Status of Nitrogen, Potassium and Phosphorus in Soils of Different Agroforestry Systems

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DECLARATION

The work described in this thesis was carried out by me at the Soil Science Department, faculty of Agriculture, University of Peradeniya under the supervision of Dr. K. A. Nandasena and Mr. E. P. N. Udayakumara. A report of this has not been submitted to any University to any other degree.

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ABSTRACT

Soil fertility is very important for sustainable agriculture. But modern agricultural practices cause soil fertility losses and also soil degradation. So that the agroforestry concept helps prevent soil degradation and also maintain soil fertility. Therefore this study was carried out to find out the effects of agroforestry on soil fertility by evaluating the N, P and K states of soils.

Two agroforestry land use systems namely alley cropping system and mix farming system have been selected. For the comparison, adjacent two land plots without any cropping system were selected as controls. Representative soil samples were taken from 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60cm depths from plots having two different cropping systems and two control plots. Soils were brought to the laboratory to be analyzed for total nitrogen, potassium, phosphorus and available nitrogen, phosphorus and exchangeable potassium

When comparing the results, there was an increase of some nutrients in agroforestry land use systems than control land. Total nitrogen, total phosphorus, total potassium and available nitrogen, available phosphorus and exchangeable potassium were high in mix farming system than its control. Available nitrogen, available phosphorus and total potassium were high in alley cropping system than its control. All the amounts of nutrients decreased with depth. Because of that much of the nutrients accumulate in the surface layer of soils. Total nitrogen, available nitrogen, available phosphorus and exchangeable potassium were significantly high in mix cropping system than control.

From the results it can be concluded that the agroforestry systems could be practiced to improve and maintain soil fertility by increasing N, P, and K status of soils.

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ABBREVIATION

ppm = parts per million

RBL = Red brown latasol

ABS = Absorbent

rpm = rounds per minutes

Conc. =Concentrated

CHAPTER 1

INTRODUCTION AND OBJECTIVES

1.1 Introduction

Air, water and land are basic resources for biological systems. Among these, the land is the most important basic resource for several biological production systems. The land and its soil profile support the plants and other living organisms. The soil provides a medium and stores nutrients and water for the growth of plants and animals. Production of food grains, vegetable, fruits, firewood, spices, fodder, timber and other crops largely depend on the land area, type of soil, availability of water , technology and several other physical and socio- economic factors. The soil, which is the uppermost layer of earth crust is important for plant growth and production of several kinds of goods, e.g., agricultural, horticultural, forestry etc. (Dwivedi, 1992)

With rapid expansion in human population, per capita availability of arable lands has been declining. All of land are not productive.There are several factors which limit the productivity of land. They are water stress, physiography, soil erosion, land degradation, floods etc. (Dwivedi, 1992) Rapid deforestation may cause serious problems of soil erosion, runoff, and depletion of soil fertility, environmental deterioration and ecological disturbances. Soil erosion causes loss of surface soil with major plant nutrients and gradual loss in soil productivity. Soil erosion is also resulted by inappropriate agricultural practices. Man's demand for food from the land has increased considerably. But production capacity of the land is limited. Not only that some areas converted for agriculture are not suitable and have caused serious land degradation. (Tejwani, 1994)

The maintaining fertility of the soil is very important for the prevention of land degradation. For sustainable soil use and maintaining soil fertility, it's necessary to introduce proper agricultural practices. The concept of the agroforestry is one of the best land use systems available today, which improve the soil fertility,

reduce soil erosion, supply wood and timber, reduce atmospheric carbon dioxide and also supply better yields. (Bandyopadhyay, 1997)
Agroforestry means practice of agriculture and forestry on the same piece of land, or otherwise mixing trees with agriculture crops. It is the practical application of science, technology and economics to a forest estate for the achievement of sustainable production of forest produce including food, fodder, fiber and industrial row materials, maintenance of soil fertility and protection of environment. It is based on the knowledge of a number of basic sciences such as ecology, geology, silviculture, pathology, economics, botany and agronomy. Agroforestry is the deliberate growing of woody plants, non-woody plants and often animals for human purposes, simultaneously or in deliberate rotations on the same unit of a land. Agroforestry is the combination of silvicultural, agricultural and other land use technologies so that their joint application will increase productivity, sustainability or equity, or achieve other social goals. (Bandyopadhyay, 1997)

Agroforestry has a high potential for sustainable plant production. It will be shown that, with good design and management, agroforestry can achieves conservation of soil fertility whilst at the same time maintaining or increase production of food and other plant products. Trees can be employed in erosion control in supplementary and direct ways.Supplementry use refers to the planting of trees on conventional soil conservation work. Such as earth structures and grass strips. In direct use, the tree component itself is the means of controlling runoff and soil loss. A forest cover will maintain or improve soil fertility, whereas continuous arable cropping without external inputs will normally degrade it. Shifting cultivators know and make use of the beneficial effects of trees on soil, and the same capacity is employed in reclamation forestry. The basis for believing that agroforestry system may have the potential for sustain soil fertility lies in the inclusion of trees. Trees improve soil through a wide range of process, including augmentation of inputs, reduction of losses and improvement of soil physical, chemical and biological fertility. (Kang and Inoue, 1991)

Therefore, the objective of the present study was to evaluate the status of major plant nutrients in two agroforestry systems practiced in Sri Lanka.

1.2 Aim

To evaluate N, P and K status in soils of two different agroforestry systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Agroforestry

2.1.1 Definitions of agroforestry

"Agroforestry refers to those land use practices in which woody perennial (trees, shrubs, woody vines, bamboos, palms) are grown in association with agricultural crops or pastures, sometimes with livestock or other animals (e.g., insects such as bees, fish), and in which there are both ecological and economic interaction between the woody plants and the other components." (Peter, 1999)

"Agroforestry land use is the deliberate inter or sequential cropping of woody and non- woody plant components (sometime with animals) in order to generate multiple products and 'services'. There are both ecological and economical interactions between the plant components." (Peter, 1999)

"Agroforestry is a dynamic, ecologically based natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustain production for increased social, economic and environmental benefits for land use at all levels." (Peter, 1999)

2.1.2 The history of agroforestry

The cultivation of tree spices and agricultural crops in intimate combination has been a practice throughout the world at one period or another in its history. There are numerous examples of this practice. In Europe until the middle ages, it used to be a practice to clear fell derelict forest, burn slash, cultivate food crops for varying periods on the cleared areas and plant or sow tree spices before, along with or after the sowing of the agricultural crops. This practice waned in Europe but continued to exist in Finland up to the end of the last century and up to the 1920s in Germany. In Central America, for examples, they initiated the structure and spices diversity of tropical forest by planting a variety of crops with different growth habits. This included tall trees, medium trees, shrubs, vines and crop in a multistory system. In Asia, the Hanunoo farming system a somewhat complex and sophisticated system, was followed. In Northern Nigeria, yam, maize, pumpkin and beans were typically grown together under a cover of scattered trees. (Chundawat, 1993)

2.1.3 Components of agroforestry

Agroforestry may be traditional and/or introduced. To cater out our day-to-day requirements, different types of trees are planted around our house along with agricultural crops particularly fruits and vegetable crops. Agroforestry is going on traditionally in all villages throughout the world in the name of the gardens. With increase in our knowledge about plants, we are now in a position to select plants or trees which will give maximum benefit in terms of production as well as soil fertility. Agroforestry may have different component: (Bandyopadhyay, 1997)

a. Agri-silvi-culture system
b. Silvi-pastoral system
c. Agro-silvipastoral system
d. Multipurpose forest production system

a. Agri-silvi-culture system:

This system consist concurrent production of agricultural crops and forest trees. Two types of system can be identified: in one case farmers grow trees in and around fields where they grow food crops; in other case, farmers, as well as large companies grow trees in farms where the main product is commercial crops. (Tejwani, 1994)

b. Silvi-pastoral system:

The silvi-pastoral system means a land –management system in which forest are manage for the production of wood as well as for rearing of domesticated animals. Silvi-pastoral system includes management of fodder grasses in natural forest or in plantation or in grassland with a view to obtaining the maximum yield of wood, fodder and other products. (Dwivedi, 1992)

c. Agro-silvipastoral system:

