# RESIDUAL EFFECT OF AGROFORESTRY LANDUSES ON SOIL FERTILITY

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## Introduction

Agroforestry landuses fulfill both productive and service functions. The main productive outputs are foodgrains, fuelwood and fodder but the most important service function is soil conservation. It means not only control of erosion but also includes the maintenance as well as improvement of soil organic, physical and nutrient status (Lyndgren and Nair, 1985). In addition, agroforestry helps to ameliorate landuse problems through cultivation of multipurpose trees in normal soils (Young, 1988a). In modern sense, soil conservation can be regarded as control of erosion coupled with maintenance of soil fertility (Young, 1988b). Grewel *et al.* (1994) reported that agroforestry system provided much higher economic returns.

Alley cropping is an agroforestry system recommended for the humid tropics (Van Den Beldt, 1990; Kang *et al.*, 1985) to improve soil fertility, reduce soil erosion, better use of labour resources and reduce conversion of grazing land into crop land by intensive cropping. Inclusion of woody species in agroforestry system helps soil fertility maintenance due to their efficient nutrient cycling. This paper shows the residual effect of tree and agroforestry system on soil fertility after completion of tree cycle.

## Material and Methods

*Site description* : The study conducted from 1983 to 1995 at Research Station, Selakui of Central Soil & Water Conservation Research & Training Institute, Dehra Dun located at 30°20'40" N latitude, and 77°52'12" E longitude, at an elevation of 517 m amsl. This experiment was conducted on marginal land, a fine silty hyperthermic, Udic Haplustalf with silty loam texture up to 20cm in depth and silty clay in deeper horizons. The soil had medium fertility with 0.095% total nitrogen, 20.7 ppm phosphorus and 68.4 ppm ammonium acetate extractable potassium. The silty loam soil at the experimental site is quite erodible with soil erodiblity factor (K) of 124 $kg^{-1}$ $ha^{-1}$ per unit of rainfall factor (Narain *et al.*, 1994).

*Landuse treatments* : Treatments imposed in two sequences are detailed in Table 1. The size of nine plots was 90 x 15 m. In agroforestry (alley cropping) landuses, paired rows of *Leucaena* and *Eucalyptus* were planted as tree barriers at 4.5 m intervals. Alternate paired rows were removed every third year to minimize tree

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**Table 1**

*Details of landuse systems in the soil conservation experiment*

| Plot No. | Sequence I 1983-85 | Sequence I 1986-88 | Sequence II 1989-92 |
|---|---|---|---|
| 1 | *Chrysopogon* grass (0.75 x 0.75 m) | Contd. | Turmeric (0.6 x 0.2m) with paired rows of *Leucaena* hedges (1.5 x 1.5m) at 22.5 m |
| 2. | Maize (0.75 x 0.24m) – wheat (0.22 x 0.05m) | Contd | Maize (0.6 x 0.2m)–wheat (0.22 x 0.05m) with paired rows of *Leucaena* hedges (1.5x1.5) at 22.5 m. |
| 3. | Maize-wheat+paired rows of *Leucaena* trees (1.5 x 1.5m) at 4.5m | Mize (0.75 x 0.24m) + wheat (0.22 x 0.05m) with paired rows of *Leucaena* trees (1.5 x 1.5m) at 10.5 m | Maize (0.6 x 0.2m) with paired rows of *Leucaena* trees (1.5 x 1.5m) at 22.5 m |
| 4. | Maize–Wheat+paired rows of *Eucalyptus* trees (1.5 x 1.5m) at 4.5 m | Maize (0.75 x 0.24m) + wheat (0.22 x 0.05m) with paired rows of *Eucalyptus* trees (1.5 x 1.5m) at 10.5m | Maize (0.6 x 0.2m) with paired rows of *Eucalyptus* trees (1.5 x 1.5m) at 22.5m |
| 5. | *Chrysopogon* (0.75 x 0.75m) + paired rows of *Leucaena* trees at 4.5 m | *Chrysopogon* (0.75x0.75m) + paired rows of *Leucaena* trees at 10.5m | Turmeric with paired rows of *Leucaena* trees at 22.5 m |
| 6. | *Leucaena* trees (1.5 x 1.5m) | Contd. | *Leucaena* trees (3.0 x 1.5m) |
| 7. | *Chrysopogon* + paired rows of *Eucalyptus* at 4.5 m | *Chrysopogon*+paired rows of *Eucalyptus* at 10.5m | Turmeric with paired rows of *Eucalyptus* trees at 22.5m |
| 8. | *Eucalyptus* trees (1.5 x 1.5m) | Contd. | *Eucalyptus* trees (3.0 x 1.5m) |
| 9. | Cultivated fallow (weed free and tilled up and down) | Contd. | Contd. |

