KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY
FACULTY OF RENEWABLE NATURAL RESOURCES
DEPARTMENT OF AGROFORESTRY

EFFECT OF TEAK (*Tectona grandis*) ON THE GROWTH AND YIELD OF MAIZE (*Zea mays*) AT DIFFERENT INTER-CROP SPACING

QUARCOO BENJAMIN (B.Sc. Natural Resources Management)

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BY

BENJAMIN QUARCOO

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DECLARATION

I do declare that except references to other people's work which have been duly cited, this work submitted as a thesis to the Department of Agroforestry, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi for the degree of Master of Science in Agroforestry is the result of my own research.

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Benjamin Quarcoo

(Student)

……………………………………………………………………

Dr. K. Twum-Ampofo

(Supervisor)

……………………………………………………………………

Dr (Mrs) Olivia Agbenyega

(Head of Agroforestry Department)

ABSTRACT

The study presents landuse systems and technology where a woody perennial (Teak) was intercropped with maize in at different planting spacing. The trials were conducted under young Teak plantation in blocks of; (200 x 500m) at ages ;(1 to 3yrs) at the village of Bosomkyekye, Ashanti Mampong.

The tree-crop interactions by biomass contribution and crop yield, soil were assessed under the different tree ages and intercrop spacing. Hence the objective for the study was to investigate the effect of Teak-Maize cultivation on soil mineral status and intercrop spacing which promotes greater crop growth and yield.

From the results soil analysis before and after the experimental trials across blocks of Teak stands did not show any remarkable difference in mineral status between blocks. Experimental results indicated that Teak age and intercrop spacing did not present any significant difference in treatment means in maize; height, leaf count, leaf area index and grain dry weight thus;($p\leq0.05$) at 2, 4 degrees of freedom. However, tables of means showed intercrop spacing; 40 x 150cm gave best crop biomass growth and dry grain yield.

Agroforestry has become a sustainable approach to community woodland and crop management. To gain wide scale rural adoption of practices, it may be worthwhile to further pursue research trials with aimed at promoting and providing useful information for community adoption for tree plantation and crop cultivation.

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CHAPTER ONE

1.0 INTRODUCTION

Teak (*Tectona grandis* Linn. F. Verberacae) is a high quality deciduous timber species, native to India, Burma, Indonesia and Colombia. It is one of the important tree plantation species which could easily be established in most regions of the world including both the humid forest and the tropical savanna zones.

The species was introduced in Ghana early in the early 1930s and has since then acclimatized well and have been adapted for industrial plantations and small woodlots. Large plantations development of teak in Ghana started in the late 1960s under the plantation development programme which was initiated by the United Nations Reforestation Programme (Prah, 1994). These industrial plantations of teak were projected to cover about 45,000 ha and to supplement wood supply as well as to safeguard the depletion of biodiversity resources of the natural forest (Dreschel and Zech, 1994).

Teak gives good and durable hardwood, hence used for wide range of furniture and construction works. The poles are extensively used as cable support for the transmission of electricity and telegraphic waves. The tree is also valued by small-scale farmers and local communities as good poles for fencing and making of rafters. It is often used as fuelwood and stakes on yam farms. Its leaves are also believed to have medicinal value, hence planted around villages and several communities (FAO and UNEP, 1981).

Cultural practices of teak plantations development in Ghana first began with the taungya system, a traditional agroforestry practice which permitted the cultivation of food crops with teak until the canopy of the trees is closed (PPMED, 1988). The practice was not very effective with the establishment programme since most people deliberately kill the teak plants to perpetuate their food crops on plots allocated to them. Others too only manage their plots to harvest their food crops after which they abandon them to be taken over by weeds. Lack of good management and indiscriminate bushfires most often result to destruction of these industrial tree plantations destroyed or growth retarded.

Farmers opinion that their activities would be stopped at later developmental stages of the plants coupled with the fact that the plants canopy closure would prevent them from carrying out any continuous farming activities make them uncompromising to adopt the practice on both the plantation sites and on their farms. Since local knowledge on the growth and yield characteristics of foodcrops like cereals and others when intercropped with teak is not well advanced in Ghana, there is the need to conduct trials with Teak to establish intercrop densities which would permit good growth and yield.

Food production in Agroforestry practices could be enhanced by the use of appropriate trial methods. Tuangya farming has proven to be sustainable livelihood to rural communities and environmentally friendly. For example in Southern Nigeria, 11,000 hectares under tuangya farming produced an estimated 12,000 tonnes of maize, 165,200 tonnes of cassava and 75,600 tonnes of yams of which 30-40% was consigned to market. (Nao, 1978)

In Trinidad, Ramdial (1980a), cites an average yield of foodcrops from Teak Tuangya as 5.0-6.6 tonnes/ha and 2.3-3.9 tonnes/ha in Pine tuangya.

Hence generating both timber and foodcrops with efficient landuse for rural communities.

Communities hesitant to adopt Teak and foodcrop trials for fear that trees on farmlands compete adversely with foodcrops for light, water, nutrients as well as their perception that teak plants impoverish the soil of plant nutrients and have allelopathic effects on any undergrowth vegetation is a drawback to afforestation with foodcrop.

A research base agroforestry trial is hence necessary to check the validity of these fears and also to assess appropriate agroforestry technologies which could effectively and sustainably integrate teak and foodcrop production in land-use systems (Owuene *et al*, 1991).

According to Banda *et al.* (1994) maize yields in Leucaena plots was sustained at 1.5 – 2.6 t/ha without chemical fertilizers and crop rotation. Root competition between Leucaena and maize for soil nutrients too was insignificant. However, Sheik and Haq (1978) studied the effect of *Acacia nilotica* and *Dalbergia sissoo* on wheat yields and revealed that distance from the base of the trees and the direction of their shade had significant effect on wheat yields for both species. Hence the choice of the tree species and the densities of foodcrops from the base of the trees would determine the level of tree-crop interaction and the magnitude of crop yield to be obtained.

Several foodcrops could be conveniently cropped under tree plantation species with good research information and management supervision, hence several international and national organizations are undertaking research to develop a better empirical understanding of the biophysical and socio-economic processes involved; thus in a bid to safeguard sustainable food production with natural resources conservation (Lundgren, 1987).

Maize (*Zea mays*) is a member of the family Graminae. It grows well on good drained, aerated and silty loamy soils containing high soil nutrients. It is the most staple grain grown in Ghana and is cultivated throughout the country. It could be stored for relatively longer periods than most cereals (Stainer, 1986).

Maize has successfully been intercropped with tree species such as *Leucaena leucocephala*, *Senna siamea*, *Gliricidia sepium* etc. in alley farms with good results (Banda *et al*, 1993). Even though the practice of maintaining variety of tree species on croplands has persisted for a long time, it has not gained much social acceptance in recent times for lack of promotional education and research information of this landuse. However, with the advent of wider spacing plantation types such as 2.5 x 2.5m or 3.0 x 3.0m, it may be beneficial to intercrop the species with foodcrops widely used by communities for food and income hence effectively optimizing landuse.

This study was hence undertaken with the objective to:

1. Assess Teak age and maize intercrop spacing which promotes good crop growth and grain yield.
2. Assess Teak and maize intercrop effect on soil physical and chemical properties, before and after experimental trials.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Concept of Agroforestry

Agroforestry is a collective name for land-use systems in which woody perennials such as trees, shrubs and bamboos are grown in association with herbaceous plants such as crops, pasture and/or livestock in spatial or temporal arrangements in which there are both ecological and economic interactions between the tree and non-tree components of the system (Young, 1989). The main components of agroforestry systems are trees, shrubs, crops, pastures and livestock together with environmental factors of climate, soils and landforms. Essentially there must be interaction between the tree and non-tree parts of the system. Agroforestry also covers biomass transfer of biological material such as incorporation of the leaf litter into the soil or feeding of such litter as browse to livestock with subsequent return to the soil as manure (Young, 1988).

