CHAPTER VII

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DISCUSSION

The present work deals with studies of the western Himalayan forest ecosystem, situated on the steep slopes and shallow valleys. It incorporates the analysis of vegetation and its variability in different stands, organic matter dynamics, productivity, cycling of nutrients and water budget estimates.

Phytosociology:

Species composition of successionaly different four stands was variable and showed marked differentiations. In F1 stand *P. wallichiana* was found as the dominant species of tree layer owing to its highest phytosociological attributes indicating importance value index in the stand. Associated with it *C. deodara* was observed as codominant based on the importance value index. Other species contributed a little the vegetation as they exhibited very low dominance value in the stand. Shrub layer was dominated by *B. aristata* and *R. moschata* with *C. bacillaris* as codominant species. Variation of lesser magnitudes were observed in the species of herbaceous layer. However, this layer was dominated by *A. schinopris* with *P. Fimbriata* as codominant species.
In stand $F_2$ (MS) tree layer was dominated by $P. smithiana$ whereas $A. spinosus$ was codominant. $T. baccata$ showed poor performance as compared to other tree species. The data envisaged the dominance of $B. aristata$ in the shrub layer while $P. utilis$ could be recognised as a condominant species. $L. quinquelocularis$ showed very low dominance as compared to other species. In herbaceous layer, $A. venustum$ and $P. timbriata$ were the dominant and codominant respectively. Minimum importance value was observed for $U. dioica$.

Tree layer in the $F_3$ stand (MS) was dominated by $P. padus$ whereas $A. indica$ appeared as codominant. Other species contributed little to the species composition as evident from the analytical attributes of $Q. semecarpifolia$ showing lowest importance value. Shrub layer was composed of $B. aristata$ and $L. quinquelocularis$ and others. The former was identified as dominant whereas latter was designated as codominant species. Few plants of $R. orocumbens$ were also found associated with shrub layer but with least dominance. $A. schinoides$ and $P. timbriata$ were the dominant and codominant species of herb layer respectively.

In $F_4$ stand (LS), tree layer was found dominated by $Q. dilatata$ and $Q. semecarpifolia$, whereas other tree species showed low density and dominance. The least dominance value was
observed in case of *T. baccata*. Shrub layer was dominated by *B. aristata* and *P. utilis*, whereas *R. procumbens* showed low dominance. Herbaceous layer was dominated by *P. amplexicaule* and *V. serpens*. The least dominance was observed for *E. strobilifera*.

A comparative study of all the four stands indicated species variability in tree layer only. Species composition of shrub and herb layers, more or less remained the same. However, their density and dominance exhibited differences within the four stands. In the present study it has been observed that there is a general tendency of some species to occur in various ways i.e. as "dominants" in one and "codominants" in others. Similar observation were also made by Raihan *et al.* (1982) in an analysis of forest vegetation at and around Nainital in Kumaun Himalaya. Species like *Viola serpens*, *Adiantum vanustum*, *Athyrium schinopris*, *Fragaria indica*, *Urtica dioica*, *Polygonum amplexicaule*, *Pollinia fimbriata*, *Ophiopogon intermedius*, *Elsholtzia strobilifera* showed these characteristics due to their wide ecological amplitude and strong competitive abilities. Variations in quantitative distributional attributes particularly in herbaceous layer can be due to the differential intensites of biotic influences such as grazing, fire and cutting. Therefore, no definite pattern could be observed in ground flora. On the contrary, tree species maintained constancy to a limited extent which may be owing to their wide tolerance to biotic influences (Kershaw 1973).
The IVI computed for various forest species (tables 2 to 5) clearly indicated that there were well defined communities distributed on the various aspects of the locality. Verma and Das (1980) and Raina (1987) also reported a similar variation while studying phytosociology of Kolars range of forests and bhadarwa forests, Jammu (J & K) respectively.

It appears that the variations in species composition are of common occurrence in Himalayas which is evident by the data observed in the present study and reported by others Saxena et al. (1978).