The system is a combination of the agrisilviculture and sivipasture system. The land is managed for the concurrent production of agricultural and forest crops and for grazing by domestic animals. If a unit of land is managed under crop rotation or practices which may include production of food grains, fodder and wood and has provision for grazing cattle, the system can be called an agrisilvipasture system. (Dwivedi, 1992)

d. Multipurpose forest trees:

In this system, forest tree spices are regenerated and managed for their ability to produce not only wood, but leaves and/or fruits that are suitable for food and/or fodder. In this system, the forest is managed to yield multiple products. (Dwivedi, 1992)

2.1.4 Classification of agroforestry

Twenty four agroforestry systems (figure 2.1) based on three types of association of tree (with crops, with pasture, and with both crops and pasture); two major function of the tree component (production and protection); two spatial arrangements (regular and irregular); and two types of temporal association (temporal and permanent). This classification is still incomplete, as apiculture and pisciculture with tree belong to special classes, more difficult to classify. (Tejwani, 1994)

	Agrosilvi-culture	Silvo-pastoral	Agrosilvo-pastoral	Agrosilvi-culture	Silvo-pastoral	Agrosilvo-pastoral	
							Production
permanent							Protection
							Production

						Protection

Regular Irregular

Figure 2.1: Agroforestry classification

Agroforestry system may be broadly classified into:

a. taungya system
b. farm and grove system
c. tree planting among agricultural crops
d. livestock in a agroforestry
e. home garden system
f. alley cropping
g. fishery based tree/fruit crops/vegetable production system
h. aquaculture in mangrove swamps
i. shifting cultivation system

a. Taungya system:

Taungya is a Burmese word meaning shifting cultivation in the hills. Farmers are temporarily allotted governments land and contracted to plant specific tree spices. While the trees are young and before the canopy closes the farmers are allowed to plant food and cash crops for their own benefit, while maintaining the trees. It is the first step towards the agroforestry. (Bandyopadhyay, 1997)

Figure 2.2: Taungya system

b. farm and grove system:

In this system farms are interspersed with groves of trees that may vary from a wild forest consciously preserved to domesticate trees. This system helps to prevent soil erosion of the sloppy lands. Whenever food crops need shade, trees are planted in the borders. Here, trees serve as boundary, live fences, and wind breaks, sources of wood, food, fruit, fodder and green manure. (Bandyopadhyay, 1997)

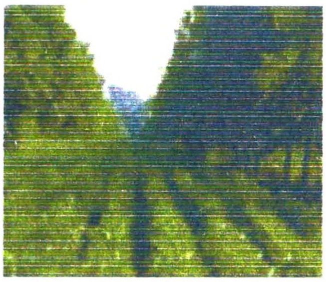

Figure 2.3: Farm and grove system

c. Tree planting among agricultural crops:

Here trees are planted in the agricultural land or in the existing plantation. Coconut, oil palm, rubber plantations etc. are interspersed with a variety of agricultural crops and spices. Coffee, tea, and cocoa are introduced in the existing plantation forest. In many agricultural fields leguminous trees are planted as a source of nitrogen, fodders, green manures and leaves. (Bandyopadhyay, 1997)

d. Livestock in agroforestry:

On one hand, land area for agricultural crops is gradually reducing due to population pressures while; on the other hand, livestock numbers are increasing. Accordingly, a number of systems are developed under the existing plantation forest where grass and fodder trees are grown for the livestock. (Bandyopadhyay, 1997)

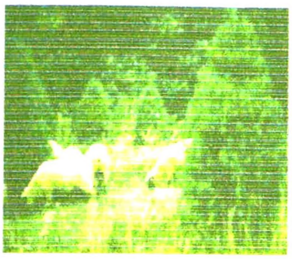

Figure 2.4: Livestock in agroforestry

e. Home gardens:

Gardens are gradually developed around or near the homes to cater the daily requirements may be for their aesthetic and ornamental value, for religious purpose, for production of food, fuel wood, vegetables, fruits, or building materials. (Bandyopadhyay, 1997)

f. Alley cropping experience:

Alley cropping, also known as hedgerow intercropping and alley farming, is a simultaneous agroforestry system where tree, mainly leguminous, are grown in dense hedges between 'alleys' of specified width where short-cycle food crops are grown. The hedges are pruned periodically and the resulting mulch is placed on the alleys to provide nutrients and control weeds.(Fergusl,1995) Alley cropping is considered to be capable of maintaining sustained production while minimizing the depletion of natural resources and use of high cost inputs. Hence, these systems have a potential of solving major farming constraint in rainfed uplands of Sri Lanka. (Gunasena and Sangakkara, 1997)

Figure 2.5: Alley cropping system

g. Fishery based tree/fruit/crops/vegetable production system:

In costal area most of the farmers have a small pond near the homesteads for storage of rainwater as a source of fresh water mainly for domestic use and fisheries. The farmers grow vegetables along the embankment of the ponds as the first row. They also grow fruit as second row and a third row of eucalyptus as it is a very fast growing tree for fuel wood. (Bandyopadhyay, 1997)

h. Mangroves forest based aquaculture system:

One of the most important roles of the mangroves is its detritus in the form of litter which is nutritive as such and also after being decomposed by microorganisms for wide range of animals and provides breeding and nursery grounds for the juveniles of many types of fishes, crustaceans and other fauna. (Bandyopadhyay, 1997)

i. **Sifting cultivation**:

Sifting cultivation is the oldest system of agroforestry and the one which most clearly demonstrates the capacity of a forest fallow to restore soil fertility. There is common misconception about its extent. While still to be found in more sparsely populated forest areas, for example in the Amazon, south-east Asia and hill regions of north-eastern India, it has long since ceased to be practiced over the greater part of the tropics. Over most of south Asia and eastern and southern Africa, for example, the dominated agricultural land use is more or less continuous annual cropping. The major land-use problem of the subhumid and semiarid tropics is not 'alternatives to shifting cultivation' but 'making annual cropping sustainable'. (Anthony, 1997)

2.1.5 Agroforestry ecosystem

We need to understand the structure, function and process of trees within farming system, in order to understand the biophysical resources, that we have at hand their constraints and potential, to contribute human welfare. To understand this agroforestry ecosystem, we need to know what the important elements of an ecosystem are its climate, topography, soils animals and vegetation and how these elements function and effect each other. We also need to understand the complex process of energy flows, biomass production nutrient cycling, and genetic codes. (Willam, 1992)

2.1.6 Agroforestry research

To develop farming system that will help increase and stabilize agriculture production through better use of natural and human resource in the seasonally dry semi arid tropics. Resource management plan are incomplete without consideration of trees. There are lands where mixes of crops, trees, and grasses are ideal. We must optimize their production and maximize returns to the farmer without determent to the environment. Unless a system is attractive to a resource-poor farmer, it may not be an adopted. Inappropriate agricultural and forestry production systems and population growth, outstripping production lead to land the degradation. Increasing number of herded, browsing animals outstrip the ability of the land to support them, leading to barren landscapes in much of the semi-arid tropics. Agroforestry, particularly sivipastoral system, can help alleviate this situation. (Rick, 1985)

2.1.7 Social values of agroforestry

A few general comments may help make explicit the values most agroforestry and agricultural scientist implicitly hold. But often confuse. Because it is concrete and measurable, improved productivity- increasing production, for example, in terms of cubic meters per hectare per year may seem like an objective rather than a value criterion, but it is I fact, the concrete side of such recognized in reasonably objective terms. Sustainability is another value, but measurement criteria for it are considerably less well developed. Equity, or "fairness", of distribution is another value that should guide agroforestry research and implementation. Measurable criteria of this value are even more elusive, but it is important in agricultural and rural development for two not unrelated reasons first, it is difficult to defend productivity improvements in land technologies paid for by public research funds that accrue to the rural rich or middle classes, but not to the poor. Second, and more pragmatically implementation of agroforestry and other land use technologies on marginal crop land, common lands and forest land is much more likely to be successful in the poor benefits as well as other classes. (William, 1992)