Economic interactions mean that the tree and the non-tree components each serve to meet some of the farmers' needs, whether for subsistence such as need for food, fodder, fuelwood or for cash. Ecological interactions refer to effects such as shading of crops by trees, protection of crops or animals by live fences, effects of trees on soil conservation and provision of shade for livestock (Young, 1989). The distinctive features and/or functions of trees in agriculture are the essence of agroforestry. Trees used in agroforestry are referred to as multipurpose trees since they have more than one service and productive function to the land-use system in which they are grown

(Agbede, 1985). The concept of agroforestry is based on multipurpose trees (MPTs). It has been said that all trees are multipurpose. The same species of trees can be managed for a single purpose such as timber or for multipurpose reasons. Teak with intercrop trials are often undertaken and gaining widespread community participation in the West African subregions. (Agbede and Adedire, 1989)

2.2 Agro forestry Practices for Soil Fertility Improvement

Several agroforestry practices have been used in soil fertility improvement, these include the taungya system, improved fallow, crops under tree cover, shifting cultivation, hedgerow intercropping and biomass transfer (Nair, 1984).

2.2.1 Shifting Cultivation

Shifting cultivation is the earliest and still the most widespread practice of agroforestry (Young, 1989). Two main forms can be identified, i.e. shifting cultivation in the forest and shifting cultivation in the Savanna (Nair, 1984). The important phenomenon in shifting cultivation that is of considerable relevance to agroforestry approach is the restoration of soil fertility during the fallow period through biological processes associated with revegetation of the given area. The soil improvement that takes place during the fallow period as well as the possibility for replacing the "traditional" fallow species with other useful plants provide sound guidelines for agroforestry as an approach to improved land management in such areas. Shifting cultivation is a sustainable system, provided the fallow is long enough to restore soil conditions to the same site as in previous cultivation. An early attempt at improving shifting cultivation was the corridor system in which the fallow is still the natural forest regeneration, but the area cleared for cultivation is a belt along the contour, moving up the slope in successive years to produce contour-aligned belts of forest at different stages of regeneration. Whilst achieving erosion control, this does not in itself change the rest period requirement and thus fails to restore the soil fully of its lost fertility. More radical attempts to improve shifting cultivation take it into the class of improved tree fallow.

2.2.2 Improved Fallow

Improved fallow involves the deliberate planting of trees with desirable characteristics for soil improvement during fallow periods. Reasons for using the rotation of crops with planted trees in place of colonization by natural vegetation may be to obtain harvested products from the trees, improve the rate of soil amelioration for both. A question of fundamental importance of agroforestry design is the relative efficiency in soil improvement of a rotational tree fallow and a spatial concurrent arrangement of trees. Most people observe that rotational tree fallows occupy well over 50% of time in the tree-crop cycle, a ratio that would be economically unacceptable as a ratio of areas in space. The apparent success of hedgerow intercropping in which the tree cover is generally below 35% suggests a greater efficiency for spatial systems. Mechanisms leading to greater efficiency of nutrient recycling under spatial systems would seem to be the cause, but what these are is not known. The answer could lie in the permanence of the tree rooting system, rather than simply alternate trees with crops. The most valuable systems are likely to be those that combine inter-cropping with rotation such as the taungya system (Porras and Luyano 1974).

2.2.3 Modified Taungya System

In the taungya practice, foodcrops are interplanted during the first few years of establishment. This does not appear desirable as regard soil fertility. Many forestry trees do not have the soil in good condition after felling and foodcrop yields are fairly low (Young, 1989a). Conversely, it is suspected that annual crops may compete for nutrients with the newly planted trees. In Kenya, soil carbon and phosphorus were substantially lower under tree plantations with foodcrops than in pure forest stand (Young, 1989a). It was assumed that the fall in fertility occurred during the cropping period. The taungya practice appears to be neutral to adverse from a soils view point becoming seriously undesirable only if substantial erosion is allowed to occur.

2.2.4 Crops under Tree Cover

Many kinds of trees are grown on cropland for productive purposes, without having any clear adverse effects on the adjacent crops. A small number of species are planted or more often preserved in part for their beneficial effects on soils and crop yields known by farmers and in some cases demonstrated by scientists. Good examples of such trees include *Fadheidia albida*, *Acacia senegal*, *Paulownia spp. and Prosopis cineraria* where such effects occur it seems logical to augment them by increasing the tree density to a full canopy situation or until light reduction counteracts the improvements in crop growth (Nair, 1984).

In Ghana, the various technologies being developed fall under; improved fallow, hedgerow inter-cropping, multipurpose trees on cropland, fuelwood production, protein banks, live hedges and protein banks. The specific technologies under MPTs on croplands include; dispersed planting, line and boundary planting and in situ live stakes for yams. Agroforestry projects in the late 1980s were to establish tree seed nurseries in order to readily provide seedlings for farmers willing to adopt agroforestry technologies. This was in line with national agroforestry policy aimed to establish and maintain 350 demonstration centres, 400 nurseries and 30, 000 ha of nationwide agroforestry systems. As at 1992, the rate of achievement stood at 119 demonstration centres, 131 nurseries and 1,642 agroforestry systems indicating 34, 33 and 5% respectively of the targets set (Anim-Kwapong, 2004)

2.2.5 Hedgerow Intercropping

Hedgerow intercropping (alley cropping) refers to a cropping system where arable crops are grown in interspaces (or alleys) between rows of planted trees of woody shrubs which are pruned periodically during the cropping season to prevent shading and to provide green manure and/or mulch to arable crop. It is commonly called alley cropping, although this name is less appropriate in that it refers to only one of the two components. Where established on slopes with the primary objective of erosion control, it may be called barrier hedges, but no clear difference exists between barrier hedges and hedgerow intercropping on slopes (Young, 1989).

Hedgerow intercropping has aroused more current interest among scientists than any other agroforestry system. Well over half of all diagnosis and design studies have suggested it as an intervention to help solve land-use problems.

The potential for maintenance of soil fertility is usually cited. It is also one of the agroforestry practices on which substantial soil research has been done (Young, 1989). The hedgerow intercropping system offers advantages of incorporating a woody species within an arable farming system without impairing soil productivity and crop yields. By adjusting the inter-row spacing of the woody species, mechanized equipment could be used, whenever deemed desirable for various field operations connected with cropping. Moreover, the trees can be cut back and kept pruned during the cropping period and leaves and twigs containing substantial quantities of nutrients applied to the soil both as mulch and a nutrient source, with the bigger branches being used as stakes or firewood. Large amounts of nitrogen can be fixed by hedgerow trees. Leucaena species for instance fixes between 75-120 kgN/ha in six months (Young, 1989).

The extent to which potential benefits of the hedgerow intercropping system can be exploited will depend, however on a number of factors. In addition to the species of crops and trees and the environment (climate, soil), tree management aspects such as method of planting species admixture pattern and the pruning regime, are also extremely important factors. Moreover, the effectiveness of the practice will depend on the general level of production of the crop (Nair, 1984).

2.2.5.1 Hedgerow Intercropping Research in the Tropics

Alley cropping research results have demonstrated various effects on soil physical, chemical and biological properties. In two separate studies in Ibadan, Nigeria and cited by Young (1989), soil changes were monitored over time. The first consisted of intercropping Leucaena species with a maize-cowpea rotation (one crop of each per year) on a sandy soil under a moist sub-humid climate. Prunings applied to the soil were compared with those on plots with hedgerows but with prunings removed. Application of prunings led to higher organic matter, potassium, calcium and magnesium and substantially improved the available water capacity. Soil organic matter was maintained over six years compared with a decline where prunings were removed. In the second experiment in which various rates of NPK fertilizer was applied and hedgerows were established with *Gliricidia sepium*, *Flemingia congesta* and *Senna siamea*, intercropped with two maize crops over two years, plus a control with no hedgerows. It was realized that organic matter decline in the control plot was reverted by *S.siamea* and *G.sepium* even with prunings removed. The obvious suggestion is root residues. Phosphorus improved under *S.siamea* and *F*.congesta but none of the hedgerows showed a decline in potassium. Soil physical properties were significantly better under all species than without hedgerows.