Biomass of different forest stands:

In all the four stands investigated, maximum biomass was observed in bole 60% to 71% and in branches ranging from 30% to 36% whereas foliar biomass ranging from 3 to 3.5%. Ashton et al. (1978) and Golley (1978) have compiled the biomass estimates for various tropical forests and plantations. The value ranged from 229 to 596 tons/ha. Tanner (1980) reported above ground biomass in his study of four different rain forests of Jamaica which ranged from 229 to 312 tons/ha.

In the present study the average biomass of 445.73 tons/ha was found in *P. wallichiana, C. deodara* forest stand, while
443.3 tons/ha for *A. pindrow*. *P. smithiana* forest stand, in coniferous stands $F_1$ (ES) and $F_2$ (MS) respectively. Whereas in broad leaved stands values were 310.63 tons/ha found in *P. dudus*, *A. indica* forest stands and 264.55 tons in *G. dilatata*, *G. semecarpifoli* $F_3$ (MS) and $F_4$ (LS) forest stands respectively. These values coincide within the ranges of other workers. Whittaker and Likens (1973 a,b) reported a mean value of 350 - 450 tons/ha biomass for some tropical and seasonal forests. However, the present value lies between 60 - 450 tons/ha as reported by Whittaker (1975) for some temperate evergreen and tropical seasonal forests.

Maximum shrub and herb layer biomass was found in $F_1$ stand (2.8 and 0.258 tons/ha respectively). Whereas in $F_4$ stand, the minimum biomass was observed in shrub and herb layer (1.84 and 0.179 tons/ha respectively).

It is evident from the previously published reports by Turner and long (1975), that the values of shrub and herb biomass in the present study are within the range as given for different forests.

However Grier et al. (1974) reported the value of above ground biomass of large shrubs and small trees under douglas fir stand as 6.4 tons/ha and 0.065 tons/ha for herbaceous layer
respectively. These values were higher than those obtained in the present study. The lower value of shrub layer may be because we have not included the small tree in shrub layer, as all trees estimated in the tree layer. While the higher values of herbaceous layer may be due to higher humidity and well developed humus layer in these stands.

On the other hand, the biomass of herb and shrub was higher in comparison to those reported by Singh and Ramakrishnan (1982) in Lailad forest stand of Meghalaya, where shrubs contributed 0.172 tons/ha and herbs contributed 0.008 tons/ha. It was interesting to note that the peak above ground biomass of shrub and herb was found in a decreasing order i.e., $F_1 > F_2 > F_3 > F_4$. The trend may be because in early stage of succession the development of under vegetation is luxuriant as compared to the climax stage.

Organic matter content of the forest ecosystem increases with the advent of the maturity of the ecosystem, the net primary production does not behave like this. According to Rodin and Bazilvich (1967) the absolute amount of the net primary productivity varies greatly in relation to bioclimatic and local ecological conditions. Therefore, a comparison of standing biomass data of forest stands and species of different climatic regions have to be made here with caution.
Productivity of different stands of some selected tree species:

maximum productivity (22.64 tons/ha\(^{-1}\)/year\(^{-1}\)) was computed for F\(_1\) stand where bole, branches and foliage contributed 3.7, 1.9 and 4.3 tons/ha\(^{-1}\)/year\(^{-1}\) respectively in case of C. deodara and 3.3, 1.6 and 7.1 tons/ha\(^{-1}\)/year\(^{-1}\) respectively for P. wallichiana. The higher productivity of P. wallichiana was due to the high contribution of foliage.

On the other hand, stand F\(_4\) constituted mostly by Q. dilatata and Q. semecarpifolia showed lowest productivity whereas the farmer contributed 6.69 tons/ha\(^{-1}\)/year\(^{-1}\) (bole - 2.0; branches - 0.996; leaves 3.7 tons/ha\(^{-1}\)/year\(^{-1}\)) and the latter rendered 5.36 tons/ha\(^{-1}\)/year\(^{-1}\). The low net primary productivity in this stand may be attributed to its slow growth and lesser density of stems ha\(^{-1}\). The total net primary productivity of this stand including shrubs and herbs was computed a 13.5 tons/ha\(^{-1}\)/year\(^{-1}\) which appeared to be low as compared to the rest of the stands. As it is evident from the study the stand approaches the maturity or climax stage the productivity is ought to be lowered as compared to the early successional stands.