2.2 Multipurpose trees, shrubs and plantation crops

2.2.1 Common useful multipurpose trees

Growing multipurpose trees can reduce the risk of total crop failure. It enhances income and protects soil from water and wind erosion. It is very important that the most suitable trees are selected at the beginning. Farmers grow multipurpose tress all along the farm boundary as living fences as well as wind breaks. Species used as living fence should have prickles so that animals do not like to eat and grow very fast. Promising multipurpose trees used as wind breaks and living fence are *Cascuarina equisetifolia, Gliricida sepium, Grevillea robusta, Leucanea leucocepala, Cajanus cajan, Erythrina poeppiginia, calliandra calothyrsu, Erythrina variegata etc.* Trees are planted as hedgerows between rows of agricultural crops to improve soil fertility, to slow down run off and to reduce soil erosion. Hedgerow plants produce much as fodder and wood used as fuel. Such plants should be fast growing and easy to propagate. Useful spices are *Callindra calothysrus, Cassia siamea, Gliricida sepium, Leucaena leucocepala, Sesbania grandiflora* and *Sesbania sesban*. (Bandyopadhyay, 1997)

2.2.2 Gliricidia in alley cropping

In the alley cropping system Gliricidia was most widely used as the tree component due to its fast growing ability and multiple uses. The principle role of Gliricidia in alley cropping is the supply nutrients to the farming systems mainly through regular loppings. Gliricidia prunings are rich in nutrient and containing 3-4.5% nitrogen, 0.2-0.3% phosphorus, 1.5-3.5% potassium, 1.4% calcium and 0.4-0.6% magnesium and these improve the soil chemical and physical properties. Several benefits have been reported due to alley cropping such as addition of nutrients to the soil via mulching, weed controlling effect due shade, control of erosion, moisture conservation and reduction of potential evaporation. Gliricidia is widely used in Sri Lanka as hade tree in tea, coffee, and cacao plantation and as a support tree for pepper, vanilla, and yams, vegetables, pole beans, and host of climbing gourd varieties.Gliricidia act as good fodder, due to its nutritive value and chemical composition.Gliricidia is the most popular fodder fed to ruminants in all agro- ecological regions extending up to elevations below 100m above sea level. (Gunasena, 1997)

2.2.3 Function of roots in agroforestry

Decomposition of root residues produces two sources of soil nutrients: a direct input from mineralization of decomposing roots, and an indirect and slower input, which includes carbon, from their humification. It was proposed that the oxidation loss of carbon and nitrogen during humification is less than that from decomposition of above -ground litter, and this suggestion has not been disproved. The tree –root-leaching or 'safety-net' hypothesis states that the deeper roots of trees can capture nutrients from the soil solution which in annual cropping system would be lost by leaching. Included in this role is a contribution to the synchrony hypothesis, for, all nutrients released from the decay of pruning are carried into deeper soil horizons before they can be taken up by crops, tree roots may prevent these from being lost from the plant-soil system. The main benefit of roots in agroforestry systems are thus uptake of water and nutrients, including uptake from depth, return of organic matter and nutrients by root decay, and recycling through reduction of leaching losses.(Anthony, 1997)

2.2.4 Plant nutrients

Plant nutrition has a decisive influence on our food, environment and culture. Because it is concerned with the cycling of plant material, agroforestry is necessarily concerned with the complete range of plant nutrients: the major nutrients, nitrogen, phosphorus and potassium; the secondary nutrients, calcium, magnesium and sulphur; and the trace elements or micronutrients, of which about seven are required for plant growth. Lack of major element nutrients seriously restricts yields almost every where. Generally large yield can only be obtained if the crops drive at least 200kgha-1 of nitrogen, 50kgha-1of phosphors, and 200kgha-1 of potassium from the soil. Plant growth is often severely restricted by deficiencies of minor element in plant tissues for instances, soils constituting half the world's land surface are unable to supply sufficient zinc to meet the needs of many crops. (Scaife, 1982)

Nitrogen (N)

Nitrogen is a vitally important plant nutrient and is the most frequently deficient of all nutrients. Plant normally contains between1 and 5% N by weight. It is absorbed by plants as nitrate and ammonium ions and as urea. In moist, warm, well-aerated soils the nitrate form is dominant. (Samuel et all, 1995)

Phosphorus (P)

Phosphorus occurs in most plant in concentrations between 0.1 and 0.4%, considerably lower than those typically found for nitrogen and potassium. Plants absorb either $H_2PO_4^{-1}$ or HPO_4^{-2} orthophosphate ions. Absorption of $H_2PO_4^{-}$ is greatest at low PH values, whereas uptake of $H_2PO_4^{-}$ is greatest at higher values of soil PH. (Samuel et all, 1995)

Potassium (K)

The potassium ion (K^+) is actively taken up from soil solution by plant roots. The concentration of K^+ in vegetative tissue usually ranges from1 to 4% on a dry matter basis. Thus, plant requirements for available K are quite high. K, unlike N, P and most other nutrients, forms no coordinated compounds in the plant. Instead it exists solely as the K^+ ion, either in solution or bound to negative charges on such organic radicals as the acid radical. (Samuel et all, 1995)

2.2.5 Influence of nitrogen on plant development

Nitrogen is an integral component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. It is an essential component of amino acids and related proteins, which are critical not only as building blocks for plant tissue but also in the cell nuclei and protoplasm in which hereditary control is vested. Nitrogen is essential for carbohydrate, use within plants and stimulates root growth and development as well as the uptake of other nutrients. Plants respond quickly to applications of nitrogen. This element encourages aboveground vegetative growth and gives a deep green color to the leaves. It increases the plumpness of cereal grains and tends to produce succulence, a quality particularly desirable in such crops as lettuce and radishes. Nitrogen deficiency is evident when the older leaves of plant turn yellow or yellowish green and tend to drop off. (Nylec, 1996)

2.2.6 Symbiotic Nitrogen fixation in agroforestry system

The important nitrogen-fixing symbioses are:

1. those between many legume tree spices and *Rhizobium*
2. those between *Frankia* and woody species within the eight nonleguminous plant families

those are nodulated by this nitrogen-fixing actinomycete. For temperate and warm temperate conditions, the most important of the *Frankia* association are with *Alunus* (Betulaceae) or *Elaeagnus* and *Hipppphae* (Elaeagunaceae), and in the tropics and subtropics, with members of the Casuarinaceae. The last family has been subject to recent taxonomic revision and is divided into four genera- *Casuarina, Allocasuarina, Gymnostoma,* and *Ceuthostoma*. The most promising candidates for agroforestry are in the first two genera. (Avery et al, 1991)

2.2.7 Nutrient transport

The capacities of mass flow and diffusion to supply nutrient to the root surface as rapidly as these nutrients are absorbed by the plant root have important bearings on the success of soil test. The situation around roots that are actively absorbing nutrients is obviously dynamic, but if the rates of transport of nutrients to the absorbing root can keep up with the rates of actual uptake, then the situation can be treated as a steady-state problem. Accordingly, it is responsible to assume that the nutrient environment of the root is the same as the average nutrient content of the soil in bulk. Obviously, a fertile soil is one that brings nutrients to the root at a rate equals or exceeds the plant's capacity for uptake. In other words, a fertile soil is one in which nutrient transport is not the rate-limiting step in the nutrient absorption process. Thus, the choice of a method for diagnosing the fertility status of the soil depends upon the process which dominates nutrient transport. (Gilmour and Allen, 1995)

2.3 Soil and land

2.3.1 Land degradation

Land degradation is the temporary or permanent lowering of the productive capacity of land. Types of land degradation include soil erosion, soil fertility decline, salinization, and water –resources degradation, forest clearance and degradation, pasture-resource degradation and loss of biodiversity. Land degradation is the negation, the opposite, of sustainable land use, in that the natural resource base is not conserved for the future. Although there are many problems in its scientific measurement, land degradation in developing countries is without doubt very widespread and in places severe. (Anthony, 1997)

2.3.2 Soil fertility

Soil fertility can be simply defined as the capacity of the soil to support growth of plants. It is common therefore to consider it in terms of soil constraints to plant growth. Using nutrient content alone to indicate fertility is too restricted since crop nutrient responses are interaction between soil chemical constituents and the effects of soil condition on movement of nutrients and their uptake by plants. Soil chemical, physical and biological properties all contribute to soil fertility and should be equally considered in fertility assessment. Despite our understanding of what contributes to soil fertility we generally limit its measurement to single soil properties such as % base saturation or more commonly to soil macro-nutrient (N P K) status. The latter can be interpreted and valued in terms of crop fertilizer requirements. Soil fertility is one of a number of factors that determine the magnitude of crop yield. (Roslyn, 1990)

