CHAPTER 2

REVIEW OF LITERATURE
The earliest ecological studies were initiated by Pound and Clements (1898-1900) on grasslands in N. America. Most of the pioneer ecological studies were on grasslands. Earlier ecological studies were limited to phytosociology, autecology and environmental studies. Ecology has gone a radical transformation in the past thirty years. New physical and chemical technologies have made it a field science. Modern technologies have changed the course of ecological research and brought about a revolution in ecological thinking. The modern emphasis in forest research is based on ecosystem approach. Various approaches to the study of forest ecosystems will undoubtedly arise because of geographic individuality and differences in interpretation, objectives and available knowledge, but this cannot affect the fundamental unifying nature of the concept (Rowe et al., 1960). The potential use of the ecosystem concept is now becoming more fully recognised (Croker, 1952; Sjors, 1955), by bringing together a variety of view points it focuses attention upon the fundamental relationships and balance between forest plants, animals and environment. Furthermore, it provides the key to a better understanding of the dynamic nature of forests.

The modern approaches in ecological research are on production studies and environmental effects on population.
An appreciable amount of data is available in this field. The notable contributions are those by Boysen-Jensen (1932); Ovington (1956, 1957, 1965a); Ovington and Madgwick (1959); Kimura (1960); Odum (1960); Tadaki (1960); Tadaki et al. (1961); Whittaker (1961, 1969); Attiwill (1962); Becking (1962); Golley et al. (1962); Whittaker and Garfíne (1962); Rees and Tinckler (1963); Westlake (1963); Loomis et al. (1966); Peterken and Newbould (1966); Satoo (1966, 1968); Kira et al. (1967); Misra et al. (1967); Pandey et al. (1967, 1970, 1972); Whittaker and Woodwell (1968); Knight and Loucks (1969); Misra (1969a, 1969b, 1972); Anderson (1970); Bandhu (1970, 1973); Misra and Singh (1970); Post (1970); Mishra and Kandya (1971-1973); Vyas et al. (1971a, 1973); Agarwal (1972); Axelsson et al. (1972); Garg et al. (1972); Nil-hlgard (1972); Kandya (1974) etc.

Ecological studies in India were initiated by early British officers. They were mainly interested in an economic exploitation of the natural resources of the country. First contribution to the study of ecology in India was by Dudgeon (1920) on "Ecology of Upper Gangetic Plains". After that ecological studies were initiated by many workers like Saxton (1922); Troup (1921); Mooney (1933); Champion (1933, 1936); Bur (1939, 1942); Hewetson (1941) etc. All these studies were mainly confined to systematics, geographical and economic aspects of forests and were purely descriptive and exploratory
in nature, Champion (1944) and Bor (1948) emphasized the importance of ecology in forestry studies.

Earlier ecological studies in forests of India dealt with structure, composition and environmental studies of communities and autecology of selected trees. Notable contributions are those of Sen Gupta (1939); Kadambi (1939, 1941, 1949a, 1950b); Prasad (1943); Misra (1944, 1946a, 1946b); Champion and Griffith (1947); Puri (1948, 1949a, 1950b); Bhatia (1958).

According to Misra and Singh (1970) the history of Indian ecology from 1910 till the present time can be divided into three phases which are:

1. Phase of descriptive ecology : 1910-1940
2. Phase of experimental ecology : 1940-1964
3. Phase of production ecology : 1965 onwards

Though there has been a greater interest of ecologists in production studies yet work on mineral cycling is scanty. Only a few papers are available where complete mineral circulation is traced with inputs and outputs in some temperate and tropical forests but work of this nature seems to be untouched for Indian forests. Increasing attention has been given to the study of exchange of chemical elements between vegetation and soil. Rennie's (1955) summary of nutrient composition of mature temperate forests includes many references to pre-1900 studies. However, the concept of biological cycling of elements in
specific ecosystem compartment and role of each compartment in whole ecosystem is more recent. According to Kornev (1959) the knowledge of the behaviour of elements in natural ecosystems is essential for the efficient management of the forest productivity.

