**Original Research Article**

# Characterization of Soil Properties and Crop Yield of a few Traditional Agroforestry Systems of District Papum Pare, Arunachal Pradesh

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**Abstract:** This study was conducted in selected agroforestry systems in Papum Pare district of Arunachal Pradesh. The soil physical and chemical properties along with crop yield of the selected agroforestry system (AFS) were determined using gravimetric, potentiometric, rapid titration, Kjeldhal, molybdenum blue and ammonium acetate method. Soil texture was sandy loam, soils were acidic in nature and acidity ranged between 5.50 to 6.40 in surface layer and 5.17 to 6.21 in subsurface layer. Among the selected AFS, SOC was found to be significantly correlated with total nitrogen and available phosphorous at $P<0.01$ level. Available potassium was also significantly correlated with available phosphorous and total nitrogen at $P<0.05$. Growth of plants was measured using measuring tape. The crop yield was done by harvesting five individuals of each crop from three subplots in each of the systems. Among the AFS, growth of maize crop was higher in orange based agroforestry system followed by arecanut and home garden based integrated agroforestry systems. In case of paddy, the growth of plant was higher in orange system as compared to other two systems. Growth performance of ginger did not differ much among the systems. The yield of maize, paddy and ginger crop was maximum in orange-based system followed by arecanut-based and home garden based system. Further, the use of diverse species in the managed AFS uplifts the soil fertility and helps in maintaining the sustainable agriculture and also it is the only established approach to resolve the multiple problems of food security of human kind under limited agricultural lands availability.

**Key words:** Agroforestry, carbon, fertility, growth, sustainable, yield

## Introduction

Agroforestry systems play an important role in soil sustainability, crop productivity and socio-economic development of the farmers along with handling of degraded lands (Chauhan and Dhyani, 1990; Fisher, 1990; Dhyani and Tripathi, 1998). These systems are complex assemblages of ecosystem components and assists in improving the resiliency of agricultural systems and also to mitigate the impacts of climate change (Luedeling *et al.,* 2014). It bridges the breach that separates agriculture and forestry by building integrated systems to address both environmental and socio-economic objectives. Agroforestry systems have the potential to control soil erosion and runoff, improve soil nutrients and water cycling as well as for greater agricultural productivity. About 85% of the population in the state of Arunachal Pradesh is residing in rural areas and are mainly dependent on agriculture. The diverse agro climatic conditions, varied soil types and high rainfall make the state suitable for agroforestry practices. The traditional agroforestry system is the most primitive system practiced in the state with wide variation in cultural diversity among various tribal clans of the state (Deb *et al.,* 2009). The major problems affecting adversely agricultural production of the region are undulating topography, erratic rainfall, heavy soil erosion, marketability, poor infrastructure and continuous land degradation.

As an integrated cropping system the production intensity is expected to be continuous. Site-specific crop selection is very important so that the ecological interactions between trees and crops are beneficial. The crop production can only be sustained at higher levels if consumption and supply are balanced, and this requires appropriate management involvements. The farmers of the state grow crops along with the trees on sloppy land or jhum field traditionally since time immemorial. Soil is the basis of production in agriculture and forestry, and soil health is the continued capacity of soil to function as a living system to sustain biological productivity, plant and animal health (Oliver *et al.,* 2013; FAO, 2015). Physical and chemical properties of soil vary to some extent in space and time within a single land use (Clark *et al.,* 2005). The sustainability of agricultural production can be compromised through intensified cropping without passable restoration of soil fertility (Roy *et al.,* 2003). But it has been observed that large area was exposed to moderate to severe land degradation, thereby, negatively impacting the land productivity. Therefore, ecological restoration or rehabilitation of these lands is decisive to sustainable land management system and integrated land use system is important.