The results of a study into alley cropping with *Leucaena leucocephala* and *Flemingia congesta* on soil chemical and physical properties in Zambia, Dullane *et al*, (1993) showed that the beneficial effects of organic matter on soil physical properties is due in part to the action of organic gums in binding soil particles into aggregates, leading to an improvement in soil structure with balanced distribution of pore sizes. This leads to improved permeability aeration and easier root penetration. This in turn provides favourable conditions for the development of fine feeder roots and mycorrhizae, increasing the efficiency of nutrient uptake and increased yields. There were also reductions in soil bulk density, increases in the pore volume fraction and infiltration rates and lower penetration resistance in Leucaena treatments. There were higher levels of Mg, K and overall CEC and higher pH values under the hedgerows, particularly L. leucocephala (Dalland *et al*, 1993).

The detrimental effects of frequent applications of nitrogenous fertilizer is a decrease in Mg and K and to some extent Ca content in the soil resulting in Al^{3+} built up in the soil and hence acidification. Young (1989) argued that it is unlikely that alley cropping can raise pH on naturally acidic soils but that further acidification may be checked by increasing the concentration of Ca and other bases in leaves brought up from the lower layers and recycled to the surface.

In a field experiment conducted for four consecutive years on tropical inceptisol at Apia, Western Samoa, to evaluate the effects of alley cropping on soil characteristics, weed population and taro yield, Rosecrance *et al*. (1992) found that hedge-biomass yield range from 5.1 to 16.1 tons/ha/yr dry weight with *Calliandra calothyrsus* and *Gliricidia sepium* performing equally well. They found biomass yields to be in the order 4m > 5m > 6m and were lower by 2 tons/ha at the 6m spacing. Weed population were significantly lower in the 4m alleys compared to the 5m, 6m and control (no alleys), with 6m supporting the significantly highest population. Soils from alley plots held significantly more water than soils from controls. Four years of mulch application measurably improved soil water holding capacity and bulk density. However no improvement was seen in the nitrogen, phosphorus, potassium, calcium, magnesium and organic carbon content in the alley plots compared to the controls. There was no positive effect of alley cropping on taro yield. In another experiment, Hulugalle and Ndi (1993) studied the effects of no-tillage and alley cropping with *Cassia spectabilis* hedgerows on soil properties and crop yields in the humid forest zone of Central Africa over a period of 2 years in Cameroon. The experimental treatment were no tillage and hand tillage, both of which were alley cropped with *C. spectabilis* prunings were cut and mulched on alley plots. No tillage had no significant effect on soil physical except to decrease soil temperature. In comparison to hand tillage, no tillage increased soil organic matter and total N in both years and soil pH in one of the years. Alley cropping caused significant reductions in dry season temperature, surface seal formation and cassava root growth, and increased exchangeable Ca, effective CEC and water infiltration compared with non-alley cropped control. Lowest maize cob and cassava tuber yields were observed when no-tillage was combined with alley cropping whereas highest yields occurred with no-tillage alone.

2.2.6 Biomass Transfer

Biomass transfer, a spatial-zoned practice and refers to the practice of cutting tree foliage from the natural forest and carrying it into cropland (Young, 1989a). This practice is very popular in Nepal and doubtless to say it improved yield or farmers would not undertake the enormous labour involved. It is however not yet a popular agroforestry practice and very little literature is available on it. The concept of biomass transfer is probably being seriously considered now as a result of the numerous benefits derived from hedgerow intercropping.

2.3 Trees and Producers of Biomass

In considering the use of leaf pruning or tree biomass as mulch in crop cultivation, knowledge of biomass production (both quantitative and qualitative) of the MPT involved is of great importance to the crop as well as be sustained for continuous use. The total biomass of tropical forest range between 200 and 400 tons/ha of dry matter per year (Young, 1989a). Only about 40% to 50% of the total biomass is added to the soil, mostly as leaves, small branches and roots. Fortunately, the nutrient accumulation rate in these parts is faster than in the rest of the vegetation (Sanchez, 1976). Yield of leaf prunings of MPTs is even lower. For the humid and sub-humid climates, net primary leaf production is of the order of 2-4 tons/ha per year (Young, 1989a). In using leaf prunings as much mulch therefore, there is the need to be conscious of the optimum level of biomass prunings that would sustain the productive life of the tree. Maximum biomass yield is obtained with the first prunings while subsequent pruning could be lower depending on the season, the MPT species involved, the height appears not to influence yield of biomass. Three prunings per year depending on the MPT and ecological zone is therefore adequate. Biomass production by trees used in agroforestry has also been studied. Yields vary depending on the agroforestry practice, the climatic zone and the management practice employed. In humid climatic conditions *Leucaena luecocephala* was recorded to give a net primary production (above-ground dry matter) or 20,000 – 30,000 kgDM/ha/yr while it gave 10,000 – 25,000 kg/DM/ha/yr under the sub-humid conditions (Pound and Cairo, 1983, quoted by Young, 1989). In hedgerow intercropping under the moist sub-humid bimodal regime, net primary production of *Leucaena leucocephala* was 6,770 kgDM/ha/yr (Kang *et al*, 1985, quoted by Young, 1989) while leaf production was recorded as 2,470 kgDM/ha/yr.

The potential dry matter production by any vegetation is closely related to the amount of solar radiation intercepted by the foliage (Huxley and Wesley, 1989). Any pruning that removes foliage and decreases light interception will reduce the rate of dry matter production by the trees. However the decrease in productivity may be less than expected because:

a) The rate of photosynthesis of the remaining foliage may increase due to the increased sink/source ratios, better illumination and increased share of root-originated metabolites ; and

b) The leaves removed may be the older, more shaded ones, which have lower rates of photosynthesis than younger leaves (Avery *et al*, 1991).

Research quotations on pruning involve how to prune (for example whether to coppice, pollard or basal prune), how much to remove (what coppicing height, how severely to pollard) and when and how often to prune these questions need to be answered with reference to the tree product required (green mulch, fodder, fuelwood or timber) and the trade-off between the productivity of the trees and of the intercrop. It must however be remembered that severe pruning can kill trees if followed by drought and that recovery will depend on the amount of foliage and storage reserves (of carbohydrates and minerals) left on the trees. Coppicing small trees is often more life threatening than coppicing large trees with thick roots and storage reserves, pollarding is usually less life threatening than coppicing.

The effect of cutting height and cutting intervals on dry production of *Leucaena leucocephala.* Lam De Wit, using three year-old trees showed that dry matter yield, were highest at 75 and 100cm cutting height in a four (25, 50, 75 and 100cm) cutting height trial, especially at the longer three-monthly cutting intervals. At the one monthly interval, dry matter yield was significantly reduced probably due to the increased number of recovery phases. Leaf nitrogen yields per tree for trees cut at three-monthly intervals were over twice as high as the total yields obtained from monthly cutting over the same period (Karem *et al*, 1991).

Measured rates of net primary biomass production under natural ecosystems serve as reference point for agroforestry. The most representative for rainforest is 20,000 kg/ha/yr(dry matter) ranging from half to over twice this value. Semi-deciduous forest, under climates with a short dry season, is only slightly lower than evergreen forest in typical value, but does not attain the very high rates of some evergreen sites. Forest at high altitudes does not necessarily have slower growth, showing a typical value of 22,000 kg/ha/yr.(Young, 1989). Savanna communities, according to Young (1989) show wide range of productivity differing between moist savanna, dominated by broad leaf species and occurring above some 1000mm/yr and dry savanna, dominated by narrow-leaved species. He further stated that representative values are 10,000 kg/ha/yr for moist savanna and 5,000 kg/ha/yr for dry savanna and that communities describe as desert shrub or the like range downwards from 2500 kg/ha/yr. In summary, studies of natural ecosystems suggest the following rates of net primary production (above-ground dry matter) that can be expected according to climatic zone (Young, 1989).

