of this century, the forests were really behaving like inexhaustible resources and maintaining the equilibrium of nutrition cycle. A certain part of wood-products, trunk wood, leaves and fruits all were used, but these were less than what forests used to grow in the same period. The soil erosion was only an academic term. The trees were utilizing the sun rays, rainwater and minerals of soil and returning the same to soil by way of leaving leaf litter and retaining enough moisture in sub soil. The sun rays are still there, rainfall is erratic now. The plants, with their reduced number still leave leaves as leaf litter, but all that is going back to soil is very little. The leaves are eaten by cattle or burnt in forest fires and washed away. Gone are the days when soil erosion was not more than soil formed by natural decomposition. Gone are the days when soil erosion meant only physical erosion of soil. Now the soil scientists are more worried about leaching away of plant
nutrients, scarcity of leaf litter for decomposition into humus, losing structure of soil; along with the physical erosion of soil. If not properly cared

The forest resources are exhaustible and still faster are exhausting the nutrients of soil, vital to plants. Under normal tropical condition of India it takes 300 years to form 2.5 cms thick new soil; whereas it takes just one year to lose it if vegetational cover is not in the proper form with soil conservation point of view. So it is vital to know what is present state of intake of nutrients in forest trees, how much is retained in them; how much is given back to soil and ultimately how much is retained in soil to renew the cycle for intake of plants. The present project is a beginning of thinking in that direction.

The national forest policy lays down that 33% of the geographical area should be under forests in such a way that 60% of hills and 20% of plains are properly forested. At present India's 23.7% of land area is said to be under forest but this is misleading. Actually this is the area legally declared as reserved or protected forests. It includes vast

\[\text{Total geographical area of India} = 326899000 \text{ hectares}\]
\[\text{Total area under forests of India} = 75351000 \text{ "}\]
\[\text{Total geographical area of M.P.} = 44345900 \text{ "}\]
\[\text{Total area under forests in M.P.} = 16813200 \text{ "}\]

(From facts about Madhya Pradesh Forests 1971)
areas of snow clad mountains, deserts, barren hills, sea beaches, grasslands and forests (not true forests from ecological point of view, because these have become devoid of tree growth because of reckless cutting and failure of nature to rehabilitate). The actual area under true forests ecologically is definitely not more than 15%. The future of billions of rupees invested in multipurpose river and irrigation projects, forest based industries (like paper, rayon, match wood and furniture, etc.) is in the cultivation of rich yielding varieties. In fact entire nation’s economy will be jeopardized if the forest area is not increased, protected and maintained in ecological equilibrium. Thus tomorrow, if not today man made forests are going to occupy a large part of our country’s land. The present forests will need rehabilitation. All this could be done with following points in mind:

(1) Basic limitations due to climate
(2) Basic limitations due to edaphic factors
(3) Basic limitations due to topography

(Assuming that biotic interferences like illicit cutting, fires and grazing could be controlled).

The silviculturists believe that whereas certain climatic factors like temperature could not be changed, yet certain factors could be kept under control, to suit the forest plants. For example, degree of opening of canopy could alter the light falling on earth or plants. The precipitation may not be
changed, but regulation of sub soil movement of moisture vital
to forest plants may be controlled, reducing hazards of both
flood and drought. The toxic effect of frost could be reduced
by maintaining vegetation cover of such species which are frost
hardy. The wind velocity can also be reduced by wind breaks
and shelter belts.

The topographical adversity could be fought by taking
advantage of aspect and choice of species which could with-
stand such drainage and loss of nutrients on higher degree of
slopes. Moderate slopes are of course most suited to forests.

The limitations due to edaphic factors are hard to tackle
and pose a challenge to scientists. A beginning has to be
made and lot of work is to be done. We must know what are
optimum requirements of nutrients in forest plants and in which
plant part these are retained. Does these increase or decrease
with age? Suppose we find that a particular plant needs so much
of a particular nutrient after a certain age, but it does not
return to the soil in available form, will it not be advisable
to eliminate such plants from the crop, after such age. Probably
this will continue to be ruled by the need of man. For
example, teak of very large size obh is required for plywood;
sal of very large size obh is required for railway sleepers,
we shall have to find such species to be introduced in such
localities which return to soil such nutrients in available
form in abundance.
The return of plant nutrients in form of leaf litter or other plant products will continue to be dependant on need of man. Whereas in majority of cases it is stem wood which is needed by man, stems of *Euphorbia* sp. are of no use to man and these decay in forests. The leaves of *Tectona grandis*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Lannea coromandelica*, *Boswellia serrata* and *Aegle marmelos* etc. are not used by man and left to decay in forests but not of *Butea monosperma*, *Diospyros melanoxylon* and *Bauhinia racemosa*. The fruits and seeds of *Madhuca indica* and *Emblica officinalis* are raw material to industries, fruits of *Diospyros melanoxylon*, *Buchanania lanzan*, *Aegle marmelos* are eaten but not of *Tectona grandis*, *Lannea coromandelica*, *Terminalia tomentosa* or *Anogeissus latifolia*. Similarly most of barks are left to decay in forests but *Terminalia arjuna* bark is priced highly for tanning. Roots, after the main tree is cut, generally decay in forests, but *Butea monosperma* root is dug by man for making ropes. Generally twigs are not exported out of forests, but any area in vicinity of thick population shall be devoid of *Anogeissus latifolia* twig being excellent fuel. The utilization pattern of man keeps on and will keep on changing, that will also have to be borne in mind. For example, until few decades ago bamboos (*Dendrocalamus* sp.) and salai (*Boswellia serrata*) were treated a problem in forests now they are assets for pulp manufacture.