Home gardens are the prevalent agroforestry practices in most part of Arunachal Pradesh. Henceforth, a preliminary survey was carried out in order to identify the different types of agroforestry practices prevalent in the selected study area of the state. Also a detailed ecological analysis of different traditional agroforestry systems (AFS), the systems managed/developed by the local farmers with scientific thought were screened and selected for study. The study aims to document the tree-crop compositions, soil properties, growth

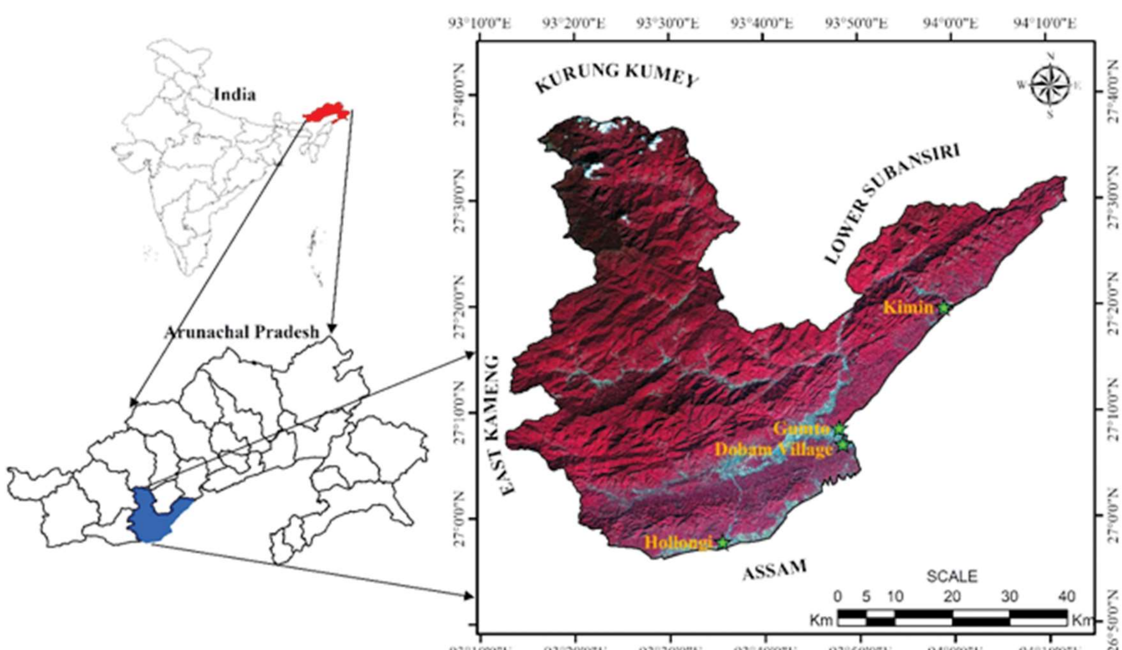


**Fig. 1.** Location map of study area.

and yield and also to screen the most suitable combination for better economical combination for improving the socio-economic status of the farmers.

## Materials and methods

### Study site

The study was carried out through extensive survey in selected areas of Papum Pare district which is generally characterized by hilly ridges, mountains and valley covered with lush green vegetation. The district is located between $26^0$ 55´ and $28^0$ 40´ N latitude and $92^0$ 40´ and $94^0$ 21´ E longitude and is bounded by Kurung Kumey district in the North, Assam in the South, Lower Subansiri district in the East and East Kameng in the West (Fig. 1). Total geographical area of the district is 2875 $km^2$ with population density of 35 persons $km^2$. The physical features of the district can be divided into foothills and hilly regions. Forest cover of the district is 1458.39 $km^2$ and the vegetation can be broadly classified as moist deciduous forest in the foot hills and wet subtropical evergreen to semi-evergreen forest at higher altitude. Soils in the valley areas are sandy loamy in texture with acidic content. More than 70% of the rain takes place in monsoon (June-September) season followed by pre-monsoon (March-May), post monsoon (October-November) and winter (December-February) seasons. As not much developed AFS are available in the districts hence those systems having proper spatial distribution