Tree species and Crop varieties
*Eucalyptus - E.* hybrid: *Leucaena - Leucaena leucocephala*
Maize - Composit (Vijay); Wheat - H.D. 1981; Turmeric - Local

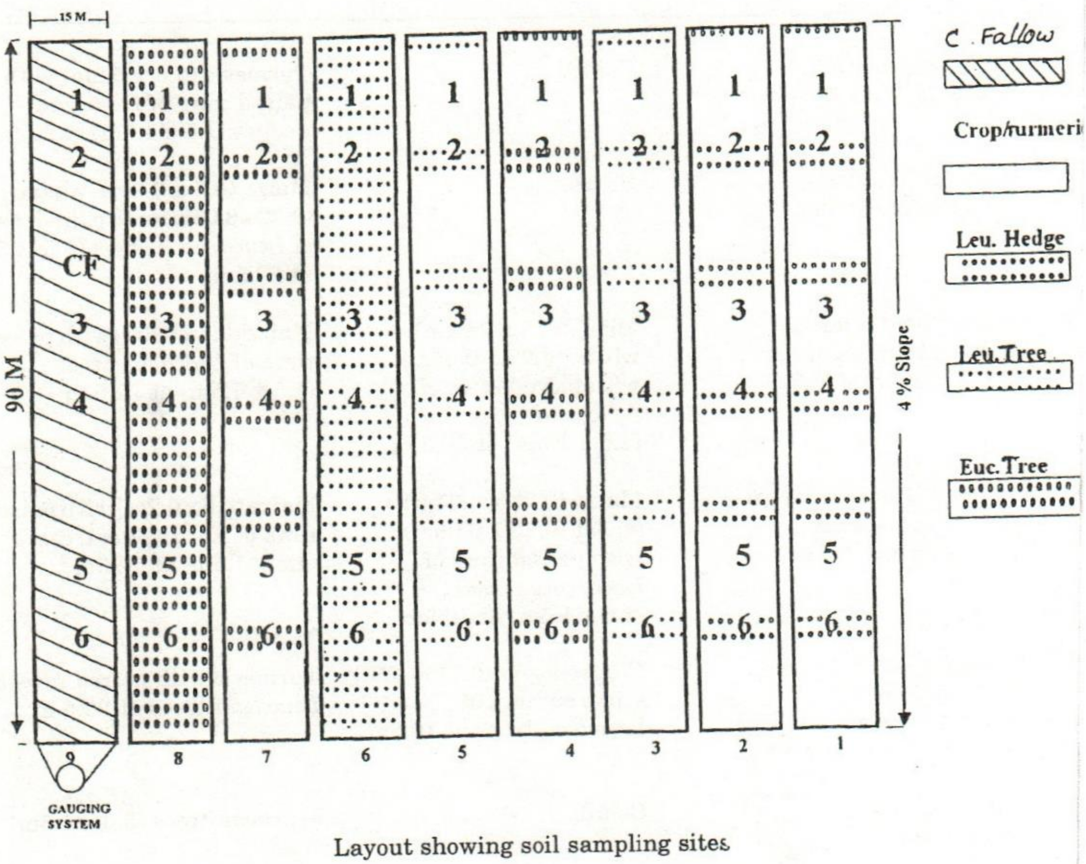
crop competition and maintain reasonable crop yield. In the second season, some of the treatments were modified (Table 1). Hedges were introduced and pruned at the height of 15 cm twice a year before sowing maize and wheat are recycled as surface mulch in the alleys after sowing of crops. The harvest of green biomass 1.27 Mg $ha^{-1}$ in June and 1.35 Mg $ha^{-1}$ in November covered approximately 1/3 of the surface area of the alleys. After drying, the twigs were removed and leaves were allowed to decompose in the field.