It is due to all above facts that scientists have realised
the necessity of forests and started thinking in the direction of research in forestry. In the beginning of present century, a large number of ecological studies were carried out in different parts of world (especially in the continent). But earlier studies of forests were fragmentary in nature concerning such aspects like structure and composition of the forests, regeneration of certain economically important species, nature of succession and climax and edaphic and other factors etc.

The present project aims at finding out mineral composition in different plant parts of some dominant forest trees of Saugar and to study how they vary in different seasons. The mineral composition in various plant parts have also been studied in different age groups. As already pointed out this is just a beginning of a large project, aiming at to correlate it with actual intake from soil and return to soil.
CHAPTER 2

REVIEW OF LITERATURE


Ecological researches in India have been reviewed by Puri (1954), Misra (1954), Mehrhomji (1969) and Misra and Singh (1970).

Ecological work done earlier in local forests mainly contribute to their structural aspects, autecology of some forest trees and study of the distribution and occurrence of fungi in the forest soils. Some notable contributions of such works are those of: Misra and Joshi (1952), Bhatia (1954, 1958), Saksena (1955), Mall and Khan (1959),
Mitra (1961), Bhatnagar (1968) and Rathore (1968).

The functional aspect of the local forests has been studied by Kandya (1974) and Sodhia (1974). Sodhia (1974) studied production and composition of leaves of some forest trees while Kandya studied production of organic matter and biomass in forest trees. Present work deals with some aspects of mineral circulation, nutrient composition and seasonal variation in some dominant forest trees. It appears that this line of work remain untouche by previous workers. However, Desmole (1975) has studied mineral circulation in grassland ecosystem of Saugar and recently Nayak (1977) studied mineral circulation in teak plant.

Nutrient composition of forests has been subject of many studies in temperate and tropical forests. Lutz and Chander (1946) summarised the work done on the amount and composition of litter fall in various temperate forests. Scott (1955) prepared a summary listing amount and chemical composition of organic matter contributed by above storey and under-storey vegetation. Nutrient content of forest litter has also been studied by Kornev (1959), Remesov (1961), Allison and Murthy (1962), Attiwill (1968), Goss et al. (1972, 1973) Egunjobi and Fasehun (1972).

Attiwill (1968) in his study of loss of elements from decomposing leaf litter in mature Eucalyptus obliqua forests concluded that loss of elements from decomposing
Leaf litter follow an order N > K > Ca > Mg > P.

Egunjobi and Fasehun (1972) studied quantities of chemical elements in monthly litter fall of Pinus caribaea L. Their study indicates seasonal variation in litter fall, with the maximum occurring in the dry months of December to March. The litter during study period (July 1969 to June 1970) contained plant nutrients in kg/ha, N=73, P=0.4, K=6.9, Ca=11.4, Mg=2.7 and Na=1.6.

Goss et al. (1972) studied nutrient content of litter fall in a watershed forest and reported 140 kg/ha/year nutrient content of the litter. They observed that N, P, K and Ca contribute 80.6% of the total nutrient composition. In another study in the Hubbard Brook Forest, Goss et al. (1973) measured rates of weight loss and nutrient release (N, P, S, K, Mg, Ca, Zn, Fe, Mn, Cu and Na) in decomposing leaves and branch tissues from yellow birch, sugar maple and beech; and branch tissue from red spruce and balsam fir. They concluded that neither leaf nor branch decomposition differed significantly over an elevational range of 220 metres. Decomposition rates for leaves varied with yellow birch > sugar maple > beech. The decomposition rate of hard wood branches was greater than that of conifer branches but difference between hard wood species was not significant.

Egunjobi (1974) studied litter fall and mineralization in the teak forest and analyzed litter fall for major nutrients.
Mean annual litter fall contained N-90.9, P-10, K-71, Ca-188, Mg-21.6 and Na-2.1 kg/ha. Over 90% of these nutrients were found in leaf litter.

Russian workers have also contributed towards the exchange of chemical elements between soil and vegetation. Some notable contributions are those of Vinokurov and Tyurmenko (1958), Smirnov (1958), Bazilevic (1960) and Bazilevic and Rodin (1966). Vinokurov and Tyurmenko (1958) studied seasonal contents of N and P in humus, upper and lower soil horizons, leaves and roots. Smirnov (1958) investigated seasonal variations in CO2, N, P and K in a podzol-conifer system.