2.3.3 Soil productivity

Soil productivity is a broader concept relating to the ability of the soil to support crop growth on a sustained basis. It might be considered as the soil's ability to maintain fertility over time. Crop yield, both amount and variability with time, can give some indication of the soil's productive capacity although productivity is not alone in determine crop yield response. Monitoring soil changes overtime can be used to assess the maintenance of soil productivity. Land productivity includes soil productivity and all other land factors which influence crop growth. (Roslyn, 1990)

2.3.4 Soil conservation

Keeping the soil resource in place is one of the major sustainability issues because it ensures site productivity and avoids negative downstream externalities such as siltation and eutrophication of surface water and in some cases pollution of costal marine resources. Several paradigm shifts are taking place in hillslope conservation management:

1. The engineering approach has yielded to the biological approach
2. The top-down watershed management approach is yielding to bottom-up approaches with a farmer or community focus
3. The pruned, leguminous alley-cropping concept of contour farming is diversifying toward a much wider array of contour hedgerow option

Many agroforestry systems help keep the soil resource in place by biological instead of engineering means. Closely spaced trees on slopes reduce soil erosion by water through two main processes: first, as physical barrier of stems, low branches, superficial roots and leaf litter against running surface water; second, as sites where water infiltrates faster because of generally better soil structure under trees than on adjacent land. Trees however, do not provide these functions until they are well established and have a developed a litter layer. Sequential agroforestry systems that include crops or ground cover while the trees are small can overcome this limitation. (Fergusl, 1995)

2.3.5 Sustainable land use

Sustainability, as applied to land use, is a more general concept than either soil and water conservation or the conservation of natural resources as a whole, and has been variously defined. Its essential feature is the link between conservation and production. Sustainable land use is that which achieves production combined with conservation of the resources on which that production depends, thereby permitting the maintenance of productivity. Expressed as a pseudo-equation:

Sustainability = productivity + conservation of resources.

For a land-use system to be sustainable requires conservation not only of soil but of the whole range of resources on which production depends. Harvesting of forests must not exceed rates of regrowth, for example, and there are wider considerations such as that of land tenure. However, the most direct and primary requirement for sustainability is to maintain soil fertility. (Anthony, 1932)

2.3.6 Nitrogen content of soils

Total N content of soils ranges from less than 0.02% in sub soils to more than 2.5% in peats. N in soil occurs as inorganic or organic n, with 95% or more of total N in surface soils present as organic N. The organic forms of soil N include ammonium (NH_4^+), nitrate (NO_2^-), nitrate (NO_3^-), nitrous oxide (N_2O), and elemental N (N_2) which is inert except for its utilization by *Rhizobia* and N-fixing microorganisms. From the standpoint of soil fertility NH_4^+, NO_2^- and

NO_3^- are the most important and are produced from aerobic decomposition of soil organic matter or from the addition of N fertilizers. Organic soil N occurs as proteins, amino acids, amino sugars, and other complex N compounds. (Samuel et al, 1995)

2.3.7 Phosphorus content of soils

Phosphorus does not occur as abundantly in soil as N and K. Total concentration in surface soils varies between about 0.02 and 0.10%. Unfortunately, the quantity of total P in soils has little or no relationship to the availability of P to plants. Organic P presents about 50% of the total P in soils and typically varies between 15 and 80% in moist soils. Like OM, soil organic P decreases with depth, and the distribution with depth also varies among soils. As organic P is mineralized to inorganic P or as fertilizer P is added to soil, the organic P in solution not absorbed by plant roots or immobilized by microorganisms can be adsorbed to mineral surface or precipitated as secondary P compounds. (Samuel et al, 1995)

2.3.8 Potassium content of soils

Potassium is present in relatively large quantities in most soils, averaging about 109%. The total K content of soils may range from only a few hundred lb/a-6 in coarse-textured soils formed from sandstone or quartzite to 50, 000 lb/a or more in fine- textured soils formed from rocks high in the K bearing minerals. K is held tightly in feldspars and micas, which are very resistant to weathering. Fixed or non exchangeable K is present mainly within clay minerals such as illite, vermiculite, and chlorite. The small particle size of clays facilitates K release. (Samuel et al, 1995)

CHAPTER 3

MATERIALS AND METHODS

3.1 Site description

The research site is a Dodangolla experimental station of the University of Peradeniya, which is situated in Kundasale. Two treatment sites and two control lands without any cropping system were selected from this area. Two selected agroforestry systems are:

1. Gliricidia and crops in alley cropping system
2. Pepper, Gliricidia and Coffee in mixed farming system

The major soil group of the study area was Red Brown Latasol (RBL).

3.1.1 Pepper, Gliricida and Coffee in mixed farming system

The mix farming system was 15 years old. Gliricida trees have been planted at 2.5m × 2.5m spacing and Coffee was grown at 1.25m ×1.25m spacing among the rows. There were two sample points in the treatment site (P1 and P2) and two sample points in the control land (P3 and P4).

3.1.2 Gliricidia and crops in alley cropping system

The alley cropping system established before 10 years .In this system Gliricidia trees have been planted at 1m × 1m spacing and the distance between two rows was 2.20m.There were two sample points in the treatment site (G1 and G2) and two sample points in the control land (G3 and G4).

3.2 Soil sampling procedure and preparation

Soil samples were collected from each of the plot from six depths. The depth was 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60 cm. Representative soil samples were brought in to the laboratory and air dried for about week and passed through 2mm sieve. Then samples were stored in polythene bags until analysis begins.

3.3 Laboratory analytical procedure

3.3.1 Determination of total Nitrogen

Total nitrogen in the soil sample was measured using Kjeldhal method. Point five grams of 2mm sieved soil was transferred into a digestion tube and 1g of catalyst mixture and 10ml of conc. sulphuric acid were added. The sample was digested using a digestion unit until the solution becomes light blue in color. After cooling to room temperature, 40ml of distilled water was added in to the digestion tube. Twenty milliliters of 4% boric acid was placed in a receiving flask and two drops of mixed indicator were added. The receiving flask was kept beneath the condenser. Then 20ml of NaOH was added into the digestion tube containing the sample. Subsequently flask was connected to distillation apparatus and distilled until the distillate in the receiving flask increased up to about 100ml. It was titrated with 0.01N HCl until the color changed from green to pink. Two replicates were used for this test. (Dwayne et al, 1982)

(For calculation see appendix I)

3.3.2 Determination of available Nitrogen

Five grams of air dried, 2mm sieved soil sample weighed into a 250ml polyethylene bottle. About 50ml of 1M KCl was added into a bottle. The contents were shaken for 30 minutes at 150 rpm. The suspension was filtered through a Whatman No. 1 filter paper. The filtrate was transferred into the distillation flask. Ten milliliters of boric acid and two drops of mix indicator were added into the receiving flask. The distillation flask was taken closer to the distillation unit. Ten grams of Mgo was added into the distillation flask and it was connected to the distillation unit immediately and distilled until the distillate in the receiving flask collected about 100ml. It was titrated with 0.01N HCl until the color changed from blue to pink. Two replicates were used for this test. (Gupta, 1999)

(For calculation see appendix II)

3.3.3 Determination of total Phosphorus

Point one grams of air dried soil sample weighed into a Pyrex beaker (there were two replicates). Four milliliters of conc.HNO_3 was added into the beaker and heated at about 100°C until red fume observed and 2ml of conc. $HClO_4$ was added into the beaker and heated at about 100°C until dense fume observed. After cooling to room temperature, it was transferred into a 50ml of volumetric flask through Whatman No.1 filter paper using distilled water. The volumetric flask was volumeraized using distilled water. The solution was transferred into the polyethylene bottle. The phosphorus content of soils was measured colorimetric ally by Olsen's method. (Olsen et al, 1954)

(For calculation see appendix III)