After harvesting the trees and crops in 1993, the field was cleaned by uprooting the roots (no crop was sown during 1994) and sorghum was sown in 1995. During sorghum growing period (1995) the soil samples were collected from 6 spots up to 90 cm depth (Sr. No. 1, 3, 5 in cropped and 2, 4, 6 under trees or hedges) (Fig. 1). Soil was analyzed for organic carbon (Walkley and Black, 1934); total nitrogen (Piper, 1944); available phosphorus (Olsen *et al.*, 1954) and potassium content (Stanford and English, 1949).

## Results and Discussion

Organic carbon content in the cultivated fallow ranged from 0.25% to

**Fig. 1**




Layout showing soil sampling sites

0.45%. The content was recorded 0.30 to 0.97, 0.36 to 0.84, 0.47 to 0.69% and 0.34 to 0.74% for sole tree cultivation of *Leucaena*, *Eucalyptus*, *Leucaena* hedge + crop and tree + crop respectively at different depths (Fig. 2).

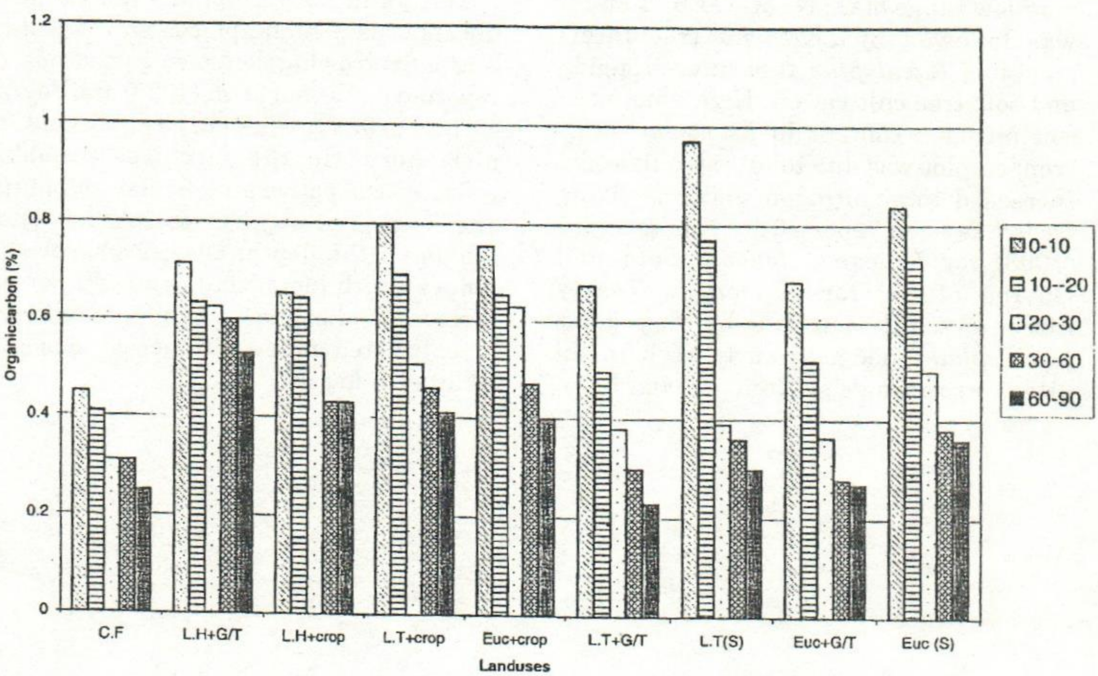
The soil under sole tree recorded organic carbon 102.22%, tree+crop had 62% and *Leucaena* hedge+crop soil recorded 52.25% more organic carbon than surface soil under cultivated fallow. The tremendous increase in the tree and agroforestry system had the following reasons :