Bazilevic (1960) traced the cycles of N and ash elements in process of steppe soil formation. Bazilevic and Rodin (1966) studied biological cycles of N and ash elements in plant communities of tropical and sub-tropical zones. They carried out their experiments in different parts of the world and compared their data of chemical elements with those of data of Burma (Puri, 1954 and George and Kohli, 1957), China (Zomm and Li, 1958, 1962), U.S.A. (Mohargue and Roy, 1932), U.S.S.R. (Parfenova, 1941, Krasov, 1960 and Troickiz, 1949). They concluded that biological cycle in the tropics is much more intense than in temperate. The total amount of chemical elements (especially N) taken up by the growing organic matter and returned in annual litter are much higher in the tropics as compared to subtropics due to year round growth of plants. In sub-tropical forest, the figures for the biological cycles are quite close
to those of temperate forest.

Seasonal variation and cycling of nutrients have been studied by many workers. Notable contributions along this line are those of Mohargue and Roy (1932, 1937), Mitchell (1936), Well (1951), Williams (1953), White (1954), Tamm (1955), Nye (1961), Miller (1963 a,b,c), Shrivastava (1965), Guha and Mitchell (1966).

Guha and Mitchell (1966) studied seasonal changes in the elemental composition (21 major and trace elements) of the leaves of some deciduous trees (three sycamore and horse chestnut and nine beech trees). They observed marked changes in elemental concentration during growing season.

Distribution and uptake of nutrients have been studied by Rennie (1951, 1955), Ovington (1956, 1957, 1958 a, b 1959 a, 1965). Ovington and Madgwick (1959 a, b) and Cole et al. (1967).

Ovington (1959 b) studied circulation of Na, K, Ca, Mg, P and N in ground flora and organic layers over mineral soil in different age series plantations of Pinus sylvestris and has prepared annual balance sheets for these minerals. He has concluded that with increase in age, the uptake decreases and an overall equilibrium is maintained in the forest.

Ovington and Madgwick (1959 a) studied uptake of nutrients in natural stands birch and analysed chemically different plant parts for six elements namely Na, K, Ca, Mg,
P, and N. He observed that the average percentage of all six elements decreases in the order: leaves, branches and bole; and roots were broadly comparable in nutrient content to the branch or bole material. Relative proportions of the various elements differ considerably for different parts of the trees, viz. the percentage of N in the leaves is almost double that of K or Ca while in the bole the percentage of Ca is nearly twice that of N and four times that of K. Nitrogen, phosphorus and potassium contribute 93% of the total of all six elements. In an age group between 6 to 55 years gross annual uptake of nutrients by the trees, exclusively roots is about 6, 28, 44, 5.6, 4.1 and 56 Kg/ha for Na, K, Ca, Mg, P and N respectively. Leaf fall returns to the soil about half of the nutrient uptake and this is further added by branches falling from trees and the death of weaker trees to give an average annual return 0.5, 25, 34, 4.7, 3.6 and 48 Kg/ha for Na, K, Ca, Mg, P, and N respectively.

Ovington and Madgwick (1959 b) have also studied distribution of organic matter and plant nutrients in plantations of *Pinus sylvestris*. They observed that percentage of the nutrients decreases consistently in the order: leaves, living branches, roots and boles except that the percentage of calcium in the boles is larger than of roots. The different concentration of nutrients in different components of plant results in different weight distribution of
nutrients as compared with dry matter within the trees. Larger trees contain a greater weight of plant nutrients as compared to smaller trees, although smaller trees contain greater percentage of nutrients.

Cole et al. (1967) studied distribution and cycling of N, P, K and Ca in a second growth douglas-fir ecosystem. Variation in the elemental composition of the trees was observed. In cycling between components they studied, uptake and transfer of nutrients from the soil to the tree, return transfer from the tree to the forest floor and leaching from the forest floor to the soil.


Keay and Bettnay (1969) studied concentration of major nutrient elements in vegetation and soils in arid zone of western Australia. Concentration of N and S were highly correlated. In case of Acacia aneura, which was present on most sites, a significant correlation between soil and foliar concentrations of P were observed. Acacia salicina was found to have high amounts of S and Ca. Chenopods
growing in saline conditions had high concentrations of Na, K, Ca and Mg.

Golley et al. (1969) have studied structure of tropical forests in Panama and Columbia. He has compared his data on mineral standing crops, with those of Pinus sylvestris plantations in U.K. (Ovington and Madgwick, 1959) and in moist tropical forest in Ghana (Greenland and Koval, 1960). Nutrient levels in Pinus sylvestris were lower than those in either tropical moist or pre-montane wet forest, except for phosphorus. Phosphorus in living trees of Pinus sylvestris was 4100 gm/m² and for all the organic matter 11,900 gm/m², compared to 3339 and 1201 gm/m², in the organic matter of Panama forest. In Ghana, P (13600 gm/m²) was also greater than in Panama. Potassium and Calcium were low. Magnesium level was equal to those in Panama vegetation.