**Fig. 2.** Photographs of selected agroforestry systems in Papum pare district, Arunachal Pradesh. Orange based AFS with *Ananas comosus* (A & B); Arecanut based AFS with *Ananas comosus* and *Livistona jenkinsiana* (C & D) and Home garden based AFS with mixed cropping of *Zea mays* and *Carica papaya* (E & F).

with agricultural association were selected for the detailed study. In the present study three major agro forestry systems prevailing in the district were selected (Orange based AFS, Arecanut based AFS and Home gardens) (Fig. 2). Sites were selected in Dobum Village (Banderdewa), Gumto Village (Doimukh), Kimin and Hollongi.

## Methodologies

Soil samples were collected using a soil corer from two soil depths *i.e.*, 0-15 cm and 15-30 cm from each of the selected traditional AFS during the study period in replicates. Soil texture, bulk density, water holding capacity, soil moisture content, pH, total Kjeldahl nitrogen, available potassium and phosphorus were estimated following methodologies outlined by Allen *et al.* (1974) and Anderson and Ingram (1993). Soil organic matter (%) was calculated multiplying the organic carbon (%) by 1.724 assuming that soil organic matter contains 58% carbon (Allen *et al.*, 1974). Growth of plants were measured using measuring tape. The crop yield was done by harvesting five individuals of each crop from three subplots in each of the systems. Statistical analysis was done using SPSS software package (version 20.0) and MS Excel. Correlation coefficient between soil parameters were done using the Pearson's correlation test function.

## Results

### Tree crop composition in Traditional AFS

Although the native people are agrarian in nature, but agriculture system in the district is very primitive and demand driven. Shifting cultivation is mostly practiced in the inaccessible areas with their indigenous technology. Paddy is found to be the dominating crop other than millets, maize, vegetables, pulses, oil seeds, etc. Prominent AFS has been screened based on its area coverage and common practices in most part of the area. The study resulted that most people prefer jhum cultivation, however, home garden concepts are widely practiced. Due to undulating physiography and family size in the area, size of AFS/home gardens varied from 0.1ha to about 1ha. The survey revealed that farmers cultivate various crops with trees in mixtures on the same unit of land. The common woody species of the integrated systems include *Macaranga denticulata*, *Citrus* sp., *Magnifera* sp., *Hevea brasiliensis*, *Artocarpus heterophyllus*, *Areca catechu*, *Melia* sp., *Albizia* sp. and *Livistona jenkinsiana*. The most preferred agri-horti crops of the study area include *Zea mays*, *Brassica juncea*, *Curcuma longa*, *Piper* sp., *Piper nigrum*, *Coriandrum sativum*, *Zingiber officinale*, *Oryza sativa*, *Elettaria cardamomum*, *Colocasia* sp., *Cucumis sativas*, *Cajanus cajan*, *Capsicum frutescens*, *Abelmoschus esculentus*, *Ananas comosus*, *Raphanus sativus*, *Allium sativum*, *Phaseolus vulagaris*, *Cucurbita* sp., *Houttuynia cordata*, *Carica papaya* and *Musa* sp. As not much developed agroforestry systems are available in the area, hence ages of trees in traditional systems varied among the systems and also the species composition. Generally, trees were planted with a spacing of 3m to 5m between plants to plant except arecanut. The mean dbh and mean height of ten individuals were measured at each site as an index of tree growth. Trees having the age variability between 10 and 15 years with mean tree height of 10 ± 0.76 – 12 ± 1.32 m and girth of 23 ± 3.68 – 50 ± 3.57 cm. Arecanut has a density of 1000 trees ha$^{-1}$ while the tree density of orange (5m x 4m) was 500 individuals ha$^{-1}$. The density of