- After 9 years experiment, the soil loss was 39.01 Mg/ha in cultivated fallow soil whereas in agroforestry landuse it was 8.68 and sole tree cultivation it was 0.56 Mg/ha (Narain *et al.*, 1998). Due to this, the sub-soil was exposed and recorded 0.45% organic carbon content in cultivated fallow.
- Litter falling and its decomposition increased the organic carbon content (Sanginga *et al.*, 1989).

When compared the *Leucaena* tree and *Eucalyptus* tree inter-cropping, organic carbon content was high in *Eucalyptus* (Table 2). It indicates the role of mineralization and immobilization turn over in releasing the organic carbon (Sanginga *et al.*, 1989).

*Total Nitrogen* : The surface soil under

**Fig. 2**




Residual effect of agroforestry landuses on organic carbon status

**Table**

*Effect of agroforestry landuses*

| Landuses | 1983 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-10 | 10-20 | 20-30 | 30-60 | 60-90 | mean | 0-10 | 10-20 |
| C.F. | - | - | - | - | - | - | 0.407 | 0.347 |
| L.H+G/T | 0.712 | 0.673 | 0.644 | 0.569 | 0.470 | 0.614 | 0.829 | 0.784 |
| L.H.+crop | 0.748 | 0.694 | 0.661 | 0.578 | 0.507 | 0.638 | 0.644 | 0.597 |
| L.T+crop | 0.685 | 0.630 | 0.573 | 0.529 | 0.488 | 0.581 | 0.883 | 0.654 |
| E.T+crop | 0.627 | 0.622 | 0.612 | 0.553 | 0.473 | 0.577 | 0.965 | 0.724 |
| L.T+G/T | 0.565 | 0.485 | 0.443 | 0.415 | 0.395 | 0.461 | 0.841 | 0.812 |
| L.T. (sole) | 0.596 | 0.586 | 0.543 | 0.484 | 0.484 | 0.539 | 1.126 | 0.832 |
| Euc. (G/T) | 0.584 | 0.570 | 0.547 | 0.418 | 0.367 | 0.497 | 0.912 | 0.668 |
| Euc. (sole) | 0.578 | 0.572 | 0.505 | 0.455 | 0.375 | 0.497 | 1.012 | 0.676 |

cultivated fallow recorded 0.062% total nitrogen and it was increased by 98.39%, 94.4% and 79.0% for *Leucaena* hedge + crop, sole tree and tree + crop cultivation respectively (Fig. 3). A similar trend in tree + crop was reported by Khonje (1989) and Atta Krah (1990).

*Leucaena* hedge cultivation recorded very low range of C : N ratio as 6 : 1 and it was followed by *Leucaena* tree inter-cropping, *Eucalyptus* tree inter-cropping and sole tree cultivation. High amount of soil nitrogen content in *Leucaena* inter-cropped plot was due to nitrogen fixation. Increased total nitrogen under N fixing trees has been reported by Kumar *et al.* (1998) for *Leucaena leucocephala* and Gavina (1987) for *Gliricidia*. Yearly nitrogen contributions by *Leucaena leucocephala* hedge rows to crop in an alley cropping system have been estimated at 120 kg $ha^{-1}$ (Balasubramanian and Sekayange, 1991).

*Phosphorus* : Available phosphorus (Olsen's) content was higher both in inter-cropping of *Leucaena* hedge + crop (11.72 ppm) and tree + crop (11.2 ppm) than that of sole tree plantation (5.47 ppm) (Fig. 4). This may be due to addition of phosphorus fertilizers in alley cropping and the high phosphorus demand placed on the soil by a rapidly growing sole tree cultivation as reported by Kumar *et al.* (1998) and Jayrao *et al.* (1987). The higher levels of phosphorus in the mixtures probably reflected the active and diverse soil fauna and flora present in these stands. When compared the depth, Olsen's phosphorus reduced with increasing depth due to the removal of phosphorus by plants whereas in cultivated fallow, it increased somewhat with depth.