3.3.4 Determination of available Phosphorus

Two grams of air dried, 2mm sieved soil samples weighed into a 250ml polyethylene bottle. Forty mililiters of 0.5M NaHCO3 was added into the bottle. Then the bottle was placed on the shaker and shaken for 30 minutes at 150 rpm. (Gupta, 1999) The filtrate was collected passing through a Whatman No.1 filter paper. The phosphorus content of soils was measured colorimetrically by Olsen's method. (Olsen et al, 1954)

(For calculation see appendix IV)

3.3.5 Determination of total Potassium

Point one gram of air dried soil sample weighed into a Pyrex beaker. Four milliliter of conc.HNO_3 was added into the beaker and heated at about 100°C until red fume observed and 2ml of conc. $HClO_4$ was added into the beaker and heated at about 100°C until dense fume observed. After cooling to room temperature, it was transferred to a 50ml of volumetric flask through Whatman No.1 filter paper using distilled water. The volumetric flask was volumeraized using distilled water. Potassium content of soil sample was determined using Flame Emission Spectrophotometer. Two replicates were used for this test. (Gupta, 1999)

(For calculation see appendix V)

3.3.6 Determination of exchangeable Potassium

Two grams of air dried; 2mm sieved soil samples weighed into 250ml polyethylene bottles. For each sample two replicates were used. Forty milliliter of 1 N ammonium acetate solution was added into the bottle. The bottle was placed on the shaker and shaken for 30 minutes at 150 rpm. The filtrate was collected passing through a Whatman No.1 filter paper and the potassium content was determined using Flame Emission Spectrophotometer. (Baruah, 1997)
(For calculation see appendix VI)

3.4 Data Analysis

Data were analyzed using Minitab software package. Two Way ANOVA procedure was carried out to determine the improvement of nutrition of treatment and control.

CHAPTER 4

RESULTS AND DISCUSSION

Total N, available N, total P, available P, total K and exchangeable K in different depths (0-60cm) of soils collected from two cropping systems were statistically analyzed.

4.1 Total Nitrogen and available Nitrogen

Total nitrogen contents of different depths of two cropping systems were given in the Table 4.1, 4.2 and figures 4.1, 4.2. Total N content of mixed cropping system varied from 1456 ppm (0-10cm depth) to 903 ppm (50-60 cm). Amount of total N in soils of mixed cropping system is significantly higher than the control soil. When the soil depth increased total N in soils with and without mix cropping system showed a decreasing trend.

High total N of soils in mixed cropping system may be due to the continuous accumulation of organic matter on the surface soil. The tree combinations of the system are: Gliricidia, Coffee, Pepper and some Jak trees. The selected mixed cropping land similar to the typical Kandyan home garden.

Total N of soils from the alley cropping system varied from 1169 ppm to 609 ppm. When compared with the soils from mixed cropping system, total N of alley cropping system showed lower values than control land. Major tree group in the alley cropping system was Gliricidia. The distance between two rows was about 2.20m. In between the rows, annual crops such as vegetables, legumes have been grown. Low amount of N of the alley cropping system may be due to the continuous uptake of N by annual crops.

Available N content of different depths of two cropping systems are given in the Table 4.3, 4.4 and figures 4.3, 4.4. Available N content of soils from mixed cropping system was significantly higher than the soils from without mix cropping system. The available N in both soils showed a decreasing trend when the soil depth increased.

However, available N in alley cropping system did not show a significant difference. But slightly increase of available N in alley cropping system than control.

Table 4.1: Total N of mixed farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	1456	1113	1127	987	966	903
Control	1246	1029	980	1036	917	833

Table 4.2: Total N of alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	1169	1001	805	595	588	609
Control	1722	1336	1190	1043	1029	854

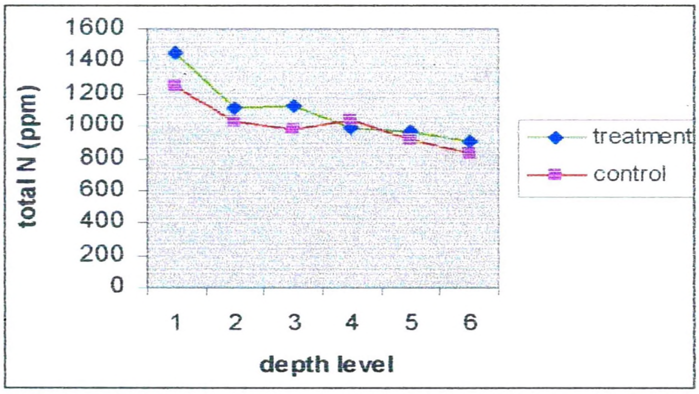

Figure 4.1: Variation of total N content in mixed farming system and its control

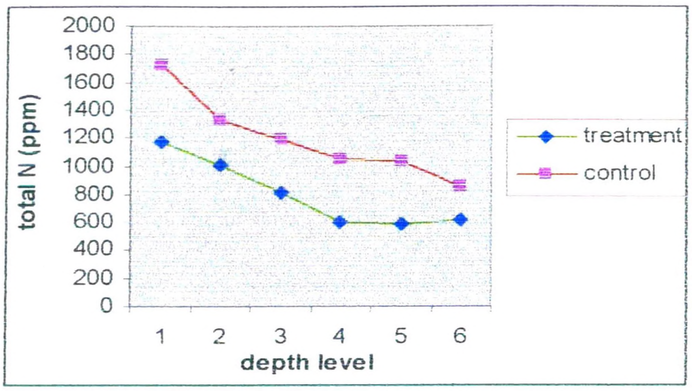

Figure 4.2: Variation of total N content in alley cropping system and its control

Table 4.3: Available N in mixed farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	27	22	28	25	22	22
Control	23	20	20	24	21	21

Table 4.4: Available N in alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	23.1	21.7	23.8	28	27.3	25.2
Control	22.4	25.2	21.6	22.4	24.5	22.4

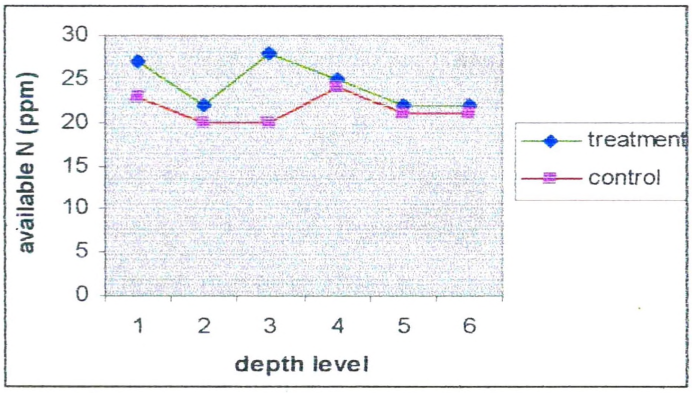

Figure 4.3: Variation of available N content in mixed farming system and its control

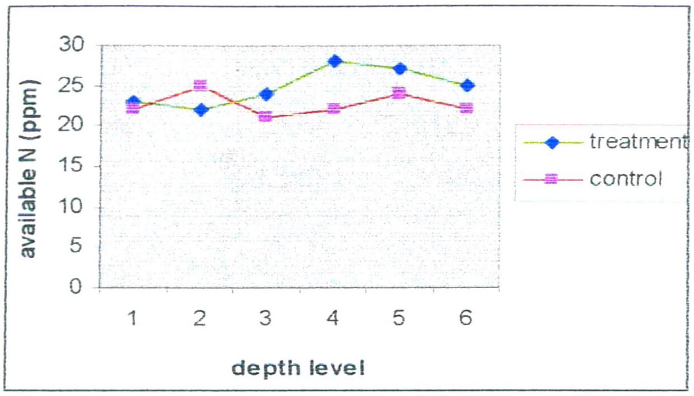

Figure 4.4: Variation of available N content in alley cropping system and its control

4.2 Total Phosphorus and available Phosphorus

Total P of different depths of two cropping systems are given table 4.5, 4.6 and figures 4.5, 4.6. Total P content of mix cropping system varied from 3540ppm to 2300ppm and P content of control varied from 3380ppm to 2180ppm.Total P content of mix cropping system was significantly higher than the control soil. When the soil depth increased, total P of soils in mix farming system and control showed a decreasing trend due to the abundance of organic matter in the surface soil.