**Table 1.** Spatial variations in soil physical properties in the different AFS.

| Systems | Depth (cm) | Sand (%) | Clay (%) | Silt (%) | Textural Class | WHC (%) | BD (g cm$^{-3}$) | Porosity (%) | Soil Moisture (%) |
|---|---|---|---|---|---|---|---|---|---|
| Orange | 0-15 | 74.80 ±2.83 | 23.98 ±1.56 | 1.22 ±0.71 | Sandy loam | 72.06 ±11.6 | 0.94 ±0.02 | 67.70 ±0.97 | 29.58 ±2.07 |
| | 15-30 | 74.60 ±1.10 | 24.00 ±0.32 | 1.40 ±0.02 | | 70.15 ±10.86 | 1.04 ±0.04 | 61.54 ±0.13 | 25.31 ±1.23 |
| Arecanut | 0-15 | 73.80 ±0.80 | 24.10 ±0.27 | 2.10 ±0.11 | Sandy loam | 66.06 ±2.73 | 1.04 ±0.03 | 60.23 ±0.44 | 23.74 ± 0.99 |
| | 15-30 | 74.20 ±0.32 | 23.40 ±0.13 | 2.40 ±0.12 | | 65.12 ±9.91 | 0.96 ±0.02 | 63.54 ±0.36 | 18.71 ±1.09 |
| Home garden | 0-15 | 71.80 ±0.43 | 25.70 ±0.22 | 2.50 ±0.03 | Sandy loam | 77.26 ±6.86 | 0.72 ±0.09 | 72.30 ±1.10 | 37.56 ±1.88 |
| | 15-30 | 72.20 ±0.55 | 25.30 ±0.2 | 2.30 ±0.3 | | 72.50 ±1.19 | 0.80 ±0.04 | 69.23 ±1.26 | 29.81 ±1.32 |

± Standard error

**Table 2.** Chemical properties of soil in selected traditional agroforestry systems.

| Systems | Depth (cm) | pH | SOC (%) | TKN (%) | Available P (kg/ha) | Available K (μg $g^{-1}$) |
|---|---|---|---|---|---|---|
| Orange | 0-15 | 5.70±0.68 | 1.79±0.08 | 0.44±0.01 | 40.83±2.32 | 206.12±10.32 |
| | 15-30 | 5.56±0.52 | 1.25±0.05 | 0.36±0.01 | 34.79±2.08 | 257.25±9.52 |
| Arecanut | 0-15 | 5.89±0.04 | 1.42±0.09 | 0.36±0.02 | 39.86±3.75 | 179.13±9.12 |
| | 15-30 | 5.69±0.07 | 1.04±0.05 | 0.27±0.01 | 11.62±1.78 | 168.74±11.77 |
| Home garden | 0-15 | 5.79±0.51 | 2.40±0.03 | 0.57±0.01 | 58.18±2.98 | 299.40±15.57 |
| | 15-30 | 5.58±0.17 | 2.36±0.03 | 0.44±0.01 | 40.47±2.32 | 200.17±12.38 |

± Standard error

**Table 3.** Correlation coefficient (Pearson's) between different soil chemical properties (0-30 cm soil depth) under different AFS.

| | pH | SOC | TKN | AP | AK |
|---|---|---|---|---|---|
| pH | 1 | - | - | - | - |
| SOC | 0.025 | 1 | - | - | - |
| TKN | 0.122 | 0.925** | 1 | - | - |
| AP | 0.413 | 0.813** | 0.922** | 1 | - |
| AK | 0.182 | 0.600 | 0.795* | 0.689* | 1 |

Correlation is significant at the 0.05 level (2-tailed); Correlation is significant at the 0.01 level (2-tailed).