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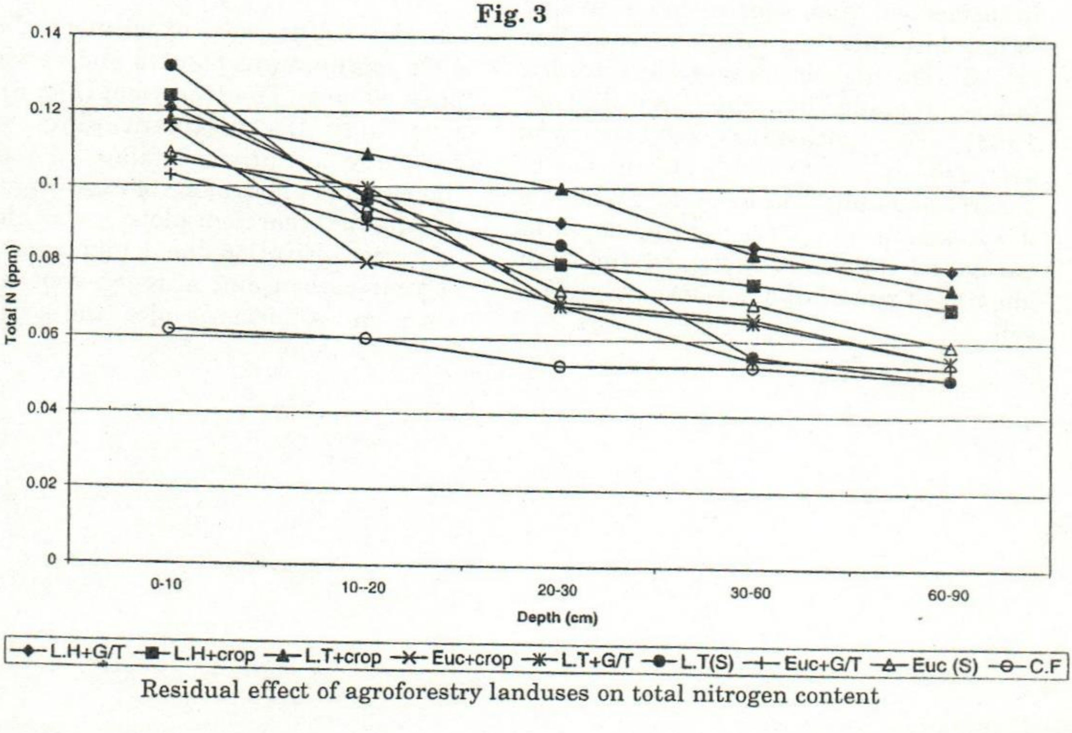
*on organic carbon status*

