AN ANALYSIS OF THE EFFECTS OF AGROFORESTRY SYSTEMS ON PRODUCTIVITY AND SOIL CHARACTERISTICS

ABSTRACT

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Shifting cultivation which is still quite prevalent in north eastern hills, has caused severe land degradation. Recent studies on evaluation of fertility status under tree-based land use systems have shown their remarkable capacity for restoration of soil productivity by protecting soil, improving soil organic matter status and continuously replenishing nutrients through recycling mechanism. Agroforestry practices have great potential to improve soil fertility via a more efficient cycling of nutrients through above- and below-ground litter inputs and retrieval of nutrients from soil depths where crop roots are not present.

Agroforestry systems differ a great deal in soil working, intercultural operation and chemical treatment, species composition and community structure. Therefore, biomass, productivity and nutrient cycling differ to a great extent from one system to another. However, the analysis of the effects of agroforestry systems on primary productivity and soil characteristics particularly on slopy land situation has not been undertaken in our country. The present study encompassing the effects of four selected agroforestry systems on productivity, soil characteristics and nutrient cycling is a pioneering attempt. The four agroforestry systems selected for the study are alder-based (**AFS 1**), albizia-based (**AFS 2**), cherry-based (**AFS 3**), and mandarin-based (**AFS 4**). The study was carried out at the ICAR Farm, Barapani (Lat. 25^0 39'- 25^0

41' N , Long. $91^0 54'$- $91^0 63'$ E), which is 22 km north of Shillong, the capital of Meghalaya. The altitude of the farm area varies between 952 and 1082 m above msl. The experimental plots representing the four selected agroforestry systems are adjacent to each other and have similar toposequence. The climate is sub-tropical. The soil is clay loam to sandy clay loam and acidic in reaction. The study was carried out over a period of two years (May '92 -April '94) on the following aspects.

1. Weed populations in four selected agroforestry systems.
2. Survival, growth and biomass of the tree species.
3. Distribution and dynamics of fine roots of the tree species.
4. Biomass and net primary productivity of crops and weeds.
5. The litter dynamics.
6. Effects of the four agroforestry systems on physico-chemical properties of soil.
7. Standing state and distribution of elements in soil and in different compartments of trees, crops and weeds.
8. Nutrient cycling in different agroforestry systems encompassing the annual uptake of nutrients from soil, their transfer to various compartments and ultimate release to the soil.

The results of these investigations are summarised below:

Weed density

The number of weed species and weed yield were more in the 'tree only' situation than in the 'tree+crop' situation. The former situation was dominated by the perennial weeds but the latter had greater number of annuals. Alder- and albizia-systems had low weed population density whereas mandarin-system had the maximum weed density.

Survival and growth of trees

Survival percentage of the four tree species did not vary between the 'tree only' and 'tree+crop' situations. Alder and mandarin recorded 100% survival followed by cherry (95%) and albizia (90%). The maximum height growth was recorded for albizia, followed by alder and cherry, while mandarin showed the minimum height. Alder had the maximum diameter (dbh), canopy spread and timber volume followed by albizia and cherry, while the least values were recorded for mandarin. The mean annual increment (MAI) in timber volume was lower than current annual increment (CAI) in all the four tree species. The overall growth in terms of increase in diameter (dbh), height and biomass production was better in the 'tree+crop' than in the 'tree only' situation.

Biomass and productivity of the tree species

Biomass of differnt compartments viz. leaves, branches and twigs, and stem of the tree species was measured during 1992-93 and 1993-94 and the standing stock of roots was determined by collecting soil cores (0-10, 10-20 and 20-30 cm soil depth) during the four seasons. Horizontal distribution of the woody roots at surface soil was also studied. The maximum fine root biomass (FRB) and necromass (FRN) were recorded during autumn season and minimum during winter. The FRB and FRN were greater in the 'tree+crop' than in the 'tree only' situation. The FRB was significantly ($P < 0.01$) greater than the necromass (FRN) in all the four tree species. The FRB/FRN ratio was maximum (3.2) during spring and minimum during rainy season (2). Coarse root biomass (CRB) was maximum during autumn and minimum during winter season. The total coarse root-mass (CRM = CRB+CRN) ranged between 343-3774 kg ha^{-1} in the 'tree only', and 263-3701 kg ha^{-1} in the 'tree+crop' situation. The ranking for CRM was: mandarin >cherry >alder >albizia.

The total root biomass (TRB = FRB+CRB) was highest in mandarin (autumn) and lowest in alder(winter season). Fine roots represented about 76% of the total roots. Fine root concentration decreased with increasing soil depth. The maximum accumulation of fine root was found in the close proximity (upto 0.5 m distance) of the tree trunk. The total root production was maximum in mandarin, followed by cherry and alder and minimum in albizia. It ranged between 4 to 8 t $ha^{-1}yr^{-1}$.