Likens and his co-workers are studying nutrient budgets, nutrient cycling and several other aspects of a small watershed ecosystem at Hubbard Brook Experimental Forest. A good number of papers have been published on nutrient cycling problems, nutrient hydrologic cycles, nutrient cycles, nutrient budgets, effects of clear cutting (deforestation) and treatment of chemicals on nutrient budgets and seasonal variations in nutrient composition. Some of their notable contributions are: Bormann (1966), Bormann and Likens (1966, 1970), Likens et al. (1967, 1970, 1971), Bormann et al. (1968, 1969, 1974), Likens and Bormann

During the present decade a large number of papers have appeared dealing with mineral circulation aspect in the forest ecosystem. Some such type of works are those of:


Boyd (1970) studied accumulation and uptake of N, P, K and Ca and reported that rapid uptake of various nutrients occur earlier than maximum growth rates.

Siccama et al. (1970) in a study of nutrients of herbaceous layer of Hubbard Brook ecosystem reported that comparable differences occur in nutrient pattern of different herbs.

Tyler (1971) studied distribution and turnover of organic matter and materials in a short meadow ecosystem.

Egunjobi (1971) studied cycle of chemical elements in a 7½ year old stand at Newzealand. The vegetation plus litter contained following amount in Kg/ha of macroelements N-874, P-32.0, S-67.4, Ca-206.4, Mg-117.8, K-306.1, Na-56.6 and the microelements Al-45.3, Fe-11.2, Sr-4.3, Ti-3.0, Mn-2.9, Ba-0.9, Ni-0.45, Cr-0.06, Mo-0.02. They also
estimated quantities of elements in litter fall, though fall and annual estimates of uptake and retention.

Golley (1971) studied mineral cycling in Tropical moist forest in Panama. It was assumed that the forest was in equilibrium condition with inputs equal to outputs, annual net change was negative for Ca, Mg, Na, Fe, and Sr. Turnover time was greatest for potassium (548 years) and for Zine (417 years) and was least for Sodium (3 years) and Iron (4 years).

Nihlgard (1972) studied and compared the plant biomass, primary productivity and distribution of chemical elements in a beech and planted spruce forest of south Sweden. He reported that results for biomass and productivity were equal in two stands but elements like Ca, Mg, and N decreased in the spruce forest soil than beech forest soil while S and Mn increased.

Christersson (1974) studied seasonal variation of nutrients in needles of pines and spruce trees of two different stands. He observed that variation in potassium content was nominal whereas calcium content of both spruce and pine needles increased during the year. The increase was significant in spruce during the summer than in pine and trees growing on clay contained more calcium than the trees growing on sand. Nitrogen content of needles increased in summer and autumn, remained constant during the winter and
then increased in spring. The trend was the same in both spruce and pine. The nitrogen contents of both spruce and pine were similar. Phosphorus contents of spruce decreased throughout the year, remained constant in pine, however, phosphorus contents of spruce and pine were similar. Changes in magnesium contents throughout the year were small. Magnesium contents of pine growing on sand and spruce on sand clay were similar whereas higher in pine growing on clay.

Shewry and Peterson (1975) studied Ca, and Mg contents in plant and soil in a serpentine area on unst Sheltan, U.K.

Trounce (1975) studied levels of mineral elements in *Larix laricina* needles.

Chapin et al. (1975) studied seasonal pattern of nutrient concentration in wet meadow tundra vegetation. Mobile elements such as N, P, and K were present in higher concentration in tundra than in comparable temperate species. The elements reached peak concentration within 10 days of snow melt and decreased to about half of their max.concentration in the course of their growing season.

Ernst (1975) studied variation in the mineral contents of tree leaves in Moimbo woodland. He observed that foliar concentration of micronutrients of moimbo trees fall within the ranges found for northern hemisphere.
Woodwell et al. (1975) studied nutrient concentration in plants of the Brook Haven Oak forest. They report that distribution of nutrient elements vary substantially among the tissues and species of a late successional Oak Pine Forest. The sums for all nutrients ranged between about 13.1 mg/g for Vaccinium angustifolium (dwarf blue berry), Quercus alba (white oak), Q. ilicifolia (bear oak), Garrya vaccina (huckle berry), Kalmia angustifolia (laurel), Q. cocinea (scarlet oak), and P. rigida for most species and most nutrients the patterns of tissue concentrations were similar. Leaves, flowers and fruits contained the highest concentration, heartwood the lowest, while twigs, bark, branches, roots and sapwood were intermediate. The eight elements had decreasing concentrations in this sequence: (N, Ca, K, (P), Mg, S). Elements grouped in brackets change their relative positions with one another in response to environmental influences.

Gosz et al. (1976) traced out the nutrient content of the forest and forest floor at Hubbard Brook Experimental forest during different seasons. The following decreasing order was noted for different elements: N > Ca > Fe > S > P Mn > K > Mg > Na > Zn > Cu.

Most of the studies conducted on mineral circulation and nutrient return to the soil from vegetation considered mainly nitrogen and ash elements leached from litter on the ground, although existing literature contained many indications
that rain leaches elements through living trees. A variety of factors such as species, age of leaves, temperature, positions of leaves, quantity and quality of applied moisture and pathological conditions have been reported to influence the amount of nutrient loss (Witherspoon, 1964).