In general, higher rates of organic matter production have been reported in the Indian temperate forests as compared to
other temperate region of the world. In temperate zone very few N P P data are available for stands older than about 75 years, however a study of a fairly low SQ, 450 year old douglas fir stand has shown an average tree foliar biomass of 8.9 tons/ha$^{-1}$/year$^{-1}$ Grier et al. (1974). In our study leaves showed a higher production rate i.e. $F_1$ - 11.42, $F_2$ - 11.81, $F_3$ - 12.40 and $F_4$ - 7.39 tons/ha$^{-1}$/year$^{-1}$. The data of the present study envisaged higher productivity of foliage which may be attributed to the variations in the species as well as their size, and also due to differences in climatic conditions. On the contrary, the total net primary productivity of the forests was lower as compared to those reported for equatorial and tropical forests.

Bartholmew et al. (1953) 32 tons/ha$^{-1}$/year$^{-1}$ at Yanambi, Zaire, Kire, et al. (1964) at Chang, Thailand 29 tons/ha$^{-1}$/year$^{-1}$, Nge 1961 at Khade, Ghana 24 tons/ha$^{-1}$/year$^{-1}$.

Above ground net primary production of certain tropical forest has been reported to be in the range of 28.7 to 11.2 tons/ha$^{-1}$/year$^{-1}$ the values being highest for equatorial and sub equatorial regions. Golley, (1978) and Westlake (1963) have revised several estimations of the plant productivity of world and gave the following probable values for average annual net primary production in various zones of the world: For temperate coniferous forests it was found as 28 tons/ha$^{-1}$/year$^{-1}$,
temperate deciduous forests 12 tons /ha\(^{-1}\)/year and tropical rain forests 50 tons/ha\(^{-1}\)/year\(^{-1}\).

**Litter production of four forest stands:**

In the present study maximum litter productivity was observed in F\(_1\) stand for the category others (4.1 tons/ha\(^{-1}\)/year\(^{-1}\)) followed by litter of *P. wallichiana* (2.74 tons/ha\(^{-1}\)/year\(^{-1}\)) and *C. deodara* (2.1 tons/ha\(^{-1}\)/year\(^{-1}\)). The total litter productivity estimated was 9.2 tons/ha\(^{-1}\)/year\(^{-1}\).

Similarly, in all the other three forest stands, the litter productivity was higher for the component marked as others. The lower litter production was found in the stand F\(_4\) (6.3 tons/ha\(^{-1}\)/year\(^{-1}\)). There may be further possible variations in the litter productivity due to high wind velocity. Softening of a part of litter component along with melting snow and others.

According to Bray and Gorhum (1964), the total amount of annual litter fall averaged 1 tons/ha\(^{-1}\)/year\(^{-1}\) in arctic alpine forests; 3.5 tons/ha\(^{-1}\)/year\(^{-1}\) in cool temperate forests and 5.5 tons/ha\(^{-1}\)/year\(^{-1}\) in warm temperate forests, and 11 tons/ha\(^{-1}\)/year\(^{-1}\) in equatorial forests. However, the range in litter production within different major climatic zones is rather wide. Thus the results reviewed by Jensen (1974) indicate a range in
total annual litter fall of 1.59 - 9.90 tons/ha\(^{-1}\)/year\(^{-1}\) in cool temperate region, 2.28 - 9.25 tons/ha\(^{-1}\)/year\(^{-1}\) in warm temperate region and 5.5 - 15.3 tons/ha\(^{-1}\)/year\(^{-1}\) in tropical region. Among the oak *Q. petraea* produced 3.86 tons/ha\(^{-1}\)/year\(^{-1}\) of total litter, *Q. rubur* 5.28 tons/ha\(^{-1}\)/year\(^{-1}\), *Q. illex* 3.84 tons/ha\(^{-1}\)/year\(^{-1}\) and *Q. cocifera* 2.28 to 2.6 tons/ha\(^{-1}\)/year\(^{-1}\) (Jensen 1974). The value of coniferous forests and broad leaved forests, recorded for the present study lies well within the range of temperate forests particularly to the warm temperate forests.