Many studies have involved inventories of forest nutrient composition. Ebermayer's (1876) classic work on the production and chemical composition of forest litter demonstrated conclusively the importance of litterfall in the nutrient cycle of the forest. Lutz and Chandler (1946) summarized the amount and composition of litterfall for a number of temperate forests. Scott (1955) compiled a summary which lists amounts and chemical composition of organic matter contributed by above-storey and under-storey vegetation. Stenlid (1958) presented nutrients return to soil through fallen litter, twigs, branches, bark and fruits. Loss of elements from decomposing leaf litter in mature Eucalyptus obliqua forest in Australia was given by Attiwill (1968). The loss of elements in his study followed the order \( \text{Na} > \text{K} > \text{Ca} > \text{Mg} > \text{P} \). Egunjobi and Fasehun (1972) observed the quantities of chemical elements in monthly litterfall of Pinus caribaea. According to them annual litterfall was 1875 Kg/ha which contained 48.2 Kg/ha of ash and 7.3 nitrogen, 0.4 phosphorus, 6.9 potassium, 11.4 calcium, 2.7 magnesium and 1.6 sodium in Kg/ha. Gosz et al. (1972, 1973) reported 140 Kg/ha/year nutrients in litter of a
watershed forest. N, P, K and Ca accounted 80.6% of the total. They also measured weight loss and nutrient release in decomposing leaves and branch tissues from yellow birch, sugar maple and beech and branch tissues from yellow red spruce and balsam fir. Egunjobi (1974) made an estimation and analysis of litterfall in a teak stand of Western Nigeria. He concluded that over 90% of the total nutrients were present in leaf litter.

Russian scientists have been concerned particularly with evaluating the magnitude of organic matter turnover and element exchange between vegetation and soil. Data have been published for Russian forests of mixed Oak by Mina (1955), of birch by Smirnova and Gorodentseva (1958), and for spruce by Sonn (1960), Monakov (1961), and Marchenko and Karlov (1962).

and nutrient content and circulation, parallel to the zonation of plant formation.

A considerable amount of work has been done on mineral circulation by a number of workers in different parts of the world. A study of nutrient cycles in tropical forests was made by Nye (1961). He measured the amount and composition of litter and of rain falling beneath tropical forests of Ghana. Miller (1963a, b, c) observed the immobilization, seasonal variation and cycling of nutrients in a hard beech in New Zealand. Numerous studies have been made on the mineral cycling by Ovington (1957, 1958, 1959a, 1959b, 1965a, 1965b) and Ovington and Madgwick (1958, 1959a, 1959b) in forests (principally pine, birch and oak woods) of U.K. Cole et al. (1967) traced the distribution and cycling of nitrogen, phosphorus, potassium and calcium in the second growth Douglas-fir ecosystem. Duvigneaud and Denaeyer (1968) made some studies on biomass, productivity and mineral cycling in deciduous mixed forest in Belgium. They also presented biological cycling of minerals in temperate deciduous forests (1970). Egunjobi (1967, 1969) compared the primary productivity and chemical element cycling in gorse and pasture ecosystems of New Zealand. Stark (1971) studied the seasonal variation and cycling of minerals in tropical forests of Amazon.

Most of the earlier studies on mineral circulation and nutrient return from vegetation to soil considered only nitrogen
and ash elements leached by rain from litter on the ground, although existing literature contained many indications that rain leaches elements from living trees. Tamm (1951), Mes (1954) and Will (1955) conducted field experiments in which they collected rain water below tree crown and chemically analysed it. They showed a considerable loss of base elements from the crown. Will's data indicated that losses were in decreasing order $N > K > Mg > Na$. Nye (1961) measured the amount and composition of rain wash and established the rates of nutrient loss from the vegetation. Attiwill (1966) made chemical composition of rain water in relation to nutrient cycling in mature Eucalyptus forests. Carlisle et al. (1967) analysed tree stem-flow, ground flora, litter and leachates in sessile oak forest and concluded that stem flow contributed small but appreciable amount of $K$, $Ca$, $Mg$ and $Na$. Reiners (1972) studied canopy through-falls in three Minnesota forests.

Minerals are added to woodlands in many diverse ways. Tamm and Toreldsson (1955) and Holstener-Jorgensen (1960) demonstrated that large amount of materials may be blown into woodlands from dirt roads or as soil from near by fields. Nye and Greenland (1960) considered that nutrient input in ecosystem either as precipitation was equal to or exceeded the loss of nutrients by water percolation through soil. Inputs of nutrients as atmospheric deposition and their importance in ecosystem have been studied by Carlisle et al. (1966), Cole
et al. (1967) and Likens et al. (1967).

A voluminous work on nutrient cycling, nutrient budgets and several other similar aspects of a small watershed ecosystem at Hubbard Brook Experimental forest has been done by Likens and his associates (1967-1974). Literature dealing with input through rains and output through run off, seasonal variations in nutrient composition etc. has been produced at this centre. Some important contributions are those of Likens et al. (1967, 1969, 1970, 1971); Bormann and Likens (1967, 1970); Likens and Bormann (1972).