Tamm (1951), Mes (1954) and Will (1955) in their field experiments collected rainwater below tree crown and chemically analysed it and reported loss of base elements (Na > K > Mg > Ca) from tree crown.

Nye (1961) measured the amount and composition of litter and added with timber fall, the establishing rates of nutrient loss from the vegetation. Reiners (1972) studied canopy through falls in three Minnesota Forests.

These days workers have also started taking interest in atmospheric deposition of nutrients. Studies of Carlisle et al. (1966), Cole et al. (1967), Liken et al. (1967) and Fisher et al. (1968) indicate the importance and variability of such nutrient input into various ecosystems. Nutrient deposited on foliar surfaces through rainfall or dry fallout may be absorbed or adsorbed by plants (Carlisle et al., 1966). Nutrients may also be leached from foliar surfaces by precipitation (Stenlid, 1958) and together with atmospheric input, deposited as enriched solution of through fall on the forest floors (Tamm 1951 a). Canopy through fall, therefore, represents an important nutrient pathway in
terrestrial ecosystems, combining the inputs of new nutrients with the cycling of old nutrients, which had been carried up to crowns to be subsequently leached down.


Sharma (1967) has analysed some desert trees of Churu (Rajasthan) and noted considerable variations in the five species developing in identical conditions. Species were rich in some elements while poor in others. Element contents varied greatly in different plant parts. Potassium and phosphorus were highest in leaves, silica and magnesium in bark while nitrogen in the wood.

Pandeya and Kumar (1963) and Pandeya and Jain (1966) presented a detailed account of mineral requirements of Shorea robusta based on Lundegardh's triple analysis method.

Foruqui (1972) studied organic and mineral structure and productivity of plantations of sal and teak while Satyanarayan (1972) made a study of primary productivity
and uptake of Ca and N in the plantations of sal.

Pandeya and Sharma (1973) determined N and P status in above ground parts of sal (Shorea robusta Gaertn) and concluded that both N and P percentage decrease from leaves to branches to bole in all growth ring groups. Within each fraction percentage of N and P remain almost similar in different age groups of the plants. Percentage nitrogen was recorded more in upper leaves than in lower one. Phosphorus followed an opposite sequence. Values of total N and P increased progressively, with age and resultant curve was hyperbola.

Ramam (1975) gave an account of primary productivity and nutrient cycling in tropical deciduous forests and compared energy relations and nutrient mobility of dry deciduous forests with that of Shorea plantations in upper Gangetic plain.

Reviewing above literature it appears that little attention has been paid in studying mineral circulation aspect of tropical forest ecosystems and especially in India little has been done along this line. The forests of Saurgar remained untouched as far as mineral circulation aspect of forest ecosystem is concerned.

A complete study of mineral circulation in tropical forest ecosystem in fact is a big task which will involve a big team of workers. The present work which is a part
of such study deals with the study of mineral status of some selected dominant trees of the forests of Saugar. In this study seasonal variations of nitrogen and phosphorus, variations of nitrogen, phosphorus, potassium and calcium contents with radial increment in different plant parts and in different species have been traced out.
CHAPTER 3

STUDY AREA

3.1 Location:

Saugar lies a few kilometres north of the tropic of Cancer and occupies almost central position in the country between latitude $23^0$ 10'N and $24^0$ 27'N and longitude $78^0$ 14'E and $79^0$ 21'E. The total area of the district is 10231 Sq.Kms. (District Statistical Book 1973) out of which 3000 Sq.Kms. (34.1%) is under forest cover.

The present investigation was carried out in a mixed stand of Gourjhamar forest range (Fig.1). The study site is situated at about 55 kms. from Saugar on Jhansi - Lakhnadon National Highway (No.26).

3.2 Topography:

Saugar stands over a hilly tract and its average elevation is 517 metres above M.S.L. The elevation ranges from 350 metres in the extreme north to 680 metres in the south west. This hilly tract forms a very undulating topography in the district. The forests are restricted to hilly areas, the hills rising to an average height of 90 to 120 metres from the ground level. The slopes vary from gentle to steep. Seasonal nallahas are common all over, with very
FIG. 1 MAP OF GOURJHAMER RANGE SHOWING STUDY AREA
few perennial streams (namely Bewas, Sonar, Dhasan, Dehar, Bina and Bila).

3.3 Geology:

The greater part of district is situated on the rocks of Vindhyan system and the Deccan trap volcanic series, the latter covering about two third of the area. Vindhyan sandstones appear to be unaltered and probably physical forces alone bring about its weathering. These rocks show two conspicuous sets of joining mutually perpendicular. The quartzites are well cemented and compact, the individual quartz grains are coated with iron oxide at their periphery and the cementing material is either silica or silicates of iron or aluminium.