Singh *et al.* (1984) reported litter production of some coniferous forests of Himachal Pradesh. He observed that contribution of *C. deodara* was 7.00 tons/ha\(^{-1}\)/year\(^{-1}\), *P. smithiana* 5.6 tons/ha\(^{-1}\)/year\(^{-1}\), *P. wallichiana* 3.1 tons/ha\(^{-1}\)/year\(^{-1}\) and *A.idendrow* 3.00 tons/ha\(^{-1}\)/year\(^{-1}\). In the present study lower rates of litter production are found. The difference in litter production by the species may be because of stem density which varied and there were disturbances like lopping of *Quercus* leaves during winter in some biotic factors. These stands were mostly of mixed type were there was mixture of conifers oaks and other broad leaved species. Therefore it was very difficult to separate leaves of conifers *Quercus* and broad leaved species. Due to this reason, the unidentified litter category named others showed maximum amount of litter.
Nutrient content in different components of some selected species in different dbh classes.

Average nitrogen, phosphorus, potassium, calcium and magnesium contents in different components of 8 tree species reveal significant differences Tables 14 to 23. A comparative study of data for these nutrients in different plant parts clearly indicate that the highest amount of nutrients were found in leaves and least in bole. The amount of minerals found to be were more in plant parts of younger trees in comparison to the older trees. Ovington and Madgwick (1959 C) concluded that in most of the parts, the nutrient concentration decreased with gradual increase in tree size in Pinus sylvestris. Wright and Will (1958) and Ovington and Madgwick (1959 a) obtained similar results for pine and birch, decrease in the mineral content with the increase in girth or age of trees has been observed by many workers such as Bhatia (1955), Mishra (1961) and Shrivastava (1965).

The average concentration of elements in the vegetation of tropics is shown to be higher in the second growth than in the mature forest (Golley et.al. 1975) because of their high requirements. Potassium was more abundant of all the elements in the early successional forests but calcium tended to be more in mature forests. (Bortholomew et.al. 1953 ; Golley et.al. 1975).
In the present investigation it was found that nitrogen was higher in conifers of all components and, in broad leaved forests, calcium was found higher than nitrogen. Many workers have also observed the rich amount of minerals in leaves as compared to other plant parts. In most of other species since leaves are thought to be most active and most of the metabolic processes are carried out here, hence higher amounts of minerals in these seems to be quite obvious. According to Woodwell (1975) most of the nutrient is directed in to metabolically more active tissues concerned with Photosynthesis, nutrient and water uptake and food transport. The above workers also recorded comparatively low amount of minerals in wood.

The relative proportion of various nutrients differ considerably for different plant parts, for example, the amount of nitrogen in almost all the plant parts of conifers was higher as compared to other minerals. The amount of potassium was found to be more than calcium in these species. In broad leaved species more calcium was seen in all plant parts as compared to other nutrients.

Overall broad leaved species showed higher percentage of minerals than conifers. It may be a well known fact that temperate conifers take up less minerals than broad leaved species. The present results appear to be in agreement with the generalization.
made by Lutz and Chandler (1946) and Morosov (1928) that the maximum nutrient requirements of a forest stand come up in early or middle life and then requirements decrease with age (Wright and Will 1958). Ovington and Madgwick (1959 a, b) also obtained similar results for pine and birch. Cole et al. also observed similar findings in a 36 year old plantation of douglas fir, the total amount of nutrients accumulated in foliage > branch > wood > bark > and roots.

With the development of secondry vegetation, the weight of elements in the living biomass increased due to linear increase in biomass with age (Toky & Ramakrishnan 1983). Similar results were found in our study, but with the increase of biomass and age, percentage of minerals were found in decreasing order. The results of this investigation are in conformity with these observations.