**Table 4.** Yield of maize, paddy and ginger crops in association with different AFS.

| | Crops | Orange | Home-garden | Arecanut |
|---|---|---|---|---|
| Maize | Yield (g/plant) | 85.47-102 | 27 - 67 | 39.21- 88.75 |
| | Yield (g/$m^2$) | 721.4- 1054.7 | 170 - 766.9 | 298.9 - 987.5 |
| | Yield (quintal/ha) | 29.3- 42.6 | 17.1- 26.4 | 21.5 - 36.3 |
| | straw (g/$m^2$) | 1493- 1666 | 591- 724 | 775 - 1563 |
| Paddy | Yield (g/plant) | 32.27 - 42.54 | 16.54 - 18.35 | 17.98 - 21.37 |
| | Yield (g/$m^2$) | 320.27 - 420.54 | 165.4 - 183.5 | 179.8 - 213.7 |
| | Yield (quintal/ha) | 32-42 | 16.54 - 18.35 | 17.98 - 21.37 |
| | straw (g/$m^2$) | 1052 - 2210 | 758 - 1322 | 875 - 1652 |
| Ginger | Yield (g/plant) | 78.76 - 82.35 | 55.32 - 73.54 | 71.32 - 88.46 |
| | Yield (g/$m^2$) | 787.6 - 823.5 | 553.2 735.4 | 713.2 - 884.6 |
| | Yield (quintal/ha) | 78.8 - 82.4 | 55.3 - 73.5 | 71.3 - 88.5 |
| | straw (g/$m^2$) | 762 - 986 | 558 - 782 | 885 - 1205 |

**Table 5.** Cost-benefit analysis for the crop combination in different AFS.

| Crop combination | Input (Rs/ha) | Output (Rs/ha) | Output/Input ratio | Net Monetary benefit (Rs) |
|---|---|---|---|---|
| | | Orange-based AFS | | |
| Maize | 7,500 | 53925 | 1:7.2 | 46425 |
| Paddy | 7,500 | 44400 | 1:5.9 | 36900 |
| Ginger | 8,000 | 80600 | 1:10.1 | 72600 |
| | | Home garden-based AFS | | |
| Maize | 7,500 | 32625 | 1:4.4 | 25125 |
| Paddy | 7,500 | 20734 | 1:2.8 | 13234 |
| Ginger | 8,000 | 64400 | 1:8.1 | 56400 |
| | | Arecanut -based AFS | | |
| Maize | 7,500 | 43350 | 1:5.8 | 35850 |
| Paddy | 7,500 | 23610 | 1:3.2 | 16110 |
| Ginger | 8,000 | 79900 | 1:10.0 | 71900 |

trees in home gardens varied greatly. There was a profuse growth of weeds in all the fields throughout the year. However, density/cover remains greater during the rainy season. Among them *Commelina bengalensis*, *Mikania micrantha*, *Mimosa pudica*, *Cyperus* sp., *Ageratum conyzoides*, *Drymaria cordata*, *Piper* sp., Fern sp., *Elusine indica* were dominant ground species.

### Soil characteristics

Qualitative and quantitative characterization of soil properties are important for farming practices and proper land management. Water holding capacity (WHC) was higher (77%) in home garden system followed by orange and arecanut based AFS. The WHC was higher in the surface (0-15cm) layer than the subsurface layer in all the agroforestry systems and it also varied slightly between the systems and depths. There were not significant differences in the bulk density among the agroforestry systems. The bulk density was maximum in arecanut based AFS as compared to the other two AFS, and generally it was higher in the subsurface layer than the surface layer in all the plots. Porosity showed reverse trend to that of the WHC and bulk density values were higher in the surface layer than the subsurface layer. There was slight variation in porosity of the surface as well as subsurface layer among the systems. Soil texture was sandy loam type in all the agroforestry systems and depth wise variation was not much. Among the AFS, clay content was low (1.8%-7.9%), silt proportion was 8.9% to 21.7% and sand was 74.8% to 89.2%. Soil moisture content varied significantly among the systems and soil depths. Soil moisture content was recorded maximum in home garden followed by orange and arecanut based AFS. It was observed that the surface layer of soil had more moisture content than the subsurface layer of the systems (Table 1).