The Deccan trap consists of ten or more horizontal flows of light grey and dark grey basalt, composed chiefly of augite, intermediate plagioclase, felspar, magnetite, ilmenite and glassy material. It is fine to coarse grained and shows colour jointings at places. The traps weather with spheroidal exfoliations which frequently give rise to large rounded boulders on the outcrops.

3.4 Soil:

The thickness, colour and texture of soil mostly depend upon the parent rocks, climatic conditions and vegetational cover of the soil. Inspite of the uniform climatic conditions in
the region, many diverse soil types do occur side by side. The variations in soil are due to topography, drainage system, erosion and last but not the least due to parent rock. The typical soil derived from deccan trap is black cotton soil and may vary in thickness from 50 cms. to 3-4 metres. At some places the soil is brown to red and even less than 50 cms. deep, sandy soil mixed with boulders and murrum is common on lower slopes of hills, on nallah banks, organic matter content is low in the soil. Due to excessive grazing and repeated fires the plant residues (leaves and twigs) are burnt or eaten and very little is left to nature to decompose it into humus. Due to lack of organic matter, the differentiation of horizons in the soil profile is not marked. While A horizon is seasonal, B horizon is differentiable into some of leaching and accumulation. The soil near nallah banks and on the bottom slopes of hills give rise to the best tree growth, having moisture availability and good drainage.

3.5 Climate:

Climatic conditions also play a great role in controlling growth and distribution of plants. The climate of Saugar has three distinct seasons i.e., rainy, winter and summer each of about 4 months duration.

The rainy season commences from mid-June and continues up to the end of September and is characterised by high
relative humidity, moderate minimum and maximum temperature and heavy rainfall. The rains are followed by winter season which ends by February. The season is marked by low temperature, moderate relative humidity with occasional showers. The summer, which begins in early March and ends in mid June is characterised by very low relative humidity, high temperature and high wind velocity.

3.6 Temperature:

The temperature also exhibits a seasonal trend with varying ranges (Table 1 and Fig. 2 a). The lowest temperature was recorded in January when the mean was 15.2°C. From then onwards rise was rapid, from 20.2°C in February to 26.3°C in March, 32.9°C in April and 33°C in May. In June when Monsoon breaks, the temperature fell down to 31.4°C. Further there was a decreasing trend upto August, when it was 25.6°C. Temperature slightly increased in September and October, when the mean was 27.4°C and 28°C, respectively. In November, temperature again declined to 22.2°C and in December it was 19.8°C.

3.7 Rainfall:

The average annual rainfall at Saugar is 1234 mm (based upon records of last 66 years, from 1910 to 1975). However, during the study period (1974 - 1975) the average annual rainfall was 1148 mm.

Maximum average rainfall (543.5 mm) was recorded in
Fig. 2 Climatic record of Saugar for study period (1974–1975)
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<td>Mean Min.</td>
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<td>20.1</td>
<td>27.9</td>
<td>32.5</td>
<td>41.0</td>
<td>43.1</td>
<td>37.9</td>
<td>27.1</td>
<td>28.5</td>
<td>34.7</td>
<td>35.3</td>
<td>30.9</td>
<td>27.1</td>
<td>32.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aver.</td>
<td>15.1</td>
<td>19.7</td>
<td>27.4</td>
<td>34.7</td>
<td>31.7</td>
<td>31.1</td>
<td>24.9</td>
<td>25.2</td>
<td>28.7</td>
<td>29.3</td>
<td>23.1</td>
<td>19.5</td>
<td>25.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>Mean Min.</td>
<td>10.3</td>
<td>12.8</td>
<td>14.4</td>
<td>22.8</td>
<td>27.6</td>
<td>25.5</td>
<td>22.4</td>
<td>22.5</td>
<td>22.1</td>
<td>21.4</td>
<td>15.6</td>
<td>16.3</td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Max.</td>
<td>20.7</td>
<td>28.4</td>
<td>36.1</td>
<td>39.4</td>
<td>40.9</td>
<td>37.9</td>
<td>36.3</td>
<td>39.3</td>
<td>30.2</td>
<td>32.1</td>
<td>29.0</td>
<td>24.0</td>
<td>32.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aver.</td>
<td>15.2</td>
<td>20.6</td>
<td>25.2</td>
<td>31.1</td>
<td>34.3</td>
<td>31.7</td>
<td>29.3</td>
<td>25.9</td>
<td>26.1</td>
<td>26.7</td>
<td>21.3</td>
<td>20.1</td>
<td>25.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Monthly Mean | 15.2    | 20.2    | 26.3    | 32.9    | 33.00   | 31.4   | 27.1 | 25.6 | 27.4 | 28.0 | 22.2 | 19.8 | 32.1 |
| Mean Max.    | 20.4    | 28.2    | 34.3    | 40.2    | 42.0    | 37.9   | 31.7 | 28.9 | 32.5 | 33.7 | 30.0 | 25.6 | 19.3 |
| Mean Min.    | 10.2    | 12.1    | 16.3    | 25.7    | 24.0    | 24.9   | 22.6 | 22.2 | 23.9 | 22.5 | 22.6 | 14.5 | 14.2 |
| Average      |         |         |         |         |         |        |      |      |      |      |      |      |      | 25.7 |
the month of August (Table 2 and Fig. 2c). November,
December and January were dry months, having no rainfall. In
winters rainfall was recorded only in the month of February
and even that was nominal (4 mm).