Return of minerals through litter fall in different forest stands. :-

A comparative account of nutrients released by different tree species is presented in (Table 25). Amount of different minerals in different components of litter are also computed in gm⁻²/year⁻¹ in table 24. In general it was found that leaves contributed maximum amount of minerals, while twigs, fruits and
cones returned very low amount of these minerals. This study also revealed that maximum amount of N, P, K, Ca and Mg were annually returned to F1 stand which followed the trend i.e., F2 > F3 > F4 stands, some variations occurred in calcium and potassium contents depending upon species in a stand. The annual return of elements through litter fall increased with age and density of trees. The return of nitrogen was found highest, followed by potassium and calcium. Similar observations were reported by Toky and Ramakrishnan (1983).

Table 25 summarises the amount of minerals returned through litterfall by different species in different stands. The differences in quantity of N, P, K, Ca and Mg for these stands observed were more or less similar. The amount of minerals returned through litter were in the order F1 > F2 > F3 > F4. This was due to production ratio in the same decreasing order, but the percentage of nutrient concentration was more or less in an opposite direction. It may be due to that the coniferous species had low concentration of nutrients as compared to broad leaved species.

Foliage accounts for most of N returned through litterfall (Gosz, 1981; Melillo, 1981). Eighty three percent of N is returned annually to the forest floor through litterfall (Cole and Rapp, 1981). Many workers have earlier reported
similar observations of different nutrients. Lamb (1975) reported that N withdrawal from needles of *Pinus palustris* was greater on infertile than on fertile sites. Amount of minerals as observed in the present study confirm the reports of earlier workers for conifers and broad leaved species in the temperate regions.

Physical and chemical properties of forest soils of different stands.

The type of soil may also play a great role, as for eg. the soil in certain Amazonian forests (Stark, 1971 a, b, Klinge and Rodrigues, 1968 a, b) are podosols which contain low quantities of nutrients and have a low exchange capacity. As a consequence, concentration of nutrients in plants are much higher than in the soil and the elements released from the litter are rapidly taken up by the plants. The litter is also low in nutrients than in other forests (Klinge and Rodrigues, 1968 b).

Physical and chemical properties of the soil profile developed on different stands are given in Tables 26 to 29. The soil are mostly coarse textured. Gravel makes up a high proportion of horizons. These soils were heavy textured. Most surface soils are yellowish brown in colour. This colour variation of soils was slightly different for different stands. Soils from
F_1 stand were found more acidic than other three stands. In these soils a narrow range of pH was found from surface to deeper layers.

The results of organic carbon estimation indicated that F_3 and F_4 stand showed maximum percentage of organic carbon as compared to F_2 and F_1 stands respectively. The cation exchange capacity of surface soil was also found higher in F_4 and F_3 stands respectively. Exchangeable Ca and Mg were present in higher quantities in the surface layer and decreased with depth in the profiles.

From the general characteristics such as depth, pH, particle size fractions other soil properties (Tables 26 to 29) it was observed that the F_3 and F_4 stand showed higher amount of minerals as compared to F_2 and F_1 stands respectively. On comparison of physicochemical properties of the soils formed under different stands in the present study, it can be seen that these soils do not exhibit much difference in properties. They differ in physical characteristics like soil particle size pH and organic carbon distribution.

It can be concluded that distribution of difference in these stands, may be due to factors like slope, aspect, temperature, altitude and rainfall etc. These are well known to
influence the distribution of different forest stands. Apart from these factors, some of the soil properties like distribution of exchangeable cations of Ca and Mg mentioned above may also be responsible for the distribution. Similar observation was reported by Dhar and Jha (1983). They also observed that geological structure of the rock, physical and chemical properties of soils from Himalayan Dhauladhar range and Kangra district (H.P.) influence the distribution.

Minerals in soils of different stands. :-

The data of soil mineral in different stands, in different depths of soil profile, expressed as gm\(^{-2}\) are given in Table 30. The figures show that the amount of different minerals in different depths were observed lowest for F\(_1\) stand, whereas higher amounts were found for F\(_4\) stand. In general the nitrogen was found higher in all the four stand at different depths. Calcium content was found higher in F\(_4\) and F\(_3\) stand as compared to other two stands. The variation in minerals i.e., nitrogen, phosphorus, potassium, magnesium and calcium varied significantly in depth of soils. The lowest amounts of minerals were observed at 105 cm depth, while highest values were found in upper 15 cm surface soil i.e., humus layer. The highest amount of nutrients in the upper most layer was due to thick layer of litter which use to decompose slowly in these stands in contrast to tropical
forests, were high temperature, and higher microbial activity is responsible for the release of these minerals from litter. Litter quality is also responsible for litter decomposition. In the present investigation amounts of all minerals were found in a decreasing order from $F_4 > F_3 > F_2 > F_1$ stands.