Soils were acidic in nature in all the AFS and acidity ranged between 5.50 to 6.40 in surface layer and 5.17 to 6.21 in subsurface layer. The SOC ranged between 1.43% and 2.38% in upper soil depth and 1.04% and 2.07% lower surface among the systems. The concentration of TKN was found to be higher in the surface layer of home garden (0.86%) and lower in arecanut (0.22%) based system. Home garden recorded the highest concentration of phosphorus followed by orange and arecanut based systems. Orange recorded the highest (356μg $g^{-1}$) concentration of K and lowest (145μg $g^{-1}$) in arecanut system (Table 2). Among the chemical properties at depth (0-30 cm) in selected AFS, SOC was found to be significantly correlated with total nitrogen and available phosphorous at $P<0.01$. Available potassium was also significantly correlated with available phosphorous and total nitrogen at $P<0.05$ (Table 3).

### Crop growth, yield and benefits

Maize crop height was higher in orange based system followed by arecanut and home garden integrated systems. The height growth rate was higher during the first 60 days. The average rate during this period was 1.61cm/day in orange-based, 1.30cm/day in arecanut and 1.57cm/day in home garden based systems after seedling emergence. In case of paddy, the height of the plant was higher in orange system as compared to other two systems. Average rate of growth of the plant was 0.64cm/day in orange-based followed by 0.48cm/day in arecanut-based and 0.37cm/day in home garden-based systems (Fig. 3). Maximum growth took place in first 60days of sowing and it was 1.25, 0.99 and 0.69cm/day in orange, arecanut and home garden association, respectively. Growth performance of ginger did not differ much among the systems, however, during each sampling period in ginger, maximum height was recorded in orange-based system followed by arecanut and home garden-based systems. The average height growth was 0.49 cm/day, 0.48cm/day and 0.41 cm/day in orange, arecanut and home garden-based systems, respectively. Similar to other two crops, ginger too resulted maximum (0.99, 0.84, 0.80cm/day) height growth during the early growth stage (up to 60 days) in the systems (Fig. 3).

The yield of maize, paddy and ginger crop were maximum in orange-based system followed by arecanut-based and home garden based system. Maize performed better (85.47g/plant to 102g/plant) in orange based system followed by arecanut (39.21g/plant to 88.75 g/plant) and home garden (27g/plant to 67 g/plant) which could be mainly associated with light availability for growth of the plant. Yield of the paddy was recorded (32.27 g/

plant- 42.54g/plant) in the orange based AFS, 16.54 g/plant to 18.35 g/plant in the home gardens and 17.98g/plant to 21.37 g/plant in the arecanut based AFS. Ginger has resulted slightly higher yield (71.32g/plant to 88.46g/plant) in arecanut based system followed by orange (78.76g/plant to 82.35g/plant) and home garden (55.32g/plant to 73.54 g/plant) based AFS (Table 4).

Cost-benefit ratio of agricultural crops was also calculated. The input cost includes seed, land preparation, sowing, weeding, hoeing and harvesting, cleaning, drying and processing for maize and ginger, and threshing for paddy. The net monetary benefit was higher for ginger crop in all the systems followed by the maize and paddy. However, in case of home garden based system the performance and production of most of the crops was poor. The cost of paddy (@Rs.12/- per kg), maize (@Rs. 15/- per kg), and ginger (@Rs. 10/- per kg), were collected from the nearby villagers/farmers (Table 5).