The total net primary production (TNP) of the tree species ranged from 18-23 t $ha^{-1}yr^{-1}$. The maximum TNP (t $ha^{-1}yr^{-1}$) was recorded for alder (22), followed by cherry (20) and mandarin (19), while the minimum was in albizia (18). The percent distribution of net primary production (NPP) in different components of the four tree species ranged from 14-23% in twig and leaf, 10-17% in branches, 21-38% in bole, and 21-44% in belowground parts. In alder, cherry and mandarin 4-11% NPP was distributed in catkins, berries and fruits. In all the four tree species, NPP was high for foliage and bole and low for branches. The contribution of aboveground biomass to total biomass was quite high in albizia (76%) and alder (79%), but in mandarin and cherry it was only 56 and 63%, respectively. In alder (0.39) and albizia (0.22 t $ha^{-1}yr^{-1}$), root nodules also contributed to the belowground productivity.

Biomass and productivity of crops

Soybean and groundnut yield during *kharif*, and linseed and mustard yield during *rabi* was lower in the 'tree+crop' than in the 'crop only' situation. The reduction in yield due to presence of trees ranged 14-31% for soybean and groundnut, and 13-43% for linseed and mustard. The maximum reduction in crop yield was observed in the cherry- followed by alder- and mandarin-systems whereas the reduction in the albizia-system was only marginal. In cherry-, alder- and mandarin-systems the crop yield in the first row (nearest to the tree) was substantially low, and it improved as the distance from the tree increased. But in albizia-system, proximity of the tree did not influence crop yield, though there was some reduction in the intercrop yield as compared to the sole crop. The peak aboveground biomass was maximum in soybean during October (246-271 g m^{-2}), and in linseed during March (106-132 g m^{-2}). Weed biomass attained peak before the crop matured. Initially, the weed biomass was more than the crop biomass, but at later stages soybean, linseed and mustard crops outyielded the weeds. However, in the case of agroforestry with groundnut as the crop, the weed biomass was greater than the crop biomass throughout the growing period. In the 'tree+crop' situation maximum total live biomass (crop + weed) was recorded in October (432-470 g m^{-2} during 1992-93, and 341-370 g m^{-2} during 1993-94). Litter accumulation in the 'tree+crop' situation was very high during *rabi*, due to high amount of litter contributed by the trees as leaffall during the crop growing period.

Belowground biomass

Belowground biomass of crops (except linseed) was much greater than that of weeds. Total belowground biomass (i.e. crop+weeds) in the 'tree+crop' situation was maximum in October 1992 in the cherry system (356 g m^{-2}) during 1992-93, and in September 1993 in the alder system (912 g m^{-2}) during 1993-94. But in the 'tree only' situation the maximum belowground biomass was observed in August in the albizia- (595 g m^{-2}) during 1992-93 and in mandarin-system (612 g m^{-2}) during 1993-94. The percentage of total belowground biomass of weeds present in the top 10 cm soil layer was much greater in the 'tree only' situation (82-84%) compared to the 'tree+crop' situation (66-68%).

Annual ANP and BNP of trees were higher than those of crops and weeds. The ANP in the 'tree+crop' situation ranged 1864-2490 g m^{-2} and constituted about 53-65% of the TNP, whereas the BNP varied 1311 to 1677 g m^{-2}. The TNP values ranged 3474 to 3816 g $m^{-2}yr^{-1}$ under the four systems. In the 'tree only' situation ANP ranged 2034-2722 g m^{-2}, BNP ranged 1162-1539 g m^{-2} and TNP ranged 3400-3884 g m^{-2}.

Litter dynamics of trees

The leaf fraction constituted 64-79% of the total litter in the 'tree only', and 53-76% in the 'tree+crop' situation. Total litter production increased from October onwards and peaked during January (albizia and cherry) or February (alder). More than 80% litterfall in the four tree species was recorded during dry periods (November to April). In the 'tree only' situation, the leaf-, woody- and miscellaneous-litter fractions contributed 63-79%, 15-23% and 5-10% of the total litter production respectively, whereas in the 'tree+crop' situation, the corresponding values for the three litter fractions were 50-75%, 15-25% and 5-25%. Annual litter production (t $ha^{-1}yr^{-1}$) in the four systems varied between 1.3 and 8.1 during 1992-93 and 1.4 and 10.2 during 1993-94.

Physico-chemical properties of soil under the four agroforestry systems

Physical properties of soil

Water holding capacity and porosity of soil improved marginally under the agroforestry systems but in the sole crop situation there was a decline. Bulk density decreased by 6% under agroforestry systems but it increased by 5% in the sole crop situation.

Chemical soil properties

Soil oraganic-C content declined significantly with duration of time after initial build up. Total N content of topsoil increased by more than 100% in alder-system, 82-100% in albizia-, 54-63% in mandarin- and only 36-54% in cherry-system over the sole crop situation. Organic-C as well as total N contents were higher in 'tree only' situation as compared to the 'tree+crop' and sole crop situation . In the subsoil layer, organic-C and total N contents of soil were quite low but the trend was same as in the topsoil. The lowest C/N ratios (6.9 and 7.6 in 'tree only' and 7.1 and 8.0 in 'tree+crop' situations) were observed in alder- and albizia-systems. Concentration of Bray's P_2-P in topsoil increased by more than eight fold as compared to initial (1.20 mg kg^{-1})

values, the maximum increase being in albizia and minimum in cherry. Besides the 'tree+crop' situation had higher P content than the 'tree only' situation.