- Humid tropics (no dry season) – 20,000 kg/ha/yr or more
- Humid tropics (short dry season) - 20,000 kg/ha/yr
- Sub-humid tropics (moist) - 10,000 kg/ha/yr
- Sub-humid tropics (dry - 5,000 kg/ha/yr
- Semi-arid zone - 2,500 kg/ha/yr

According to Young (1989) forest characteristically contains large quantities of living biomass (including wood) and therefore, a large inventory of chemical elements. About 20 to 25 percent of the total living biomass of the tree is in roots and there is a constant addition of organic matter to the soil through dead and decaying roots. Under a moist tropical forest, the net annual contribution of dead roots was around 2600 kg/ha. In addition to this there could be significant formation of soil organic matter during active root growth, much of it directly from the root tissue without the intervention of soil microfauna (Nair, 1984). The major recognized avenue for addition of organic matter (and hence of nutrients) to the soil from the trees standing on it is through litterfall, that is through dead and falling leaves, twigs, branches, fruits and so on. The bulk of organic matter and nutrients that are so added to the soil are located in the topsoil. Potassium, calcium and magnesium on the other hand are concentrated in the biomass, except in high base status soils (Young, 1980a). That is why forest clearing leads to a considerable loss of the nutrients and those in the biomass being exported from the system and those in the soil being lost by leaching and runoff.

2.4 Tree-crop Interface

The presence of trees may have both positive and negative overall effects on the soil and the crops growing in between or beneath them. The positive interactions at the tree-crop interface (TCI) are those relating to microclimate amelioration and nutrient balance. In agroforestry systems microclimate amelioration involving soil moisture and soil temperature relations result primarily from the use of trees for shade or as live support, live fences or windbreaks and shelterbelts. Temperature, humidity and movement of air as well as temperature and moisture of the soil, directly affect photosynthesis, transpiration and the energy balance of associated crop. (Rosenbert *et al,* 1983). The net effect may translate into increased yield.

The major yield decreasing effect of the TCI arises from competition for light, water space and nutrients as well as from interactions via allelopathy. Shading was found to be more important than the below-ground competition in an intercropping study with pearl millet and groundnut in India (Willey and Reddy, 1981). Similarly Verinumbe and Okari (1985) showed that competition for light was a more critical factor than root competition for intercropped maize between teak trees (*Tectona grandis*) in Nigeria. In another Nigerian study, Kang *et al.* (1981) attributed low yields from maize rows adjacent to *Leucaena* hedgerows to shade.

Intercropping trees and arable crops substantially increases biomass production per unit area because roots of trees can exploit water and nutrients below the shallow roots of crops and mixed canopy c an intercept more solar energy. A systematic approach to intercropping research at ICRISAT and elsewhere for a decade revealed the major principles underlying the substantial yield advantages of intercropping over sole cropping. Some of these interactions could be positive or negative. The four basic biophysical elements affecting crop productivity are light, water, nitrogen and other nutrients particularly P and K (Stoorvogel *et al* 1993)

2.5 Tree-Crop Spacing and Yield

Karim *et al.* (1993) studied the effects of spacing between hedgerows (alley widths) and the spacing of trees within hedgerows of *Gliricidia sepium* on the growth and yield of maize at Senehum in Southern Sierra Leone. Four between-row spacing (2, 4, 6 and 8m) were combined with 3 within-row spacing of 0.25, 0.50 and 1.00m) in a split plot design. Maize at densities of 20,000 – 40,000 and 53,333 plants ha^{-1} were established in the alleys and also as pure crops. N.P.K. fertilizer was applied to all the plots before pruning of the trees began. When pruning started only the pure maize plots received fertilizer, prunings from the hedgerows were returned to the appropriate alleys in the other plots.

Plots with the highest maize population consistently gave the best yields before prunings, but lower population gave improved yields after pruning. Yields of maize increased with increasing alleys before the start of pruning after which narrow alleys of 2 and 4m out yielded the wider ones by almost double, probably because of large amounts of nutrients applied on prunings. Lack of light limited grain yields before the start of prunings when there was some shade by the hedgerows. Alleys of 2-4m wide planted no closer than 0.50m within rows resulted in more than twice the yield of maize in the 8m alleys planted at 0.25m within rows, once the hedgerows were well established.

Moreover according to Khan and Ehrenreich (1994) on a research study to assess the influence of boundary trees (*Acacia nilotica*) on the growth and yield of associated wheat crops under irrigated conditions in Punjab, Pakistan, indicated that the close proximity to the trees adversely affected the tillers/m^2 weight/1000 grain and grain yield of wheat up to a distance of 8.5m from the trees. Plant height and grain/spike were least affected. In general the growth and yield of wheat improved as distance from the plant increased. Tree size did not affect wheat height, tillers/m^2, grains/spike or weight/1000 grains. The grain yields were slightly lower near the largest tree with (50 – 54.9cm dbh).

Sheik and Haq (1978) studied the effect of *Acacia nilotica* and *Dalbergia sissoo* on wheat yield. Five trees of different species were selected in two different localities of uniform height, diameter and crown size. Taking each tree as replication and its trunk as center, circles of radius 2, 4, 6 and 9m were drawn in adjacent wheat yields.

Wheat yields were calculated by taking samples against these distances. The study revealed that distance from the tree base and direction of shade had significant effect on the wheat yield for both species. The yield was lowest at the distance of 2m from the center of tree, and hence made this summary:

i) Trees in close proximity depress the crop (wheat) yields.

ii) Effect varies with the crop and tree species.

2.6 Need for Tree Plantation

Tree plantations in the humid regions of Africa are established primarily using exotics, *Eucalyptus spp*, *Pinus spp.*, *Tectona grandis*, *Gmelina arborea*, *Cedrela odorata* and *Acacia spp*. (Evans, 1996). In the humid regions of Africa, the area under native species plantation is less than 15 percent. In Africa over 80 native tree species have been tested in various trials, of which more than 60 have been tested in Cote d'Ivoire and west of Ghana (FAO, 1993). However, in Ghana, as in many other countries in the region, only plantations of exotic tree species have succeeded despite substantial effort committed toward the establishment of native species plantations (Cobbinah, 1997). A plausible explanation for widespread failure of native species in plantations is the high incidence of insects and disease pests that develop in these monocultural plantations and a failure to recognize the important ecological characteristics of species selected for plantations (Cobbinah, 1997).

According to FAO projections (FAO, 1993), global wood consumption is estimated at 3.5 billion m^3y^{-1} in 1990 and is expected to reach 5.2 billion m^3y^{-1} by 2010. According to Evans (1996), industrial wood consumption is expected to rise to 2,600 million m^3

annually by the year 2030. Evans (1996) further noted that at the consumption level of 4,000 m^3y^{-1} it would take 75 years to use up the world's resources of wood; this assumes no increment, no regeneration, and no planting at all. Evans (1996) attributed the main causes of forest destruction to clearance for agriculture, intensive logging for veneer, sawn timber and more recently for chip board, exploitation for charcoal and firewood. The consequence of forest destruction is deforestation and resultant land degradation problems. In Ghana, the total wood utilized for fuelwood for an estimated population of 15 million in 1990 was 13.9 million m^3y^{-1} of which charcoal accounted for 6.53 million m^3 (47% of the fuelwood consumption) (World Bank, 1988). The World Bank (1988) projected that by the year 2000 the charcoal component would rise to 10.77 million m^3y^{-1} (52%). The annual total wood volume currently used for timber and fuel in Ghana is together estimated to be 16.4 million m^3 (Chachu, 1997). By the year 2020, Ghana's population is expected to reach at least 30 million and corresponding fuelwood consumption is projected to reach 28.8 million cubic metres. This trend is equally significant in Latin America and the Caribbean. In Brazil, for example where about 80 percent of the planted forest of tropical Latin America are located, the consumption of wood is estimated to be 281 million m^3y^{-1} of which 75 million m^3y^{-1} are supplied by planted forests (Reis, 1997).