3.8 Relative humidity:

Relative humidity is also an important factor in
determining the growth of forest trees. Average monthly
relative humidity (%) was maximum during July to September,
which is the period of maximum plant growth. The minimum
values of % relative humidity were observed in summer months
especially during March to May. The data for relative humidity
which is based on the observations of last 30 years is given
in Table 3 and shown in Fig. 2b.

3.9 Ombrothermic diagram:

The effectivity of the climatic factors like temperature,
precipitation, length of dry period and relative humidity can
be understood in a better way by means of "OMBROTHERMIC
DIAGRAM", (Gaussen, 1960). In this diagram months are
plotted on the base, on the left temperature is recorded in
centigrades and on the right the rainfall in mm. The thermal
and ombric curves are drawn together in order to bring out
the length of the dry period. The scale of temperature is
taken double to that of rainfall, because a month is
considered to be dry when its mean rainfall is less than twice
its mean temperature. Fig. 2b shows that on an average
Table 2: Distribution of rainfall at Saugar* during the study period.

<table>
<thead>
<tr>
<th>Months</th>
<th>1974</th>
<th></th>
<th>1975</th>
<th></th>
<th>Average rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainy days</td>
<td>Rainfall (mm)</td>
<td>Rainy days</td>
<td>Rainfall (mm)</td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>February</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>8.00</td>
<td>4.00</td>
</tr>
<tr>
<td>March</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>April</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June</td>
<td>3</td>
<td>91.0</td>
<td>8</td>
<td>142.00</td>
<td>166.5</td>
</tr>
<tr>
<td>July</td>
<td>13</td>
<td>301.0</td>
<td>15</td>
<td>302.0</td>
<td>301.5</td>
</tr>
<tr>
<td>August</td>
<td>16</td>
<td>655.0</td>
<td>14</td>
<td>432.0</td>
<td>543.5</td>
</tr>
<tr>
<td>September</td>
<td>4</td>
<td>56.0</td>
<td>17</td>
<td>232.0</td>
<td>139</td>
</tr>
<tr>
<td>October</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>77.0</td>
<td>38.5</td>
</tr>
<tr>
<td>November</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total: 36 1103.0 63 1193 1148

Average: Number of rainy days: 50/year.

* Data obtained from India Meterological Department, Nagpur-5
Table 3: Average monthly relative humidity at Saugar*
(Values in percentage)

<table>
<thead>
<tr>
<th>Months</th>
<th>8.30 a.m.</th>
<th>5.30 p.m.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>53</td>
<td>38</td>
<td>45.5</td>
</tr>
<tr>
<td>February</td>
<td>46</td>
<td>26</td>
<td>36</td>
</tr>
<tr>
<td>March</td>
<td>31</td>
<td>18</td>
<td>24.5</td>
</tr>
<tr>
<td>April</td>
<td>24</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>May</td>
<td>29</td>
<td>18</td>
<td>23.5</td>
</tr>
<tr>
<td>June</td>
<td>58</td>
<td>45</td>
<td>51.5</td>
</tr>
<tr>
<td>July</td>
<td>91</td>
<td>82</td>
<td>86.5</td>
</tr>
<tr>
<td>August</td>
<td>90</td>
<td>82</td>
<td>86</td>
</tr>
<tr>
<td>September</td>
<td>83</td>
<td>73</td>
<td>78</td>
</tr>
<tr>
<td>October</td>
<td>58</td>
<td>46</td>
<td>52</td>
</tr>
<tr>
<td>November</td>
<td>43</td>
<td>34</td>
<td>38.5</td>
</tr>
<tr>
<td>December</td>
<td>47</td>
<td>37</td>
<td>42</td>
</tr>
</tbody>
</table>

* Data (Based on observations of 30 years) obtained from India Meteorological Department, Nagpur-5.
7 months (November to May) were Xerio in the study period. Rest of the months were wet and rains occurred mostly from June to September.

3.10 Vegetational cover:

Under the soil and climatic conditions discussed above, thick forest is the natural vegetation cover of the ground. The forests of Saugar are now mostly restricted to hilly areas.

Various foresters, botanists and ecologists have tried to classify the forests of India. The most recognised system of classification is that of Champion and Seth (1968). According to this system the forests of Saugar district are classified as follows:

A. 5 A/ C 1 - Southern Tropical Dry Deciduous Forest
   (Dry teak bearing forest)
   (a) Very Dry Teak Forest
   (b) Dry Teak Forest

B. 5 A/ C 3 - Southern Tropical Dry Deciduous Forest
   Southern Dry Mixed Deciduous Forest

Broadly forests of Saugar may be classified into (i) Teak Forest (with more than 50% of teak trees) and (ii) Mixed Forest (with or without teak).