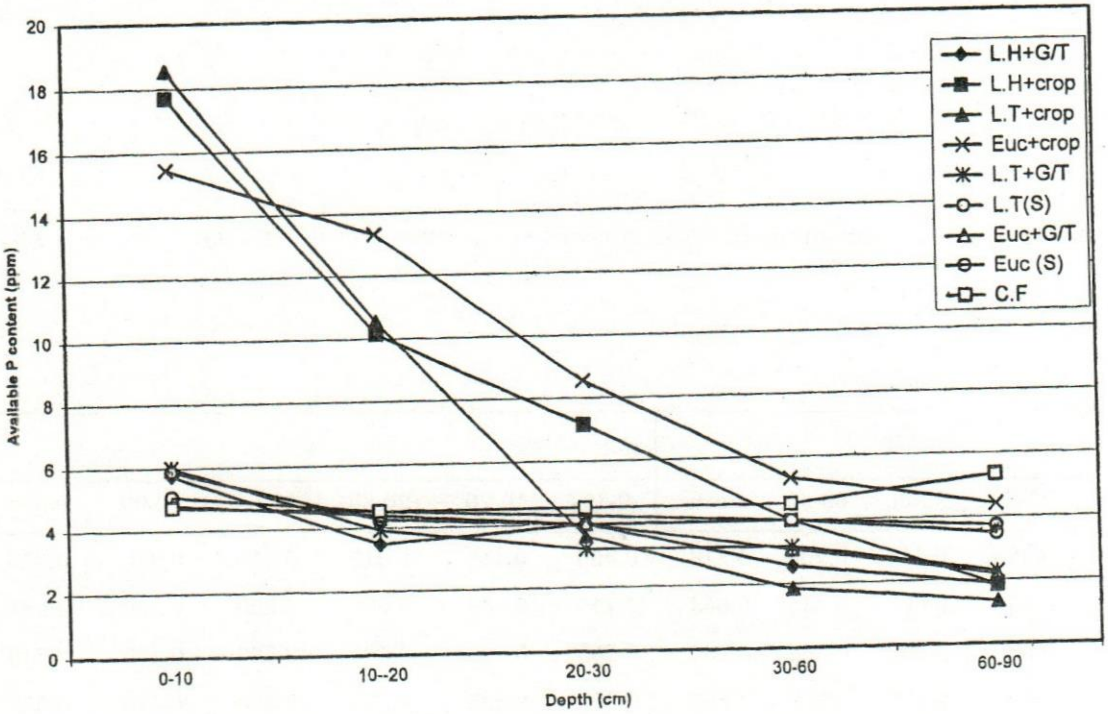
| 1993 | | | | 1995 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20-30 | 30-60 | 60-90 | mean | 0-10 | 10-20 | 20-30 | 30-60 | 60-90 | mean |
| 0.325 | 0.304 | 0.206 | 0.318 | 0.450 | 0.410 | 0.310 | 0.310 | 0.250 | 0.346 |
| 0.670 | 0.601 | 0.432 | 0.663 | 0.715 | 0.635 | 0.625 | 0.600 | 0.530 | 0.621 |
| 0.555 | 0.496 | 0.368 | 0.532 | 0.655 | 0.645 | 0.530 | 0.430 | 0.430 | 0.538 |
| 0.594 | 0.499 | 0.169 | 0.559 | 0.800 | 0.695 | 0.510 | 0.460 | 0.410 | 0.575 |
| 0.556 | 0.499 | 0.148 | 0.578 | 0.755 | 0.655 | 0.630 | 0.470 | 0.400 | 0.582 |
| 0.565 | 0.404 | 0.230 | 0.570 | 0.675 | 0.497 | 0.380 | 0.300 | 0.230 | 0.430 |
| 0.724 | 0.427 | 0.352 | 0.692 | 0.970 | 0.770 | 0.390 | 0.360 | 0.300 | 0.558 |
| 0.617 | 0.488 | 0.184 | 0.574 | 0.685 | 0.520 | 0.365 | 0.280 | 0.270 | 0.424 |
| 0.571 | 0.487 | 0.413 | 0.632 | 0.840 | 0.730 | 0.500 | 0.380 | 0.360 | 0.562 |

**Fig. 3**




Residual effect of agroforestry landuses on total nitrogen content

**Fig. 4**




Residual effect of agroforestry landuses on available phosphorus content

In agroforestry system, the phosphorus content was increased from 3.73 ppm in cultivated fallow in 9.46 ppm in various treatments.