The need to minimize deforestation effects through establishment of forest from native and exotic species has become apparent in recent investigations. Presently, money is being invested in search of plant species with different potential as well as the development of adequate technologies for the proper cultivation of such species to gain higher yields in less time. This would help satisfy the increasing demands for forest products and to decrease the destruction of natural resources.

The increased plantation establishment rate is beneficial for socio-economic and ecological gains. Socio-economic benefits include job creation, income generation, raw materials for timber industries, charcoal for iron and steel industries, etc. Ecological benefits include maintenance of soil fertility, watershed protection, shelterbelts, windbreaks, etc. Further plantation forest can contribute toward reducing the world's wood deficit (Reis, 1997).

Forest harvesting has not been properly managed in Ghana and has been one of the factors responsible for the poor quality of most of the occurring reserves (Hawthorne and Abu Juam, 1995). It was estimated by the 1991 rate of timber harvesting in Ghana that, most economic species would reach extinction by the year 2020 (Hawthorne and Abu Juam, 1993).

The annual log requirement of the timber industry is currently more than three times the annual allowable cut (AAC). There is consequently a large imbalance between the sustainable AAC and the demands of our industries, hence the urgent need to supplement the existing supply with short rotation plantation grown timber. The existing industrial timber plantations, amounting to some 38,000 ha of variable quality stands, made up of 15,000 ha from the Forest Services Division (FSD) and 23,000 ha from the private sector, including 11,000 ha of rubber plantations is only about 15% of the total plantation area required. There is therefore an enormous need for tree plantation need in the country which calls for all stakeholder participation in plantation forestry development. Consideration could be given to fast-growing species such as *Senna siamea* for firewood, *Cedrela odorata* for craft and minor wood needs, *Gmelina arborea* and *Tectona grandis for timber*. Special consideration could be given to *Tectona grandis* which gives good and durable wood and could easily be established well in almost all over the country (Agyemang, 2000).

2.7 Silvicultural Characteristics of Teak

2.7.1 General Description of Teak (*Tectona grandis* Linn. F.)

A member of the verbenaceae family, *Tectona grandis* is a deciduous tree with variable size and form according to locality and conditions of growth. In favourable localities, teak may reach heights of 40-45m, with bole up to 25-27m. Heights of 35m and diameter at breast height (dbh) of 70cm in 46 year-old teak have been reported in Madhya Pradesh, India (Bhoumik and Totey, 1990). Diameter at breast height (dbh) typically ranges between 30cm and 90cm (Borota, 1991; Farmer, 1972; Kadambi, 1972). In April 1996, the largest standing teak tree in Baw Forest reserve of Myanmar had a dbh of 85cm and height of 46m (Centeno, 1997). In drier regions teak is smaller. At older ages, teak becomes moderately fluted and buttressed at the base. Leaves of teak are large, opposite and decussate in arrangement (Borota, 1991; Farmer, 1972; Hedegart, 1975). The species develops thick tap root system which may persist or disappear, strong lateral roots may also be formed. Exposed teak suffers from wind, which causes branching, but this may be minimized if protected with shelterbelts. Seedlings and coppices of teak are very sensitive to abnormal drought, fire, drainage and frost. Teak produces vigorous shoots when coppiced (Borota, 1991; Kadambi, 1972; Keogh, 1987; White, 1991).

2.7.2 Uses for Teakwood

Teak has excellent wood properties making it one of the valuable multipurpose timbers of the world (Keogh, 1987). It is resistant to termites, fungi and adverse weather conditions. Teak seasons without splitting, cracking, warping nor physically altering shape and it is employed in a wide range of uses such as exterior and internal joinery, window and door frames, flooring, cabinet work, garden furniture, decking, boat building, bridges, railway carriages, sleepers, etc. (Borota, 1991; Keogh, 1987; White, 1991). In Ghana under the Forest Resource Management Project which began in 1989, the Rural Forestry Division of the Forestry Department initiated numerous community teak plantations. Communities are now benefiting from the teak plantation by obtaining poles for construction, yam stakes, rafters and fencing posts (Squire 1993).

2.7.3 Distribution

Teak is indigenous through the greater part of Myanmar, Indian Peninsula, western parts of Thailand and Indo-China from latitude 12^{o} to 25^{o} North and from about longitude 73^{o} to 104^{o} East (Beard, 1943; Parameswarappa, 1995; Street, 1962; White, 1991). Centuries ago, it was introduced into Java and some of the smaller islands of the Indonesian Archipelago (Parameswarappa, 1995; Street, 1952; White, 1991) and later into the Philippines. Today the species is naturalized in these countries (Beard, 1943).

Long established teak plantations now extend from 28^{o}N to 18^{o}S in countries like Sri Lanka, Malaysia, Pakistan, Indonesia, Zambia, Tanzania, Uganda, Cote d'Ivoire, Ghana, Togo, Nigeria, West Indies, Honduras, Trinidad, Jamaica, Argentina and

Panama (Parameswarappa, 1995; White, 1991). Currently, teak is being planted on savanna woodland and on parts of the High Forest eco-region of Ghana. Indications are that teak growth is better in the moist and high forest zones than in savanna woodlands zones.

2.7.4 Habitat and Climatic Requirements of Teak

The distribution of teak is largely determined by climate, geology and the soil (Parameswarappa, 1995). The rate of growth and the quality of teak from plantations largely depends on the type and quality of planting stock, the physical and chemical characteristics of the soil, environmental conditions and management techniques. Teak grows and survives a wide range of climatic conditions but thrives best in fairly moist, warm tropical climates (Kadambi, 1972; Street, 1962). Much of teak's natural range is characterized by monsoon climates with rainfall between 1300 and 2500mm per year and dry season lasting 2 to 5 months (Salazar *et al*, 1974). Optimum rainfall for teak is between 1500 and 2000mm in Togo. However, prolonged droughts in India have killed both trees and coppice sprouts (Ryan, 1982).

The species tolerates wide variations in temperature, from 2 to 48^{o}C (Troup, 1921). In the west coast of India, the optimum climate for teak growth has a temperature range between 16^{o}C and 40^{o}C. Teak may extend into regions of slight frost, but throughout almost all of its range, teak has not been found in frost regions (Kadambi, 1972; White, 1991).

Teak is intolerant to shade and requires full sunlight (Borota, 1991; White, 1991). The species establishes best on terrain cleared of competing vegetation. It is unable to stand much competition from other plant species or from trees of the same species. The crown of teak requires freedom on all sides for proper development. However, in very hot and dry areas, teak seedlings and saplings benefit from protection against the hot afternoon sun. In Madhya Pradesh, teak saplings in the shade of bamboo, exhibits slow growth. However, teak growth increased when bamboo was removed and full overhead light was restored. Photoperiod also appears to have minor effect on its growth and development (Kasoa-ard, 1981).