## Discussion

Traditional integrated farming has the capacity to build the profitability and simultaneously keep up the supplement balance rather than defense the nature. Trees must be appropriate for becoming under the pervasive agro-climatic conditions and utility of trees for addressing the necessities of timber, fodder, fuel-wood, other products, etc. Inclination might be given to indigenous and quickly growing species, and leguminous and other nitrogen-fixing species. Species that give crude material to house businesses ought to be supported. In spite of the fact that the essential concern is to keep up the creation level of the arable crops, in any case, accentuation must be likewise given that it ought to be non-impedance with arable crops. Further, quick growth and short growth period, non-allelopathic consequences with associated crops, capacity to fix atmospheric nitrogen, fast decomposition of litter, capacity to withstand pruning, multipurpose utilization, etc. must also be given due importance. Continuous cultivation and intensification of land uses affect the particle size distribution (Voundi and Tonye, 2002). Greater values of bulk density could be related with erodible nature of the soils and also due to low clay and high sand content (Gupta *et al.,* 2010). Increase in bulk density with soil depth could be due to greater compaction that might have occurred in the lower horizons of the soil profiles with time. Bulk density also depends on soil organic matter present in the soil and the total volume of soil pores (Gupta *et al.,* 2010). Higher values of porosity could be due to more soil organic matter content (Gupta *et al.,* 2010). Decline in porosity leads to reduce pore size distribution which has an impact on productive capacity of the agricultural soil.

The variability in water holding capacity in soil depths of the system can be ascribed to presence of higher organic matter and clay fractions (Gupta *et al.,* 2010). Maximum SMC were observed in the rainy season while minimum during the winter period as the rainfall was less. Therefore, rainfall in the present study may have large influence on the SMC. Spatial variations in soil moisture content could be also due to evapo-transpiration and precipitation which is influenced by topography, soil texture, and soil management. The acidity of soil may be because of accessibility of nutrients and organic matter present in the site. The quality of litter, its decomposition and nutrient release could be probable reason for acidity. Low soil pH may be likewise because of the infiltration and permeation of surface material to the subsurface soil profundities because of substantial downpour during the rainy season. Leaching and runoff losses of nitrate nitrogen, cations (Ca, Mg, K) from the surface soil further limit the pH. Soil acidity restrains crop production and obstacles root advancement.

The organic matter makes certain the agricultural productivity and the long-term management of soil stores (Cerli *et al.,* 2009). The differences in soil organic carbon under various systems might be because of integrated tree-crops composition and soil quality management aspects (Arunachalam and Arunachalam, 2000). Soil having adequate concentration of organic matter can improve the soil physical and chemical properties and also regulates the soil erosion (Cerli *et al.,* 2009). Higher level of SOC in the upper soil depth might be because of the aggregation of plant materials. The organic manures used during the agricultural cropping time could be the probable cause of higher content of nitrogen.

Phosphorus is a basic supplement in farming fields. Variations in available P concentration among the AFS could be primarily due nature of litter. Higher concentration of available potassium is due to good proportion of potassium conserved in the soil through the residues; however, soil acidification may decrease the quantity of potassium. Soil characteristics and productivity of the agricultural fields are largely influenced by the soil organic matter (SOM) (Campbell *et al.,* 1996). However, continuous cultivation practices cause considerable losses of SOM and other nutrients (Polyakov and Lal, 2004). Soil nutrients (N, P, K) are removed from the soil through the agricultural products (food, fiber) and crop residues. Litter is the main source of soil organic matter and plant available nutrients in natural or semi-natural ecosystems. Rate of decomposition depends on various factors such as chemical composition of litter, and a variety of climatic and edaphic factors (Melillo *et al.,* 1982).

## Conclusions

With the prevailing problems of developmental activities and degradation of natural ecosystems, agroforestry system (AFS) is the only established approach to resolve the multiple problems of human kind. It represents the integration of sustainable land use system with wide scope and ample opportunity. From the present study it is clear that well managed agroforestry provides a positive effect on soil fertility thereby improving the soil health and net productivity. However, it was found that some of the woody species were intentionally used by the growers without knowing much about their positive impacts on soil improvement and economic benefits. Hence, a better understanding of the positive effect of the woody species, soil quality and economic benefit is much needed for the growers.

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