In the mixed forests the dominant species are Terminalia tomentosa, Diospyros melanoxylon, Anogeissus latifolia, Lannea coromandelica, Butea monosperma and Aegle marmelos (Kandya 1974). There is of course, Tectona grandis the most
dominant species. In fact Ëœak is the natural climax species here. Therefore in the present study only above species were taken into consideration. Whereas, generally the crop consists of Ëœak in varying quantity mixed with these 6 major species (being taken up in this study), pure patches of Anogeissus latifolia, Butea monosperma, Terminalia tomentosa, Acacia catechu, Aegle marmelos, and Lannea coromandelica are also common. These patches of non climax species are generally due to edaphic or biotic sub-climaxes. For example; limitation of soil depth have only Acacia catechu, water logged patches have Terminalia tomentosa and excess of clay allow only Aegle marmelos to grow well.

The other important and commonly found trees here are Lagerstroemia parviflora, Adina cordifolia, Pterocarpus marsupium, Terminalia arjuna, Sterculia urens, Madhuca indica, Boswellia serrata, Mitragyna parviflora, Dalbergia paniculata, Cochlospermum religiosum, Bridelia retusa and Emblica officinalis. The lower storey has Holarrhena antidysenterica, Zizyphus xylopyrus, Cassia fistula and Nyctanthes arbortristis.

The density of cover varied greatly from bare soil to a full cover. However majority area covered in the present study have density between 4 to 7. On the lower slopes of hills, near nallah banks and in between hills, the density is generally 7 to 8, whereas on hill top or plateau the density is generally .3 to .5. The majority of trees
were middle aged to matured age class. The natural regeneration by seedling is almost absent to scanty.

Prasad (1976) has found that young and matured poles (upto 60 cm, obh) contribute 22% to the volume, middle aged (61 to 105 cm, obh) 51% and 27% came from matured plants (more than 105 cm, obh).
CHAPTER 4

MATERIALS AND METHODS

As described in Chapter 3 present work was carried out in Gourjhamar forest range. The study site was mixed stand. Six dominant tree species viz. Aegle marmelos, Anogeissus latifolia, Butea monosperma, Diospyros melanoxylon, Lannea coromandelica and Terminalia tomentosa were selected on dominance basis for the study purpose.

4.1 Sampling:

Sampling of material was done in July-August, November-December and March-April, representing rainy, winter and summer seasons respectively. Trees of all species under study were divided arbitrarily in following five girth (dbh) classes:

<table>
<thead>
<tr>
<th>Girth (dbh) class</th>
<th>Girth (dbh in centimetres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 cm (Sampling)</td>
</tr>
<tr>
<td>2</td>
<td>25 cm (Young tree)</td>
</tr>
<tr>
<td>3</td>
<td>50 cm (Young tree)</td>
</tr>
<tr>
<td>4</td>
<td>75 cm (Mature tree)</td>
</tr>
<tr>
<td>5</td>
<td>100 cm (Mature tree)</td>
</tr>
</tbody>
</table>
Any tree falling in the intermediate girth was included in its nearest girth class. In each girth class composite samples of following ten plant parts were collected:

1. Leaves
2. New twigs
3. Old twigs
4. Branch bark
5. Branch wood
6. Stem dead bark
7. Stem living bark
8. Stem wood
9. Root bark
10. Root wood

However, in case of saplings only following five plant parts were considered:

1. Leaves
2. Branches (bark+wood)
3. Stem bark
4. Stem wood
5. Root (bark+wood)

The fragment new twigs included twigs of the current year, whereas 2-3 year old branches were considered as old twigs. Stem dead bark is that part of bark which is easily detachable from the stem surface. Thus this portion includes cork, whereas living bark consists of cambium, secondary
phloem and cortex.

Leaves, new twigs and old twigs were hand plucked. Stem dead bark was scratched by knife. Stem wood, branch-bark and branch wood were collected with the help of an axe and stem borer. For collection of underground parts, i.e. root wood, roots were dug out upto a considerable depth and then samples were collected with the help of an axe.

After collecting, all these samples were kept in polythene bags, labelled and brought to the laboratory.

4.2 Oven drying:

Samples were oven dried in hot air oven for 24 hours at 80°C. In case of hard samples viz. wood and bark, oven drying was done, for more than 24 hours, till the samples became totally free from moisture. Oven dried samples were kept in polythene bags.

4.3 Grinding:

Oven dried samples were ground to obtain fine powder. Soft samples viz. leaves and stem bark were grinded directly in the electric grinder, whereas hard samples viz. wood, twigs and bark were grinded first in mortar and pestle and then in electric grinder. Finally grinded material was sieved and then fine powder was stored in polythene bags and glass bottles.
4.4 Chemical analysis:

Oven dried and ground samples were chemically analysed in triplicate for estimation of nitrogen, phosphorus, potassium and calcium content.

For chemical analysis of plant material methods given by Jackson (1958) were followed. Nitrogen was determined by microkjeldahl method whereas phosphorus, potassium and calcium by wet digestion method. Estimation of phosphorus was done colorimetrically and that of potassium and calcium by flame photometry.