2.7.5 Site and Nutrient Requirements of Teak

Teak establishes itself on a variety of geological formations and soils (Hedegart, 1976; Kadambi, 1972; Seth and Yadav, 1959). It grows best on deep, porous, fertile, well-drained alluvial soil with neutral or acidic pH (Kadambi, 1972; Salazar *et al,* 1974; Watterson, 1971). In the Indian Penninsula, the species grows on soils derived from granite, gneiss, schist and other metamorphic rocks. The species also does well on limestone that has disintegrated to form a deep loam. On hard limestone, where the soil is shallow, teak growth is poor. As a rule the species requires fertile soil for best growth (Parameswarappa, 1995; Salazar *et al,* 1974), notably those rich in Ca and Mg (White, 1991). Nitrogen nutrition, rooting depth and precipitation are the most important variables influencing teak growth in West Africa (Drechsel and Zech, 1994).

The distribution of nutrients in teak has been the subject of numerous investigations (Weaver, 1993). The percentage of nutrients on 1 year-old teak seedlings decreases in the following order N > Na > Ca > K > P (Lalman, 1985). Nutrient concentrations were highest in leaves in stem and roots. The seedling nutrient composition increased from 8 to 9 months, after which N, P and K decreased remarkably and Ca and Na decreased slightly. Besides N, Drechsel and Zech (1994) also believed P and Ca to influence teak growth. Samples of 40 of the best quality teak trees representing the age diameter range attained during the first 15 years of plantation establishment in Nigeria's Gambari Forest Reserve were analysed for N, P, K. Ca and Mg (Nwoboshi, 1984). This study indicated that Teak plantation had an above-ground dry weight of 592,000 $kgha^{-1}$ and contained 2,980 $kgha^{-1}$K, 2,228 $kgha^{-1}$Ca, 1,788 $kgha^{-1}$N, 447 $kgha^{-1}$P, and 377 $kgha^{-1}$Mg. Further, the minimum annual nutrient requirement at 15 in $kgha^{-1}$, were 556K, 328N, 357Ca, 76P and 62Mg. The relative amount of the element found in foliage decreased with age, whereas that in branches and trunk increased with age. Nutrients taken up by teak are considerably greater than that required for pine plantation in the same area or in a 49 year-old secondary forest in Ghana (Nwoboshi, 1984).

2.8 Propagation and Management

Teak plantations are mainly established stumps which are easier to plant and provide more rapid establishment and vigorous growth (Weaver, 1993). A stump plant is a cutting of plant material (about 5cm above root collar with roots trimmed to about 10-15cm of its length). The stump is planted into prepared ground at the beginning of the rainy season (Borota, 1991). Spacing of plant depends on management objectives and site characteristics. For example on sloping terrain, wider spacing (3.5 by 3.5m) has been suggested to encourage ground cover and to avoid soil erosion (Weaver, 1993). Despite the success of the stump method, planting stock is still produced from seeds in spite of the quantitatively limited and late seed production, low germination rates and substantial variability in growth and woody quality (White, 1991).

A viable option for the production of high volumes of quality teak wood is to establish pure plantations on well-preserved and well-drained soils and manage them to reach average height before flowering sets in. Normally 1,200 to 1,600 plants per hectare are used with closure of canopy commonly taking place between the third and fourth year (Centeno, 1997; Kadambi, 1972). A common strategy to grow long knot free boles is to keep the stand close and at high density during the first year of development when rapid height growth occurs. This keep crown small and subsequently limits the size of the branches (Centeno, 1997).

The age at which first thinning is done is determined by the dormant height, which is in turn determined by site quality (Centeno, 1997). On best site classes, first thinning might by possible when the dominant height reaches 9.5m and second thinning when the dominant height reaches 17-18m. When thinning is light, only small temporary canopy gaps are created and total production per hectare will not deviate significantly from the carrying capacity of the site. If thinning occurs too late, a stand is affected by stagnation with loss of growth potential. However if a stand is thinned too early or too heavily, the trees tend to produce more side branches and epicomic shoots (Centeno, 1997). Lowe (1976) noted that a 10-15 year delay of thinning may not affect the growth potential of the final tree crop. Keogh (1987) noted that if thinning is delayed beyond 10 years, the final tree crop would be unable to respond fully to later thinning. Based on the assessment of economic and silvicultural considerations, a rotation of 25-45 years may at present be considerable as the optimum cycle to achieve viable financial returns and the production of market quality timber (Centeno, 1997). Weaver (1933) noted that pure teak plantations have rotations 50-80 years, whereas in areas where species grow in mixed stands, a rotation is about 70-80 years. When managed under coppice systems, teak rotations range from 40-60 years. Fifty-year Indian yield tables allow for 80-year rotations (FAO, 1956). Timber volume predicted from yield tables on site class at 80 years was 340m^3 per hectare (Borota, 1991). Borota (1991) and Keogh (1987) noted that the rotation for obtaining high quality logs is usually around 70 to 80 years.

In Asia, teak trees are allowed to develop for 60-year or more before harvesting. At such ages the mean annual increment (MAI) may vary from three to 10m^3 $ha^{-1}yr^{-1}$. According to Parameswarappa (1995), the world's fastest teak growth is in plantations at Chittagong District (Bangladesh) at Kapati. Trees 21 years old had an average height of 29.3m and average diameter of 30.0cm. The stem timber volume was 34.09m^3 and small timber volume was 8.66m^3 per acre. In tropical America, most teak plantations are managed on short rotations, usually 20 to 30 years. The MAI at these ages varies from 10 to 20m^3ha^{-1}.

Although fire is often an important component for the regeneration of teak within its natural range, fire tends to weaken teak and causes unwanted side-effects, especially after the four year of establishment (Keogh, 1987). Very young stands may recover quickly by producing vigorous coppice shoots. In general, older stands of teak are more resistant to fire. However it is advisable to provide fire protection during each dry season. From the four year until the time when the bark is thick enough to withstand high temperatures, teak may be killed and stripped in spots thereby rendering the wood susceptible to fungal attack. In the drier forests fire may kill young trees and may damage large trees. Fire is also associated with epicomic branching. Furthermore, fire also accelerates erosion under teak by removing undergrowth and protective litter layers (Keogh, 1987; White, 1991) and may result in loss of nutrients.

Repeated fires may also reduce site potential, thereby causing a decrease in growth rate. For example, in Burma, Trinidad and Thailand, soil erosion in pure teak plantations have been attributed to the burning of undergrowth (Kadambi, 1972). Balagopalan (1987) studied the effect of fire on soil properties in different forests of Kulamau, Kerela, India and concluded that fire had no effect on soil texture.