Total P content of alley cropping system was lower than the control, but did not show a significant increase. When considering the first depth level there was an increase of total P in alley cropping system than the control.

Available P contents of different depths of two cropping systems were given in the Table 4.7, 4.8 and figures 4.7, 4.8. Available P in mix farming system showed a significant increase than the control. When the soil depth increases, available P content of soils from mix farming system showed a decreasing trend. In the alley cropping system there was no significant difference of available P, but there was a slightly increase of available P than the control. When considering the first and fifth depth levels there were significant increase of available P in alley cropping system than the control.

Table 4.5: Total P in mix farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	3540	2180	2130	2170	2300	2300
Control	3380	2100	2060	1860	2200	2100

Table 4.6: Total P in alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	4500	3380	2420	2220	2460	1900
Control	3540	4300	3180	2740	3700	3940

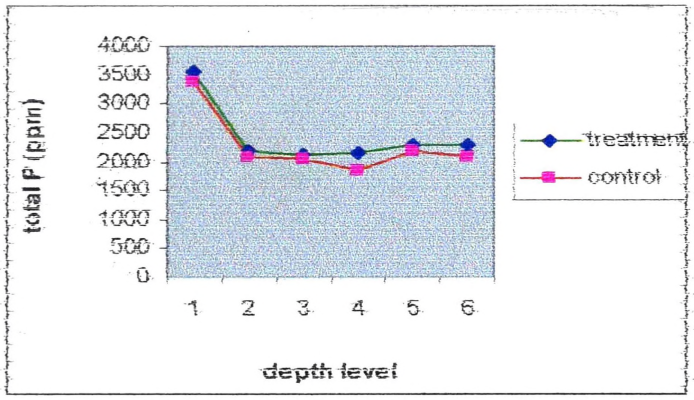

Figure 4.5: Variation of total P content in mix farming system and its control

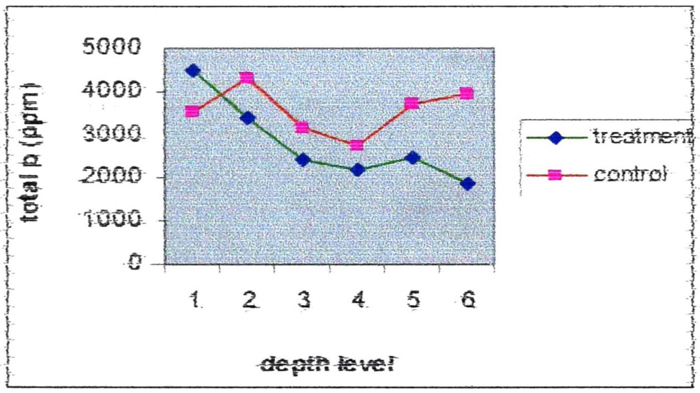

Figure 4.6: Variation of total P content in alley cropping system and its control

Table 4.7: Available P in mix farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	48	40	26	30	36	37
Control	44	32	19	21	21	20

Table.4.8: Available P in alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	185	43	60	55	132	78
Control	116	45	90	37	61	64

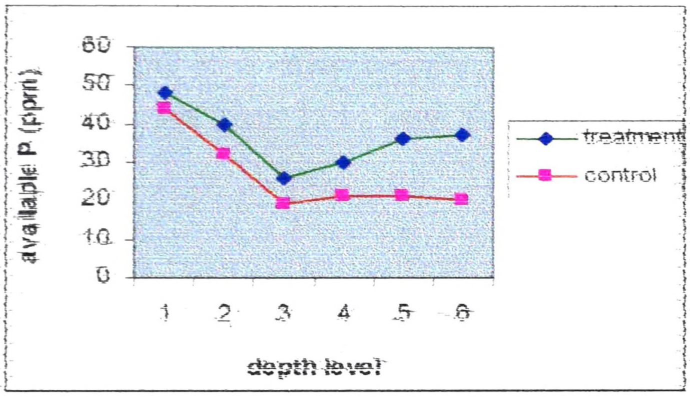

Figure 4.7: Variation of available P content in mix farming system and its control

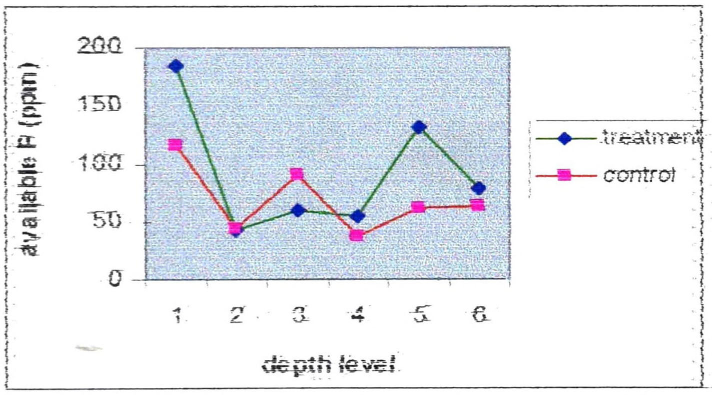

Figure 4.8: Variation of available P content in alley cropping system and its control

4.3 Total Potassium and exchangeable Potassium

Total K contents of different depths of two cropping systems were given in the Table 4.9, 4.10 and figures 4.9, 4.10. Total K of mix cropping and alley cropping systems did not show a significant difference. But there were slight increases than the controls. Total K content of mix cropping system showed significant differences than the control of soils from the first and the second depth levels. In the first depth level of alley cropping system there was significant increase than control.

Available K content of different depths of two cropping system were given in the table 4.11, 4.12 and figures 4.11, 4.12. Available K of mixed cropping system showed a significant increase than control. But there was no significant increase of available K in alley cropping system than the control. When the soil depth increases available K in soils from two cropping system showed a decreasing trend.

Table 4.9: Total K in mixed farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	16950	19300	13300	15100	15700	7850
Control	10900	8500	6700	12100	10300	11500

Table 4.10: Total K in alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	11500	6000	5450	4900	1850	1850
control	6650	5450	4300	4900	4300	5450

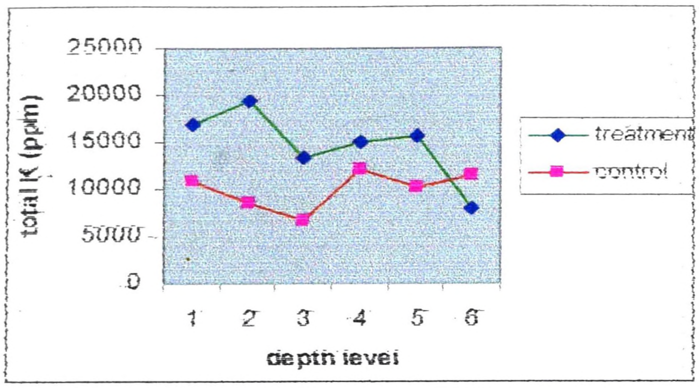

Figure 4.9: Variation of total K content in mixed farming system and its control

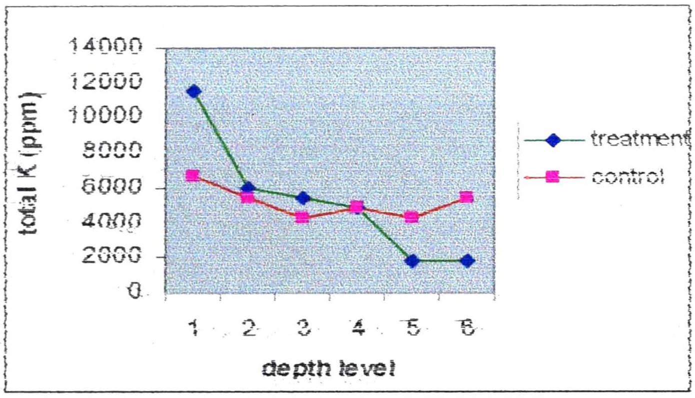

Figure 4.10: Variation of total K content in alley cropping system and its control

Table 4.11: Exchangeable K in mixed farming system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	1138	729	797	819	841	796
Control	865	615	682	728	797	610

Table 4.12: Exchangeable K in alley cropping system (ppm)

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
Treatment	685	592	638	547	547	524
Control	615	660	660	592	547	524