Notable contributions on uptake of nutrients have been made by a number of workers such as Rennie (1955); Menzel (1954); Wright (1957); Ovington and Madgwick (1959a); Loach (1960); Manson and Whitefield (1960); Monakov (1961); White (1964); Will (1964); and Van Den and Wareing (1966). Ovington and Madgwick (1959a) studied uptake of nutrients in natural birch and observed that average percentage of six elements (Na, K, Ca, Mg, P and N) decrease in order leaves, branches and bole.

Some fragmentary studies on the nutrient composition and their status in various plant parts have been done by a number of workers like Metz (1952); Wright and Will (1958); Leyton (1960); Bowen et al. (1962); Smith (1962); Oland (1963); Gagarin (1966); Harada and Sato (1966); Popvic (1966); Chapman
(1967); Borowski and Grochowski (1969); Golley et al. (1969); Harada et al. (1969) and Keay and Bettenay (1969).

Harada and Sato (1966) studied the dry matter and nutrient contents of the stem of mature Cryptomeria trees and their distribution in the bark in Japan while Popvic (1966) investigated nitrogen content of pine stem wood in Sweden. Borowski and Grochowski (1969) made similar studies of pine stem in Rogow. Golley et al. (1969) compared his data on mineral standing crops of Panama and Columbia with those from scotts pine plantations in U.K. (Ovington and Madgwick, 1959) and moist tropical forest of Ghana (Greenland and Kowal, 1960). Keay and Bettenay (1969) during their studies on major nutrient element in vegetation and soils in arid zone of western Australia found a significant correlation between soil and foliar phosphorus in Acasia aneura, high amounts of S and Ca in Acasia salicina and high concentrations of Na, K, Ca and Mg in chenopods growing in saline conditions.

A good amount of work has also been done on leaf analysis by a number of workers. Notable among these are: Alway et al. (1934), Mitchell (1936); Bard (1945); Tamm (1951b, 1955); White (1954); Will (1957); Guha and Mitchell (1965); and Christersson (1974).

A number of papers dealing with mineral contents and mineral circulation have appeared during the last decade.
notable among these are of Boyd (1970); Duvigneaud and Denaeyer-De-Smet (1970); Siccama et al. (1970); Egunjobi (1971); Stark (1971), Tyler (1971); Nåhlgard (1972); Switzer and Nelson (1972); Christersson (1974); Chapin et al. (1975); Ernst (1975); Rochow (1975); Shewry and Petersen (1975); Troung (1975); Woodwell et al. (1975) and Gosz et al. (1976).

Boyd (1970) studied accumulation and uptake of N, P, K and Ca and concluded that most rapid uptake of various nutrients occurs earlier than maximum growth rate of plants.

Duvigneaud and Denaeyer-De-Smet (1970) compared the cycles of minerals in two forests in Belgium. They showed that in Wavreille forest, established on a deep mineral-rich soil, had a luxury mineral cycle of K, Ca and N while Virelle mixed oak forest developed on a shallow, rockey calcareous soil was frugal in turnover of K and N but had luxurious consumption of Ca.

Stark (1971) explored the nature of nutrient cycling and nutrient reserves in Amazonian vegetation. Plants were sampled for leaves, wood, bark, roots, litter and litterfall at twelve sites in Brazil and Peru. He reported that leaves from all sites and all ages were higher in Ca, K, Mg, N and P than other plant parts. All plant parts were higher in all elements than wood except for N and K in Peru. Bark from all sites was consistently high in Ca. While roots had high level of Fe
and Zn. Old leaves showed a tendency to reduce their content of N before they shed.

Egunjobi (1971) observed the cycling of chemical elements in 7½ year old stand at New Zealand and estimated their quantities in the gorse ecosystem. The vegetation and litter contained N, 874; P, 32; S, 67.4; Ca, 206.5; Mg, 117.8; K, 306.1; Na 56.6; of macroelements in kg/ha and following quantities of microelements in kg/ha Al, 45.3; Fe, 11.2; Sr, 4.3; Ti, 3.0; Mn, 2.9; Ba, 0.9; Ni, 0.45; Cr, 0.06 and Mo, 0.02. Quantities of elements contained in average annual through fall and annual precipitation were also estimated.

Golley (1971) studied the mineral cycling in Tropical moist forest in Panama. It was assumed that 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), for Zinc (417 years) and was least for sodium (3 years) and iron (4 years).

Tyler (1971) worked out distribution and turnover of organic matter and materials in a shore meadow ecosystem.