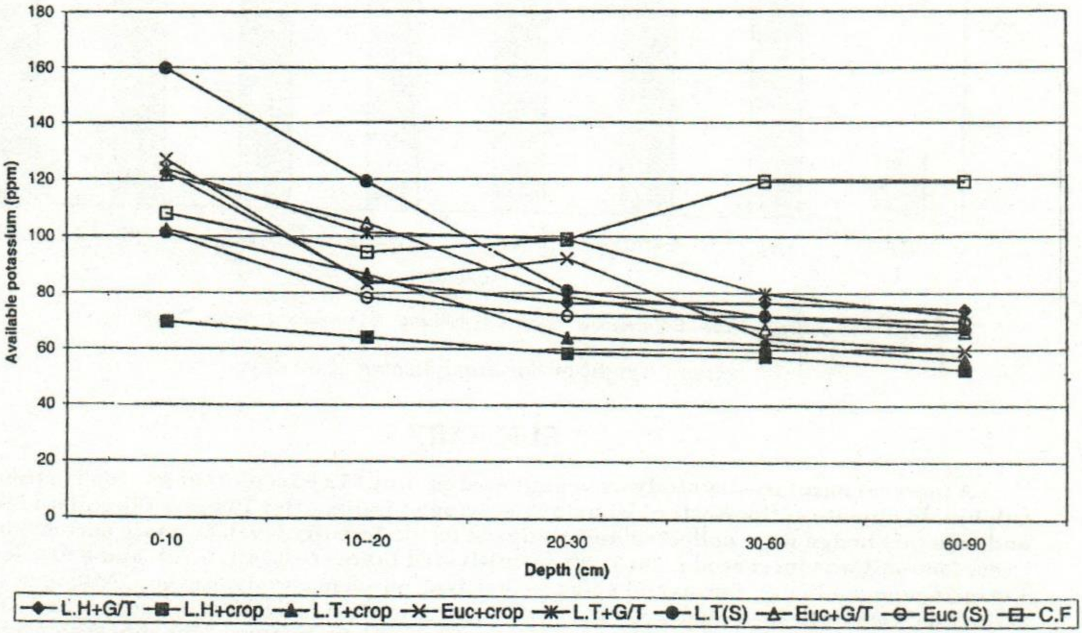
*Potassium* : Potassium content was increased in agroforestry system especially in surface soil when compared to cultivated fallow but this increase was very less (Fig. 5). The highest content was recorded in sole cropping *Leucaena* (Grewal *et al.*, 1994). The potassium content was decreased with increasing depth due to absorption of nutrient by plants. Whereas it was increased with increasing depth in cultivated fallow. It indicated the high amount of runoff and soil loss at surface soil.

Potassium content in alley cropping of *Leucaena* was 36.4 ppm higher than the initial content of soil (Prasad, 1994). Thus, agroforestry system improves the soil fertility level.

## Residual effect of Agroforestry

After nine years experiment, during 1995 sorghum was planted and harvested after 60 days. The crop yield (Fig. 6) was very high in treatment plots when compared to cultivated fallow. It reflects the residual effect of agroforestry system. Among the treatment plots, it was high in sole tree cultivation due to high amount of organic carbon and nitrogen content. In *Leucaena* + Turmeric plot, the sorghum