Soil nutrients N, P, K, Ca and Mg and their circulation in ground floor and organic layers over mineral soil in different age series plantation of *Pinus sylvestris* have been studied by Ovington (1959 b) in detail. He concluded that with increase in age, the uptake decreases and an overall equilibrium is maintained in the forest floor. Toky and Ramakrishnan (1983) reported higher amounts of minerals in the soil. However, in the present study the values of these minerals in soils were lower. The tropical evergreen forests have higher soil fertility than the temperate region. This is supported by Rodin & Bazilevich (1967) and Edwards & Grubb (1982). They are of the view that annual uptake and return of elements may be greater in tropical forests than in temperate forests and a larger proportion of the elements appears to be in the vegetation.

**Hydrological cycle**

**Variation in colour of stemflow and throughfall in different tree species.**

The rain water passes through stems and leaves and gets
coloured when collected as stemflow and throughfall. The colours differed in different species, which were obviously due to leaching and washing and or exuding out of a resins, tannins, dyes and other phenolic compounds. Standard number of colours and ranges for stemflow and throughfall waters are given in Table 31 which emphasized that colours of samples under different tree species varied from lighter to darker shades. These samples were usually dark in the beginning of rains and than further rains they showed dilution and some times became almost colourless.

Colours of stemflow waters of eight tree species were found darker than throughfall waters this variation may be due to relatively larger amount of colouring pigment in stem barks and higher retention of water on stem surface than on leaves. Stemflow water of *Abies bidentata* showed dark cinnamon colour to primrose in comparison to dark colour of other species.

Throughfall water samples showed light colour in four tree species i.e. *Abies bidentata*, *Picea smithiana*, *Aesculus indica* and *Prunus padus*, whereas other species showed almost colourless water. The variation in colours is already shown in Table 31. Similar colour variations in stemflow and throughfall waters were reported by Yadav and Mishra (1980) and Nye (1961). The latter pointed out that the stemflow and throughfall samples were dark coloured under mature tropical forests of Ghana. Our results are in conformity with the above observations.
Distribution of rainfall under four forest stands as a stemflow, throughfall and interception loss

The detailed distribution of precipitation (rainfall) under four forest stands is already, given in table 32 to 35 and (Fig.6). The data clearly indicate that these stands had not much difference in percentage distribution of stemflow, throughfall and interception loss. The average range of stemflow was 5.97% to 6.86%. Whereas throughfall from 73% to 81.86%, interception loss was 11.26% to 19.14%. Maximum stemflow and interception loss was observed in F1 stand. Due to this throughfall water was observed lower than other stands. Minimum value of interception was found in F2 stand. Due to lower interception, maximum throughfall and stemflow water were observed.

Broad leaved stands showed less differences in these values, because these stands (Prunus padus and quercus) had a similar crown structure and density of stems. Opakunle (1989) observed rainfall, in a mature cacao plantation of Ibadan, Nigeria, the variation in throughfall was found 5.9% to about 95.5% of rainfall with an annual mean of 73%, monthly stemflow varied from 0.2% to 8.8%. In his study interception loss ranged between 1.4 and 92.9% of rainfall with an annual mean of 24.3%. The minimum throughfall was about 50% of incident rainfall reported Ray (1970) under Alstonia scholaris in West Bengal.
whereas, as much as 87% was reported under oak *Quercus petraea* by Carlisle *et al.* (1965). Throughfall was recorded 80 - 89% by Hamilton and Rowe (1949) in a partially deciduous shrub vegetation of California.