Nil-hlgard (1972) while comparing the plant biomass, primary productivity and distribution of chemical elements in a beech and planted spruce forest of South Sweden found that figures for biomass and productivity were about equal in two
stands but some 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 in chemical content of needles of pines and spruces of two different stands and found that the nutrient status of both plants growing on sand and clay was very similar except for Ca and Mg. Spruce trees, whether growing on clay or sand contained more calcium than pine trees.

Studies on seasonal pattern of nutrient concentrations in wet meadow tundra vegetation by Chapin et al. (1975) showed that N, P and K were present in higher concentrations in tundra than temperate species, within ten days of snow melt the element reached at peak and decreased to about half of their maximum concentration in course of their growing season.

Ernst (1975) observed the variation in the mineral content of leaves of trees in Moimbo woodland. Similar studies were made by Troung (1975) in Laxrix laricina needles. Rochow (1975) studied mineral nutrient pool and their cycling in Missouri forest along with the uptake. Shawry and Peterson (1975) estimated Ca and Mg contents in plants and soil in a serpentine area on Unst Shelton, U.K.

Woodwell et al. (1975) found that distribution of nutrient
element varied substantially among the tissues and species of a late successional oak-pine forest at Brook-haven. Among tissues, flowers, leaves and fruits contained the highest concentration and heart wood the lowest.

Recently Gosz et al. (1976) worked out the nutrient and organic matter content of the forest and forest floor of Hubbard Brook forest during different seasons. The order of abundance of element in forest floor was $N > Ca > Fe > S > P > Mn > K > Mg > Na > Zn > Cu$.

In India, literature on such studies is scanty. Satyanarayan (1972) studied primary productivity and uptake of Ca and N in plantations of sal. Forouqui (1972) observed organic and mineral structure and productivity of plantations of sal and teak.

Ramam (1975) worked out primary productivity and nutrient cycling in tropical deciduous forest ecosystems. He compared natural dry deciduous forest and Shorea plantation in upper Gangetic plains for energy relations and nutrient mobility.

Some work of this type has also been done in Indian grasslands. Agrawal (1973) made ecological studies in the mineral circulation in the grasslands of 'Bhata' soils of Bilaspur. Dakwale (1975) studied the biogeochemical cycles in grassland ecosystem of Sagar.

In India, work on mineral circulation is fragmentary dealing with its few aspects. Majority of work in this field concerns with foliar analysis, notable contributions are those of Puri
(1954, 1959); Puri and Gupta (1950, 1954); Bhatia (1955); George and Kohli (1957); Joshi (1959); Mishra (1961, 1971); Shrivastava (1965); Kohli et al. (1969); Yadav (1970) and Sodhia (1974).

Literature on other aspects of mineral circulation is also scanty. Considerable among these are Pandeya and Kumar (1963); Seth et al. (1963); Kaul and Shrivastava (1964); Pandeya and Jain (1966); Sharma (1967); Bandhu (1971, 1973); Singh (1967, 1969, 1971); Bhatnagar (1968); Misra (1969b) and Pandeya and Sharma (1971).

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

Bandhu (1973) studied biomass and mineral status of a dry deciduous forest near Varanasi. He analysed the plants for N, P and Ca.

Sharma (1967) presented data on chemical analysis of some desert trees and found high concentration of K and P in leaves, of N in wood and of Si and Mg in bark.

Pandeya and Sharma (1971) during their studies in river Narmada's upper catchment area determined the nitrogen and phosphorus status in the aboveground parts of Sal and recorded the following decreasing order of N and P leaves branches
bole. Percentage of nitrogen was more in upper leaves than lower leaves. Phosphorus followed an opposite trend.

A good amount of work has been done on the various aspects of forest ecosystem of Sagar. Misra and Joshi (1952); Bhatia (1958) and Mishra (1961) studied the structure and composition of forests. Studies on formation, development and decomposition of litter layers were made by Bhatnagar (1968). Autecological investigations of tree species and forest herbs were made by Mall (1953); Bhatia (1954); Sharma (1955); Mall and Raina (1957), Rathore (1968) and Nayak (1973). Saksena (1955); Vyas (1963); Verma (1964); Dakwale (1966) and Agrawal (1970) observed the distribution of fungi in forest soils and organic matter overlying the forest soils. Recently some work has been started related to organic productivity (Kand-yay, 1974; and Sodhia, 1974) and mineral circulation in forest ecosystem of Sagar.

The present work dealing with the mineral circulation in some forest trees with special reference to teak is one of such attempts in this direction. The main objects of the present work were to have an estimation of the crop of important minerals in the trees of *Tectona grandis* of different ages and to study the distribution of minerals in different components of trees in different seasons.