2.9 Effect of Teak on Soil Chemical Properties

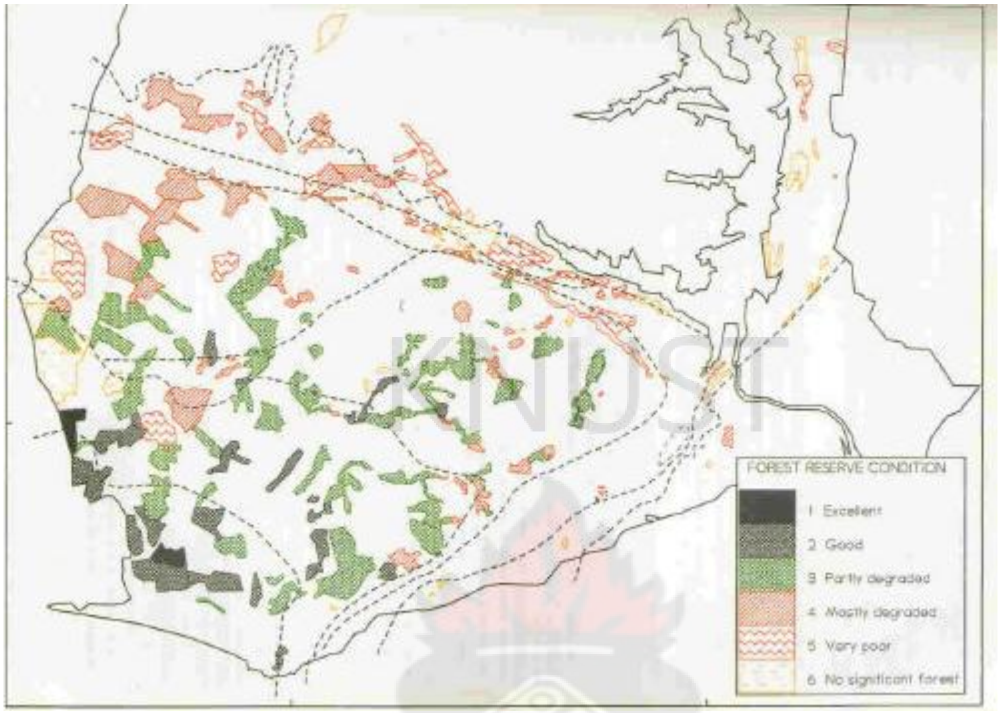
In the tropics, there is a general belief that plantations and natural forest have different effects on the ecosystem. Studies conducted by Prasad *et al.* (1985), Singh and Totey (1985), Mongia and Bandyopadhyay (1992) indicated that organic matter (OM) content, cation exchange capacity (CEC) and exchangeable cation are higher in soils under natural forests and mixed plantations than in soils under monocultures. It is also believed that plantation forestry may result in soil compaction and nutrient immobilization in the standing biomass (Aborisade and Aweto, 1990; Ceorge and Varghese, 1992). Mongia and Bandayopadhyay (1992) compared changes occurring in soils of tropical forests after clear felling for high value plantation crops of *Pterocarpus dalbergiodes* (Pandauk),*Tectona grandis* (Teak), *Heavea brasiliensis* (Rubber) and *Elaeis guineensis* (oil palm). Their results indicated a decline in OM, P and available K when the forest was removed for raising plantation crops. Also $CaCO_3$ content was completely lost from the soil profiles. Similarly in South Andaman, India, Mongia and Bandayopadhyay (1994) soil N, P, K, organic carbon C and pH were found to be lowest under teak, rubber, oil palm and padauk plantations under natural forests. In Ethiopia, Michelsen *et al.* (1993) observed lower OM and nutrient content in soils under two exotic plantation species (*Cupresus lusitanica* and *Eucalyptus globules*) compared to soils under *Juniperus procera* and natural forest.

Conversely in India, Krishnakumar *et al.* (1991) compared the ecological impacts of *Heavea brasiliensis*, *Tectona grandis* plantations and the natural forest on soil properties, nutrient enrichment, understorey vegetation and biomass recycling. The study indicated all stand types retained high OM input that helped enrich the soils. Although teak had the highest OM content in the surface layer, depletion of OM with depth was highest for teak and less for natural forests. The depletion pattern for rubber was close to that of natural forests. A study under different climatic conditions in Western Chats, India revealed that sites with very high densities of teak were characterized by higher organic carbon as well as exchangeable, Ca and CEC (Singh *et al,* 1986). In Nigeria, Totey *et al* (1986) compared the exchanges of soil chemical properties under three different vegetation covers, mixed wood forest, Eucalyptus and teak plantations. The study indicated that the rate of weathering, ratio of clay to non-clay fractions, OM, CEC and exchangeable Ca and Mg were higher under teak cover than under Eucalyptus and mixed forest. They attributed the higher CEC under teak to a higher level of soil OM. Higher available Ca and Mg were also attributed to the incorporation and decomposition of teak leaf litter rich in Ca and Mg (Hosur and Dason, 1995). Marquez *et al.* (1993) studied the effect of teak chronosequence (2, 7 and 12 years) on soil properties in Ticoporo Forest Reserve. They observed that Ca and Mg content, pH and CEC were significantly higher in soils of 12 year-old plantation as compared to two and seven year-old plantation. However, available soil P concentration showed a significant decline with age of plantation. They attributed these differences to the possibility that older teak trees could take nutrients more efficiently from deeper soil horizons and recycle nutrients to the soil surfaces leaf litter.

Hase and Foelster (1983) assessed the potential impact of the removal of teak plantations on the nutrient status of young alluvial soils in the Venezuela. The calculated nutrient budgets suggested that the base depletion after three removals would lead to a reduction in teak productivity on productive sites located away from rivers. Soils located on low topographic position near rivers, however, could withstand continued harvest because nutrient lost would be replaced by ground water inputs. However, research on long-term influences of pure teak plantation on soil properties is incomplete and fragmentary (Jose and Koshy, 1972; Yadav and Sharma, 1968).

(Salifu, 1997) compared soil chemical properties under two distinct forest covers (logged native forest, and teak plantations) at three different forests in Ghana; (Basomoa in Tain II and Yaya forest reserves) in Brong Ahafo region. Within the Yaya locations, N, Mg and OM concentrations in the surface soil horizon were significantly higher under logged forest than under teak plantations. Phosphorus and K concentrations were also significantly higher under logged forest at Basomoa. Similarly, there were fewer differences in total nutrients in the soil under adjacent logged forest compared to teak plantations in the Basomoa and the Yaya locations. Higher nutrient concentrations and contents in soils under logged forest were due to more undergrowth, litter and organic matter depositions. Higher nutrients under the logged forest may also be due to a lesser demand for these nutrients by tree species in these forests. Lower soil macro-nutrients contents in soil under teak may have been due to lower organic matter content under teak cover or associated with higher nutrient demand immobilization by teak.

Fig 2.1 Forest Reserves conditions in Ghana (Source;Hawthorne & Abu-Juam 1995)



There are about 25 forest reserves with a total area of 3567km2, located across the forest regions in Ghana. All the Forest reserves are suitable for Teak and foodcrop cultivation. There are some 25 forest reserves with a total area of 3567km2 located across the forest regions in Ghana. (Hall and Swaine, 1981).

Due to bad logging and fires especially since 1983, less than 2% of the forest reserve area is considered as good without any signs of degradation. Most parts of the reserves are either partly degraded (30%) or mostly degraded (40%) whilst about 28% of the area is either very badly degraded or contains no significant forest vegetation. This state of degradation predisposes the forests to fire irrespective of their location in the moist zon e.Since 1983 forest fires have crossed the dry forest into the moist forest zone thus

Estab lishing a new fire frontier further down south. Consequently most forest reserves in the North-west subtype of the Moist Semi-deciduous Forest type are subject to occasional burning contrarily to the general observations prior to the fire insurgences into the forest reserves. (Hawthorne & Abu-Juam, 1995)

2.10 Effect of Teak on Soil Physical Properties

Pure teak stands have also been associated with physical soil deterioration such as erosion (Centeno, 1997). However, there is limited conclusive evidence in this regard (Brandis, 1921; Centeno, 1997) except when teak is planted on steep slopes where there is limited undergrowth or where excessive burning has taken place (Centeno, 1997; Manning, 1941). According to Laurie and Griffith (1942) surface soil under teak plantations sometimes hardens, decreasing aeration and increasing soil erosion. Salifu (1997) noted higher surface soil horizon bulk densities (Db) were observed under teak plantation (1.33g cm^{-3}) than under the native logged forest. However, similar studies by Laurie and Griffiths (1942) under other pure teak plantations in India did not indicate significant soil deterioration. Laurie and Griffith (1942) concluded that poor planting techniques and under-thinning were at least partially responsible for the above changes in soils under pure teak plantations. Studies by Bell (1973), Chunkao *et al.* (1976), Karanakaran (1984) and Kushalappa (1987) have shown that soil erosion and sediment yields were higher under teak plantations than other cover types due to heavy grazing pressures and repeated fires, soil bulk density has been found to increase under teak plantation management but not under virgin forests (Mongia and Bandayopadhyay, 1992). The high bulk density was attributed to loss of OM under teak as compared to natural forest. Aborisade and Aweto (1990), Kadambi (1972), Mongia *et.al* (1992) observed that establishment of large-scale teak plantations leads to soil deterioration through increased erosion, soil compaction and consequent decrease in aeration. In Kerala, India, Jose and Koshy (1972) studied the morphological, physical and chemical characteristics of soils and influenced by Teak on soil profiles beneath a natural forest and Teak plantations of; 15, 30, 60 and 120 years were compared. Organic matter content in the plantation correlated with the age of the stand. They observed that soils beneath teak plantations less than 30 years old had higher bulk densities, lower amount of pore space and water holding capacity than older plantations and natural forests, indicating that physical condition deteriorated as teak plantation got older.