Voigt (1960 b) reported a throughfall value in red pine (*P. resinosa*) and Rothcher (1963) observed in douglas fir forest the value was 76% of total rainfall. Though there were differences in physiogramy of tree and climatic conditions. The results of stemflow and throughfall of the present stands very well matched with the reports of other workers.

Carlisle *et al.* (1965) reported lower interception percentage for oak in high rainfall area and higher interception percentage in low rainfall area. Ovinton (1954) has also observed that the greater amounts of precipitation was intercepted in light rains and least in heavy rains in oak forests. Similar results are reported by Yadav (1978) in a tropical dry deciduous forest. Table 32 to 35 show the variation in stemflow, throughfall and interception percentage of total incident precipitation as observed in the present study. From these results it is evident that the stemflow and throughfall increase with the incident precipitation, while interception loss decreases. Similar results were observed in the present study.
Contribution of stemflow, throughfall and interception loss by different species in different stands.

In this study percentage of rainfall as stemflow and throughfall was studied in four forest stands of 8 species. Comparative study of these 8 species showed variation in stemflow and throughfall are presented in Table 36. The stemflow and throughfall of different species showed marked variations. The value of percentage distribution of rainfall depends upon the forest vegetation. Different tree species and their tree architecture may be responsible for stemflow, throughfall and interception loss.

The percentage of stemflow and throughfall in the present study revealed that P. wallichiana had a maximum contribution of stemflow water, while Q. semecarpifolia minimum. In general insignificant variation were found in throughfall water of these species which showed more or less similar values. The interception loss varied from species to species depending upon crown structure and leaf area of tree species, as well as absorption or evaporation of water by leaves of tree species. Similar results were reported by Ovington (1954) who found uneven distribution of rain fall and variability in throughfall under an oak plantation. Yadav (1978) also reported similar results for a deciduous forest of Saugar. The results of present study are in conformity with the studies of above workers.
Distribution of precipitation under different forest stands as stemflow, throughfall and interception loss.

A comparative summary, of stemflow, throughfall and interception loss of different forest stands is given in Table 37. The study of stemflow, throughfall and interception loss revealed that coniferous species showed higher values of stemflow and throughfall as compared to broad leaved species. Throughfall values were slightly lower because of higher interception loss. Broad leaved stands also did not show much variation in stemflow, throughfall and interception loss. Variation in values may be due to leaf area and architecture of these tree species.

A little lower interception percentage values were reported by Smith (1974) i.e. 10.6% in Eucalyptus forests, whereas highest 33% reported by Voigt (1960 b) in hemlock. Such higher values of interception losses were also reported for broad leaved tree species by Kittredge (1948) & Clark (1940). Interception loss of about 25 to 50% was reported by Hyner (1940) in the herbaceous vegetation. Summary of total stemflow, throughfall percentage of incident precipitation in different forest stands are given in Table 38, in water which passes through different species and reaches the forest floor are also presented. Results of the present study are in conformity with the ranges given by earlier workers in the literature.
Input of minerals through rains and output of minerals through washing and leaching in different forest stands.

To provide quantitative estimates for the interasystem cycle of different stands, the amounts of nitrogen, phosphorus, potassium, calcium and magnesium removal from the canopy are presented in Table 39 to 43. In this study concentration of these minerals was generally found to be higher in stemflow water, while throughfall water showed low concentration of all these minerals. Similar results were reported by Eaton et al. (1973), Yadav and Mishra (1985), Nye (1961) and Miller (1963). These studies indicated large variability in chemical characteristics of rain water, stemflow and throughfall waters, which mostly depended upon vegetation and geographical location of the study site.

In the present study range of enrichment factors for total N and P in the stemflow and throughfall waters were relatively low. However, difference in N and P content showed little variation in quantity from stand to stand. Calcium and potassium content were higher in all the forest stands. Monthly variations are also estimated and presented in Table 39 to 42. Overall calcium and potassium were higher because of higher cation exchange capacity as compared to other minerals.
Similar reports given by Eaton et al. (1973) and Cole et al. (1975) that the incorporation of N and P elements in various complex compounds makes them more resistant to leaching than those which are present in ionic form in the cell sap e.g. (K and Na) and get easily exchanged. George (1979) reported similar findings about N, P, K, Ca and Mg in his study of Eucalyptus plantation. Therefore, results of the present study are in conformity with the above observations.