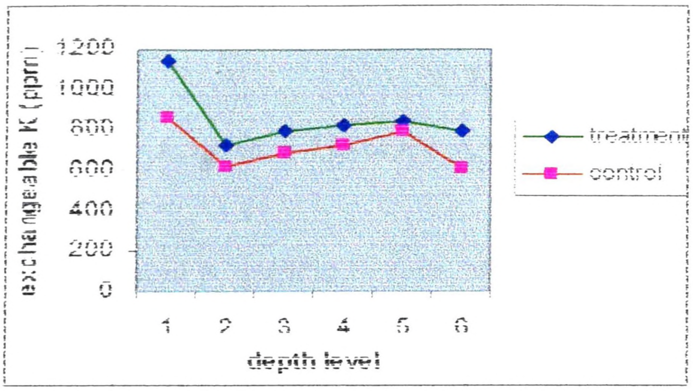

Figure 4.11: Variation of exchangeable K content in mixed farming system and its control

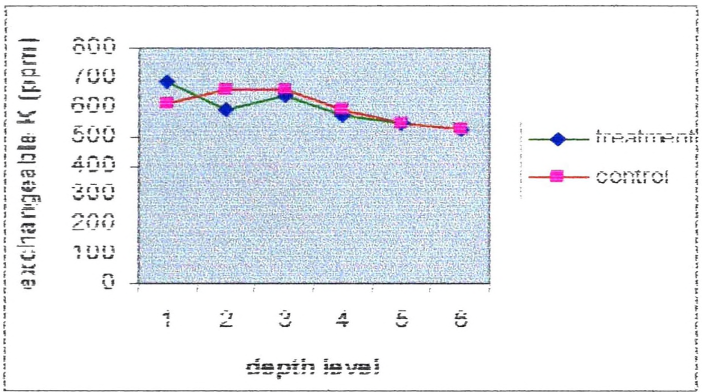

Figure 4.12: Variation of exchangeable K content in alley cropping system and its control

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Total N, P and K content in soils of two mixed cropping systems was higher than the soils without any cropping system. Total K content in soils of alley cropping system was higher than the control. But total N, P content in soils of alley cropping system was lower than the soils without any cropping system. Because continuous uptake of nutrients by annual crops. All nutrients decreased with the depth of soil. Therefore much of the nutrients accumulate in the surface layers of the soils.

Available N, P and exchangeable K content in soils from two different agroforestry systems was higher than the soils without any cropping system with few exceptions.

Therefore the practice of agroforestry systems is very valuable in agriculture for maintaining soil fertility status.

REFERENCES

Anthony, Y. (1932) Agroforestry for soil conservation. ICRAF, PO Box 30677, Nairobi, Kenya, pp9-135.

Anthony, Y. (1997) Agroforestry for soil management. International center for research in Agroforestry, Nairobi, Kenya, 2nd Ed, 320p.

Avery, M. E. (1997) Biophysical Research for Asian Agroforestry. Oxford and IBH publishing house PVT. LTD, New Delhi, 292p.

Bandyopadhyay, A. K. (1997) A Textbook of Agroforestry with Application. Vikas publishing house PVT. LTD, New Delhi, 110p.

Baruah, T. C. (1997) A Textbook of soil Analysis. Vikas publishing house PVT. LTD, New Delhi, 330p.

Chundawat, B. C. (1993) Textbook of Agroforestry. Oxford and IBH publishing CO. PVT. LTD, 188p.

Dewivedi, A. P. (1992) Agroforestry principles and practices. Oxford and IBH publishing CO. PVT. LTD, 365p.

Dwayne, R Buxton, Kristine, Gates, Richard. C and Dinauer, (1982) Methods of soil Analysis part 2. Madison publisher, Wisconsin, USA, 2nd Ed, 1159p.

Ferausl, S. (1995) Agroforestry, Science, Policy and Practice. Kluwer, Acadamic publishers, Pardrecnt, Boston, London, V.30, pp5-42.

Gilmour, C. M., Allen, O. N. (1965) Microbiology and Soil fertility. Oregon state university, Corvallis USA, 164p.

Gunasena, H. P. M. (1997) Gliricidia in Sri Lanka. Publication of university of Peradeniya , Oxford Forestry institute (UK) Forestry Research link, 66p.

Gunasena, H. P. M., Sangakkara, U. R. (1997) Agroforestry Research in Sri Lanka. Publication of university of Peradeniya , Oxford Forestry institute (UK) Forestry Research link, pp15-30.

Gupta, P. K. (1999) Soil, Plant, Water and Fertilizer Analysis. Arobios, Near Nasarani Cinama, Chopasani Road, Jodhur 342002, India, 437p.

Kang, B. T., Inoue, T. C. (1991) Tropical Agriculture research Series. Tropical Agriculture Research Center, Ministry of Agriculture, Forestry, Fisheries, Nairobi, Kenya, pp147-207.

Metson, A. J. (1956) Methods of Chemical Analysis for Soil survey samples. Department of Scientific Industrial research, Wellington, New- Zealand, 207p.

Nylec, B. (1996) The nature and properties of soil. Prentice,Hall of India Private Limited, New Delhi, 412p

Olsen, S. R., Cole, C. V., Watanabe, F.S. and Dean, L. A. (1954) Estimation of available Phosphorus in soils by extraction with Sodium Bicarbonate. U.S. department of Agric. civ 939, 232p.

Peter, H. (1991) Tropical Agroforestry, Blackwell science KK, MG Kodenmacho Building, 7-10 Kodenmacho Nihombashi Chuo-KV, Tokgo 104, Japan, 371p.

Rick, J. (1985) Agroforestry research in the Semi- Arid Tropics. International crops Research institute for the Semi- Arid Tropics, pp11-30.

Roslyn, T. P. (1990) Agroforestry for sustainable Production. Published by commonwealth secretariat publications, Marlborough house, London, 147p.

Samuel, L., Werner, L., James, D.and John, L (1995) Soil Fertility and Fertilizers. Prentice, Hall of India Private Limited, New Delhi-110001, 634p.

Scaife, A. (1982) Plant nutrition, proceeding of the Ninth international plant nutrition Colloquium. Commonwealth Agricultural Bureaux, V1, pp1-100.

Tejwani, K. G. (1994) Agroforestry in India, Oxford and IBH publishing CO. PVT. LTD, New Delhi, 233p.

William, R. (1992) Social Science Application in Asian Agroforestry. Oxford and IBH publishing CO. PVT. LTD, New Delhi, 187p.

APPENDIX I

CALCULATION OF TOTAL NITROGEN

In the digestion Organic N converted in to the Inorganic N.

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ (Distillation)

$NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$ (Distillation)

$H_2BO_3 + NH_4^+ + HCl \rightarrow H_3BO_3 + NH_4Cl$ (Titration)

(Metson, 1956)

Volume of 0.01 HCl required = x

Mass of N $= x \times 0.01 \times 14 \times 1000$

Total nitrogen in ppm $= 0.01 \times x \times 14 / 0.5$

APPENDIX II

CALCULATION OF AVAILABLE NITROGEN

Soil is extracted for available N by shaking with an appropriate extractant.Then, NH_4^+ and NO_3^- present in the extractant are converted to NH_3.

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

$$NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$$

$$H_2BO_3 + NH_4^+ + HCl \rightarrow H_3BO_3 + NH_4Cl$$

(Metson, 1956)

Volume of 0.01 HCl required = x

Available in ppm $= 0.01 \times x \times 14 \times 100 / 5$

APPENDIX III

CALCULATION OF TOTAL PHOSPHORUS

The total P content of soils was measured colorimetrically by Olsen's method. (Olsen et al, 1954)

ABS for standard:

ppm	ABS
0.1	0.011
0.2	0.022
0.5	0.058
1	0.12
2	0.248

$y = mx + c$

$y = 0.125x - 0.00325c$

Total Phosphorus in ppm = $x \times 1000 / 0.1$

APPENDIX IV

CALCULATION OF AVAILABLE PHOSPHORUS

The available P content of soils was measured colorimetrically by Olsen's method. (Olsen et al, 1954)

ABS for standard:

ppm	ABS
0.1	0.019
0.5	0.117
2	0.314
5	0.669

$y = mx + c$

$y = 0.129x + 0.0352$

Available Phosphorus in ppm = $x \times 1000 / 2$

APPENDIX V

CALCULATION OF TOTAL POTASSIUM

Total K content of soil sample was determined using Flame Emission Spectrophotometer

Readings for standard

ppm	reading
1	0.11
5	0.45
10	0.86

$y = mx + c$

$y = 0.0833x + 0.0292$

Total potassium in ppm = $x \times 1000 / 0.1$

APPENDIX VI

CALCULATION OF EXCHANGEABLE POTASSIUM

Exchangeable K content of soil sample was determined using Flame Emission Spectrophotometer.