**Fig. 5**




Residual effect of agroforestry landuses on available potassium content

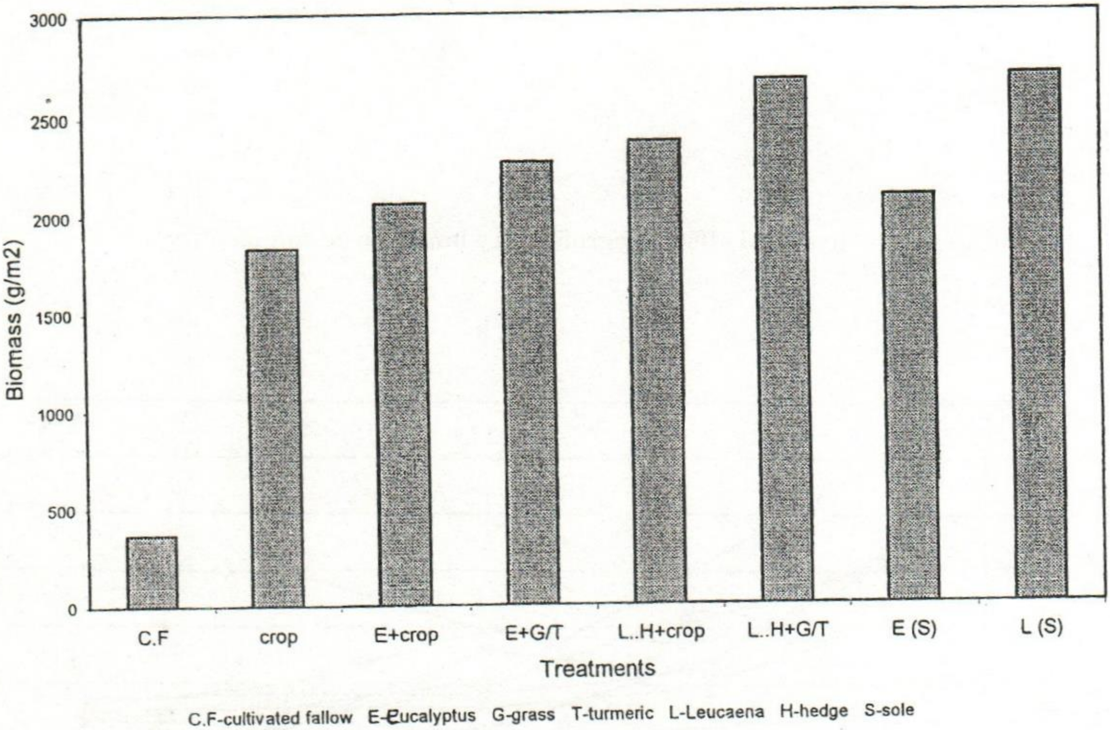
yield was high. It may be due to addition of fertilizers. Among the agroforestry system, there was not much difference in the yield.

## Conclusion

Agroforestry system improved the soil fertility in terms of organic carbon and major nutrient such as N, P and K content. In this sytem, the organic carbon, N, P, and K content was increased by 77.8%, 91.9%, 153.62% and 6.5% respectively when compared to cultivated fallow. Among the agroforestry systems, *Leucaena* hedge inter-cropping recorded high amount of total nitrogen and phosphorus, whereas sole tree cultivation recorded high amount of organic carbon and potassium content.

The system also protects the soil from runoff and soil loss and increases fertility (productivity) level that interns reduces the cost of cultivation. Its residual effect also increases the yield of sorghum from 3.7 t/ha in cultivated fallow to 22.8 t/ha in various treatments.

**Fig. 6**




Green weight of *Sorghum bicolor* at 60 days


## SUMMARY

**A ten-year agroforestry study was conducted on nine 15 x 90 m plots at 4% slope in the warm sub-humid climate of the Western Himalayan region of India. After 10 years the soil under crop and tree (or) hedge were collected and analyzed for its fertility level. Organic carbon content in surface soil was increased from 0.45% in cultivated fallow to 0.74%, 0.76% and 0.91% for tree + crop, *Leucaena* hedge + crop and sole tree cultivation respectively. Carbon, Nitrogen (C : N) ratio was very less in hedge + crop intercropping system. The total nitrogen and Olsen's phosphorus was quite high in alley cropping system when compared to sole tree cropping. Agroforestry landuse system increases the phosphorus content 2.5 times when compared to cultivated fallow land. there was not much difference in potassium content between cultivated fallow and other treatments except sole cultivation of *Leucaena* tree. In agroforestry cultivation, all the nutrients were decreased with increasing the depth, but in cultivated fallow the phosphorus and potassium content increased with increasing the depth. The yield of sorghum in treatment plots was increased significantly due to increased fertility level by agroforestry system.**


## मृदा उर्वरता पर कृषिवानिकी भूमि उपयोगों का अवशिष्ट रहता प्रभाव

प्रताप नारायण, आर० सरस्वती व एन०एस० सिंधवाल


### सारांश

एक दस वर्षीय कृषिवानिकी अध्ययन भारत के पश्चित हिमालीय भूभाग की मामूली गरम उपार्द्र जलवायु, 4% ढाल