**Nutrient budgeting:**

Annual budget of nitrogen, phosphorus, potassium, calcium and magnesium in 8 species of different forest types, and contribution of herbaceous layer was computed. The detailed standing state of mineral uptake, release and return of different trees and different stands are presented in Tables 43 to 46. The amount of herbaceous vegetation uptake and return through it are also shown in these tables.

It was found that F1 stand had the maximum amount of N, P, K, Ca and Mg as compared with other three stands. Significant differences between species to species uptake retention and release of minerals were observed. In conifers nitrogen was taken up in higher quantity, while calcium in broad leaved species. In all the stands phosphorus was observed in the least quantity.
Herbaceous vegetation contributed very little amount and variation in the quantity of these minerals in different stands showed little differences (Fig. 7 and 8).

Similar reports were given by Bhartari (1986) while studying the uptake retention and release of minerals in *Pinus patula* plantation. He stated that the uptake of nitrogen was highest and lowest amount for phosphorus, as compared with other minerals. Uptake of nitrogen vary with site conditions, species, stage of stand development and rate of growth (Cole 1981; Cole & Rapp 1981 & Gosz 1981). Generally nitrogen uptake by forests followed the pattern: temperate > boreal, deciduous broad leaved > coniferous evergreen, with the broad leaved taking up approximately twice as much as the conifers (Cole 1981; Gosz 1981). These results match very well with the present investigation.

**Total crop nutrients in standing stage of different forest stands:**

In this study total crop nutrients in the standing stage of different stands are shown in Table 47. The amount of nitrogen phosphorus, potassium, calcium and magnesium were found to be higher for F1 stand as compared to other three stands. This variation in quantities of mineral because of higher biomass in
the $F_1$ stand the following decreasing trend was observed: $F_1 > F_2 > F_3 > F_4$. The study revealed that conifers of this region showed a very high amount of minerals, whereas broad-leaved stands showed lesser quantity of minerals as earlier reported because of lesser biomass.

The comparative value of amount in standing stage of different species revealed the higher value for $P. wallichiana$ and lower value for $Q. semecarpifolia$. Total crop minerals in different stands can be summarised in the following decreasing order:

- $F_1$: $N > K > Ca > Mg > P$
- $F_2$: $N > K > Ca > Mg > P$
- $F_3$: $N > Ca > K > Mg > P$
- $F_4$: $Ca > N > K > Mg > P$

Greenland and Kowal (1960) reported that most of the minerals are found in the living biomass of trees in moist tropical forest of Ghana. Ovington (1965) stated that in tropical forests there is little accumulation of dead material and the bulk of the nutrients were contained in the living trees. In the present study similar results were found in the standing crop minerals. The reports of earlier workers match very well with the present investigation.
Annual uptake, retention and release of nutrients of different species. :-

Table 48 summarises the annual uptake, release and retention of nitrogen, phosphorus, potassium, calcium and magnesium by different species, as reported by some workers in India and abroad. The values of different minerals were higher than reported by Parashevnikov (1962). The difference may be because of old age of stand and species.

In the present study it was observed that the amount of minerals were taken up by temperate trees were lower as compared to their biomass ratio. In tropical deciduous forests Ramam (1975), Johri (1977) and Nayak (1977) reported higher uptake by trees as compared to tree biomass ratio. In our studies the lower uptake may be due to slow growth of trees in the region. Therefore, the results of present study are in conformity with the earlier reports of those workers.

Ovington (1959) stated that forest research is to be fully effective, and needs to orient towards obtaining a better appreciation of ecosystem, in relation to quantitative studies of biological and physical processes, effective productivity and the accumulation, transformation and flow of energy and materials (water, minerals, elements etc.) through different woodland ecosystems.
In India available information of the quantitative aspects of the processes concerned in forest ecosystem dynamics are too scanty and incomplete. These processes constitute an expression to the forest ecosystems and are perhaps more significant than the trees themselves.