Soil pH was invariably higher in alder, albizia and mandarin systems as compared to cherry-system and the sole crop situation. Exchangeable Al^{+3} decreased drastically in alder- and albizia-systems, whereas in the sole crop situation and other two systems the decrease was only marginal. The decrease in exchangeable Al^{+3} content was corroborated with significant increase in soil pH during the same period.

Exchangeable Ca^{+2} contents of topsoil first declined and then increased. However, in the sole crop situation there was a gradual decline in exch. Ca^{+2}. Maximum increase was recorded by albizia system followed by alder and minimum in cherry system. The exch. Mg^{+2} contents of topsoil recorded a gradual increase in all the cases. But in the subsoil layer, there was a decline in 1992 and then an increase in 1994. Exch. K^{+1} increased in alder, albizia, and mandarin systems, and also in sole crop situation but in cherry system it showed some decrease.

The total exchangeable cation (Ca^{+2}, Mg^{+2} and K^{+1}) contents of soil increased in the agroforestry systems, the maximum being in the albizia-system folliowed by the alder-system.

Nutrient cycling in agroforestry systems

Tree leaves had the highest concentration of elements followed by fruits and branches, and the bole had the lowest. The concentration of N in the leaves was ca 1.6 times greater in alder and albizia than in cherry and mandarin. Weeds showed a markedly higher concentration of P compared to trees and crops. Further, fruits and grains had higher concentration of K as compared to branches, bole, root and litter in trees, and shoot in crops. Among the cations, there was preponderance of Ca and K in the leaves and branches of trees. Crops showed a markedly higher concentration of Mg than trees and weeds. The amount of almost all elements was greater in the 'tree+crop' situation than in the 'tree only' situation. Among the four tree species, alder contained maximum nutrients followed by albizia, while mandarin had the lowest. The crops grown in the agroforestry systems, such as soybean, groundnut, linseed and mustard, and weeds contained a large amount of nutrients in their above- and below-ground parts. Due to better crop growth and higher grain yield, a greater stock of nutrients was recorded under albizia system, whereas the lowest stock was recorded under cherry system. In weed species, the shoot portion had more K than N. In the 'tree only' situation perennial weeds stored more nutrients in their aerial parts.

Among the four systems, the uptake of N, K and P was highest in the alder-system and lowest in the cherry system. However, Ca content was highest in the albizia- and Mg in the mandarin-system. The pattern of uptake of nutrients was as follows: **N > Ca > K > Mg > P**. The trees absorbed between 47-65% N, 43-54% Ca, 41-48% K, 34-48% Mg and 26-40% P in the 'tree+crop' situation. The corresponding value in 'tree only' situation was 44-60, 35-50, 37-47, 42-57 and 22-34% N, Ca, K, Mg and P in that order respectively.

Significant amounts of nutrient from the soil pool were taken up by the agricultural crops (soybean, groundnut, linseed and mustard) in the 'tree+crop' situation. The rate of uptake by the crops was highest in the albizia system followed by mandarin system, while the lowest uptake by crops was recorded in the cherry system. In the 'tree+crop' situation the nutrient uptake by weeds was also significantly high.

Tree litterfall, crop residue, weed debris, decomposing roots, externally supplied manure (FYM) and fertilizers applied for crops were the important sources of nutrient input to the soil. Annually, a considerable quantity of nutrients was added to the soil. The amount (kg ha^{-1}) ranged from 111-182 for N, 16-20 for P, 77-96 for K, 82-161 for Ca, and 42-70 for Mg in the 'tree+crop' situation. The corresponding amounts in the 'tree only' situation ranged from 113-185, 18-23, 80-137, 80-160, and 30- 61 kg $ha^{-1}yr^{-1}$ respectively, for the nutrients in that order. The alder system recycled maximum amount of N, P, K and Ca into the soil, the lowest amount was recycled in the mandarin system. However, the amount recycled of Mg, was more in the cherry- and mandarin-systems than in alder- or albizia-systems. A high amount of nutrients was exported through pruning of branches and leaves from trees in the alder-, albizia-, and cherry-systems, and through the harvest of straw/stalk and grains of agricultural crops in the case of 'tree+crop' situation. Maximum loss of N (54-72%) was through harvesting of grains and removal of straw/stalk of crops. But in the 'tree only' situation the loss of nutrients occurred only through pruning of branches and leaves. The loss of nutrients was maximum from the alder-, followed by albizia-system and the lowest was from the cherry system. The largest stocks for all the elements except K were contained in the soil pool. Even the alder system which contained the largest biomass, stored 91% of system's N, 97% of P, 93% of Ca and 92% of Mg in the soil.

It is concluded that alder and albizia tree species make excellent associates in agroforestry systems, promoting higher availability and faster cycling of nutrients. Besides, the requirement of external inputs into these systems is much lesser compared to the cherry- and mandarin-systems.

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