Readings for standard

ppm	readings
0.5	0.06
1	0.11
2	0.2
5	0.54
10	1.1
50	3.85

$y = mx + c$
$y = 0.11x - 0.0053c$

Available Potassium in ppm = $x \times 1000 / 2$

APPENDIX VII

TOTAL NITROGEN IN MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	85345	85345	17.38	0.000
Depth	5	1090680	218136	44.43	0.000
Interaction	5	79460	15892	3.24	0.016
Error	36	176746	4910		
Total	47	1432231			

Least Squares Means for response

Depth	Mean	SE Mean
1	1351.0	27.95
2	1068.7	27.95
3	1053.5	27.95
4	1011.5	27.95
5	946.3	27.95
6	868.0	27.95
Land		
1	1092.0	16.14 (treatment)
2	1007.7	16.14 (control)

Hypothesis:

Ho: There are no different between treatment and control

H1: There are different between treatment and control

$\alpha = p' = 0.05$

p'>p, so reject H0

APPENDIX VIII

TOTAL NITROGEN IN ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	1921600	1921600	67.09	0.000
Depth	5	2937730	587546	20.51	0.000
Interaction	5	113370	22674	0.79	0.563

Least Squares Means for response

Depth	Mean	SE Mean
1	1445.5	59.07
2	1165.5	59.07
3	997.5	59.07
4	819.0	59.07
5	808.5	59.07
6	731.5	59.07
Land		
1	794.5	34.10 (treatment)
2	1194.7	34.10 (control)

Hypothesis:

Ho: There are no different between treatment and control

H1: There are different between treatment and control

H $\alpha = p' = 0.05$

p'>p, so reject H0

APPENDIX IX

AVAILABLE NITROGEN IN MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	79.1	79.1	7.48	0.010
Depth	5	113.7	22.7	2.15	0.081
Interaction	5	77.7	15.5	1.47	0.223
Error	36	380.2	10.6		
Total	47	650.7			

Least Squares Means for response

Depth	Mean	SE Mean
1	24.85	1.1817
2	21.35	1.1817
3	24.15	1.1817
4	24.85	1.1817
5	21.70	1.1817
6	21.70	1.1817
Land		
1	24.38	0.6822 (treatment)
2	21.82	0.6822 (control)

Hypothesis:

Ho: There is no significant difference

H1· There is significant difference between treatment and control

$\alpha = p' = 0.05$

p'>p so reject H0

APPENDIX X

AVAILABLE NITROGEN IN ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	4.1	4.1	0.19	0.664
Depth	5	40.0	8.0	0.38	0.862

Least Squares Means for response

Depth	Mean	SE Mean
1	23.80	1.6569
2	23.45	1.6569
3	25.20	1.6569
4	25.20	1.6569
5	25.90	1.6569
6	23.80	1.6569

Land		
1	24.85	0.9566 (treatment)
2	24.27	0.9566 (control)

Hypothesis:

Ho: There is no significant difference

H1: There is significant difference between treatment and control

$\alpha = p' = 0.05$

p>p' so do not reject H0

APPENDIX XI

TOTAL PHOSPHORUS IN MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	70533	70533	16.82	0.009
Depth	5	2970700	594140	141.69	0.000
Error	5	20967	4193		
Total	11	3062200			

Least Squares Means for response

Depth	Mean	SE Mean
1	3460	45.79
2	2140	45.79
3	2095	45.79
4	2015	45.79
5	2250	45.79
6	2200	45.79
Land		
1	2437	26.44 (treatment)
2	2283	26.44 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

P'> p so reject H0

APPENDIX XII

TOTAL PHOSPHORUS IN ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	1702533	1702533	3.47	0.122
Depth	5	3705200	741040	1.51	0.331
Error	5	2455067	491013		
Total	11	7862800			

Least Squares Means for response

Depth	Mean	SE Mean
1	4020	495.5
2	3840	495.5
3	2800	495.5
4	2480	495.5
5	3080	495.5
6	2920	495.5
Land		
1	2813	286.1 (treatment)
2	3567	286.1 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p> p' so do not reject H0

APPENDIX XIII

AVAILABLE PHOSPHORUS IN MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	330.75	330.75	34.63	0.002
Depth	5	58670.42	11734.08	1228.70	0.000
Error	5	47.75	9.55		
Total	11	59048.92			

Least Squares Means for response

Depth	Mean	SE Mean
1	215.50	2.185
2	36.00	2.185
3	22.50	2.185
4	25.50	2.185
5	28.50	2.185
6	28.50	2.185
Land		
1	64.67	1.262 (treatment)
2	54.17	1.262 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p'>p so, reject H0

APPENDIX XIV

AVAILABLE PHOSPHORUS IN ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	1633	1633	2.05	0.211
Depth	5	15598	3120	3.92	0.080
Error	5	3980	796		
Total	11	21211			

Least Squares Means for response

Depth	Mean	SE Mean
1	150.50	19.95
2	44.00	19.95
3	75.00	19.95
4	46.00	19.95
5	96.50	19.95
6	71.00	19.95
Land		
1	92.17	11.52 (treatment)
2	68.83	11.52 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

P> P' so do not reject H0

APPENDIX XV

TOTAL POTASSIUM OF MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	64171875	64171875	5.59	0.064
Depth	5	37759375	7551875	0.66	0.671
Error	5	57349375	11469875		
Total	11	159280625			

Least Squares Means for response

Depth	Mean	SE Mean
1	13700	2395
2	13900	2395
3	10000	2395
4	13600	2395
5	13000	2395
6	9675	2395
Land		
1	14625	1383 (treatment)
2	10000	1383 (control)

Hypothesis:

H0: There is no significant difference

H1: There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p>p' so do not reject

APPENDIX XVI

TOTAL POTASSIUM OF ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	20833	20833	0.00	0.948
Depth	5	44806667	8961333	2.03	0.227
Error	5	22034167	4406833		
Total	11	66861667			

Least Squares Means for response

Depth	Mean	SE Mean
1	9075	1484.4
2	5725	1484.4
3	4875	1484.4
4	4900	1484.4
5	3075	1484.4
6	3650	1484.4
Land		
1	5258	857.0 (treatment)
2	5175	857.0 (control)

Hypothesis:

H0: There is no significant difference

H1: There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p>p' so do not reject H0

APPENDIX XVII

EXCHANGEABLE POTASSIUM IN MIXED FARMING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	56719	56719	17.31	0.009
Depth	5	138945	27789	8.48	0.017
Error	5	16381	3276		
Total	11	212045			

Least Squares Means for response

Depth	Mean	SE Mean
1	1001.0	40.47
2	672.0	40.47
3	739.5	40.47
4	773.5	40.47
5	818.5	40.47
6	703.0	40.47
Land		
1	853.3	23.37 (treatment)
2	715.8	23.37 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p' >p so reject H0

APPENDIX XVIII

EXCHANGEABLE POTASSIUM OF ALLEY CROPPING SYSTEM

Two-way ANOVA: response versus land, depth

Analysis of Variance for response

Source	DF	SS	MS	F	P
Land	1	341	341	0.30	0.607
Depth	5	29929	5986	5.27	0.046
Error	5	5676	1135		
Total	11	35946			

Least Squares Means for response

Depth	Mean	SE Mean
1	650.0	23.82
2	626.0	23.82
3	649.0	23.82
4	569.5	23.82
5	547.0	23.82
6	523.5	23.82
Land		
1	588.8	13.75 (treatment)
2	599.5	13.75 (control)

Hypothesis:

Ho: There is no significant difference

H1 There is a significant difference between treatment and control

$\alpha = p' = 0.05$

p>p' so do not reject H0

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