2.11 Relationship between Bulk Density and Soil Physical Properties

Bulk density (Db) is defined as the mass of a unit volume of oven-dry soil at 105^oC. This volume includes solids and pores. Thus, Db is an indirect measure of the total pore space in the soil since Db relates to the combined volumes of solids and pore spaces, soils with a high proportion of pore spaces to solids have lower Db than those that are more compact and have less pore spaces. Consequently, any factor that influence pore space affects Db. Knowledge of bulk density is of importance in determination of nutrient content and other physical and chemical properties of forest soils. Values of Db are necessary to convert laboratory measurements of soil nutrient concentrations, exchange capacities, water contents and biological populations from concentration to a mass basis (Federer *et al,* 1993). Bulk density is an important soil physical property that can directly or indirectly affect plant growth. Bulk density is an important weight measurement of the soil and affected primarily by texture and structure (Brady and Weil, 1996).

Bulk density and total pore space are readily altered by tillage operations and other disturbances such as scarification and compaction by heavy equipment at harvest. Bulk density of soil is closely correlated with porosity and in turn, with water infiltration capacity and the degree of aeration. In general, coarse fragments create large pore spaces in soil volume and may result in a lower Db when calculation is based on coarse fragment less than 2mm.

Increased aggregation of particular soil will result in a corresponding increase in total pore space and the weight per unit volume or Db of the soil will decrease the Dbs of clay, clay loam and silt loam surface soils normally range from 1.0 Mgm^{-3} to as high as 1.6 Mgm^{-3} depending on soil conditions. A variation from 1.2 to 1.8 Mgm^{-3} may be found in sands and sandy loams (Brady and Weil 1996). These general trends apply until coarse fragment content of the soil become significant.

Bulk density can be determined by taking a natural structural aggregate from the soil and by means of sense of weighing in air and in Kerosene Db, real density, porosity and water volumes of aggregates may be calculated (Rennie, 1957). Gamma ray attenuation has also been used for measuring both water content and Db in soil (Gurr, 1962) but the equipment is relatively elaborate and expensive. The most common method used is the sample cylinder which is simple and convenient (Armson, 1977). This method has problems of unknown compaction of sample, difficulty or sampling soils with high coarse fragment level or root content (Federer *et al,* 1993), and poor measurements due to samples falling apart when cylinder is extracted from the soil profile.

In view of the difficulties involved in determining Db, several researchers have developed equations to predict bulk densities of soils based on one or two soil properties. Ball (1964) observed that Db is closely related to OM fractions which can easily be determined by loss on ignition (Adam, 1973). Ball (1964) observed that Db tends to decrease as mineral soil OM increases, particularly in forest soils, which tends to be high in organic matter and in aggregate stability near the surface. Curtis and Post (1964) developed an empirical regression of logDb on logOM (loss on ignition) for stony and sandy loam soils in the northeastern United States. This relationship was curvilinear and valid for O, A, E and B horizons of Vermont forest soils. Federer (1983) and Huntington *et al.* (1989) obtained very similar equations. Huntington *et al.* (1989) concluded that the relation between Db and OM in the mineral soil for New England and that of Federer (1983) support the use of organic matter to obtain estimates of Db for use in the calculation of soil carbon pools. Jeffrey (1970) suggested that the relationship between OM and Db might be universal. In California, Alexander (1980) observed that the square root of organic carbon was the best predictor of Db in both upland and alluvial groups of soils, but the orders of importance of other independent variables differed from one group to the other. Federer *et al.* (1993) observed that Db of forest soils in New England were closely and inversely related to the organic fraction of the soil. Rawls (1983) proposed a method for predicting Db of natural undisturbed soils based on the percentages of sand, clay and OM and concluded that the method could be useful for predicting Db when only particle size information is available and for predicting the effect of Om had on Db. In Ghana, regression models for Db of soils under teak cover were developed using OM, particle size distribution and pH. Significant linear relationships were found between Db, OM, clay, silt, volume of coarse fragments and pH (Salifu, 1997).

2.12 Maize

Maize (*Zea mays* L.) is a member of the family Graminae. It performs well on good drained, aerated, deep silty loam soil containing abundant nutrients. It originated from Central America and ranks second after wheat in the world production of cereal crops. The total area devoted to maize worldwide in 1989 was 129 million hectares with grain yield of 470 million tones. In the same year, maize produced in Africa was 36.4 million tons (Owueme *et al*, 1991) with Ghana accounting for 715,000 metric tons (PPMED, 1993).

2.12.1 Importance and Constituents of Maize

It's the most important staple grain crop grown in Ghana and is cultivated throughout the country even in drier northern areas, north of latitude 10^{o}N where Guinea corn and millet are important substitute cereals (MOFA, 2001). It could be stored for longer periods than most food crops. This quality coupled with its countrywide demand makes it food widely used food item by people during famine periods. A grain of maize contains carbohydrates, but also significant quantities of proteins and oil and small amount of minerals in the following proportions: 76-88% carbohydrates; 5-15% protein; 4-5% fat and 1.3% mineral. Common varieties include "Dobidi", "Abelehe" and "Obaatanpa", which contain essential amino acids such lysine and tryptopha (Owuene *et al*, 1991).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study was undertaken under young Teak plantation blocks at Bosomkyekye, a village which is about 50km from Kumasi along Ashanti-Mampong – Ejura road.

3.2 Bio-physical Environment

3.2.1 Climate

The Bosomkyekye area is within the forest-savanna transition zone. It has a bimodal rainfall pattern which falls in two distinct seasons. The major rainy season starts from about April or May and lasts till July. A short dry spell occurs in August after which the minor rainy season sets in from September till end of October. The long dry season then begins from November lasting till March or April. The peak of the dry season is in December to January and sometimes extends to February. This period is marked by the dry desiccating harmattan winds characterised by cloudless dry, hot weather during the day and coldness at night and early morning. Annual rainfall figures range between 1200-1400mm, (FAO/UNEP 1981)

Temperatures are high throughout the year ranging between 25^{o}C in August/September and 34^{o}C in February/March. During rainy periods, relative humidity range between 79-86% at 0900 hours, decreasing to 62-80% at 1500 hours. In the dry season it varies from 58-83% at 0900 hours and from 35-71% at 1500 hours.

3.2.2 Vegetation and Land-Use

Vegetation of the area falls under the savanna woodland which is characterized by medium height trees interspaced by grass and shrubs. At present the bulk of the original vegetation is removed and replaced by extensive cover of grass predominantly *Panicum maximum* and *Pennisetum odorata* (elephant grass) in poorly drained sites.

Teak stands have been established in the area and common food crops grown include, maize, cassava, yam, cowpea, and groundnuts (FDPB Report, 1997)

3.2.3 Relief and Geology

The area is generally low lying and nearly flat with slopes between 0-3%. Depressions and valley bottoms which are quite extensive and are susceptible to water logging or flooding during the rainy season. Commonly occurring soil types include Lima series, Volta series and Wenchi series. Lima series are soils which occur on gentle lower slopes of 3% or less. They are pinkish-grey and imperfectly drained loamy sands developed from colluvial and alluvial sands. Teak establishment on Lima series is assessed to be moderate. Limitation to fast growth is posed by the droughtiness and poor nutrient retention capacity due to the sandy texture. Lima series in FAO/UNESCO classification is Dystric regosol. (FAO/UNESCO, 1988)

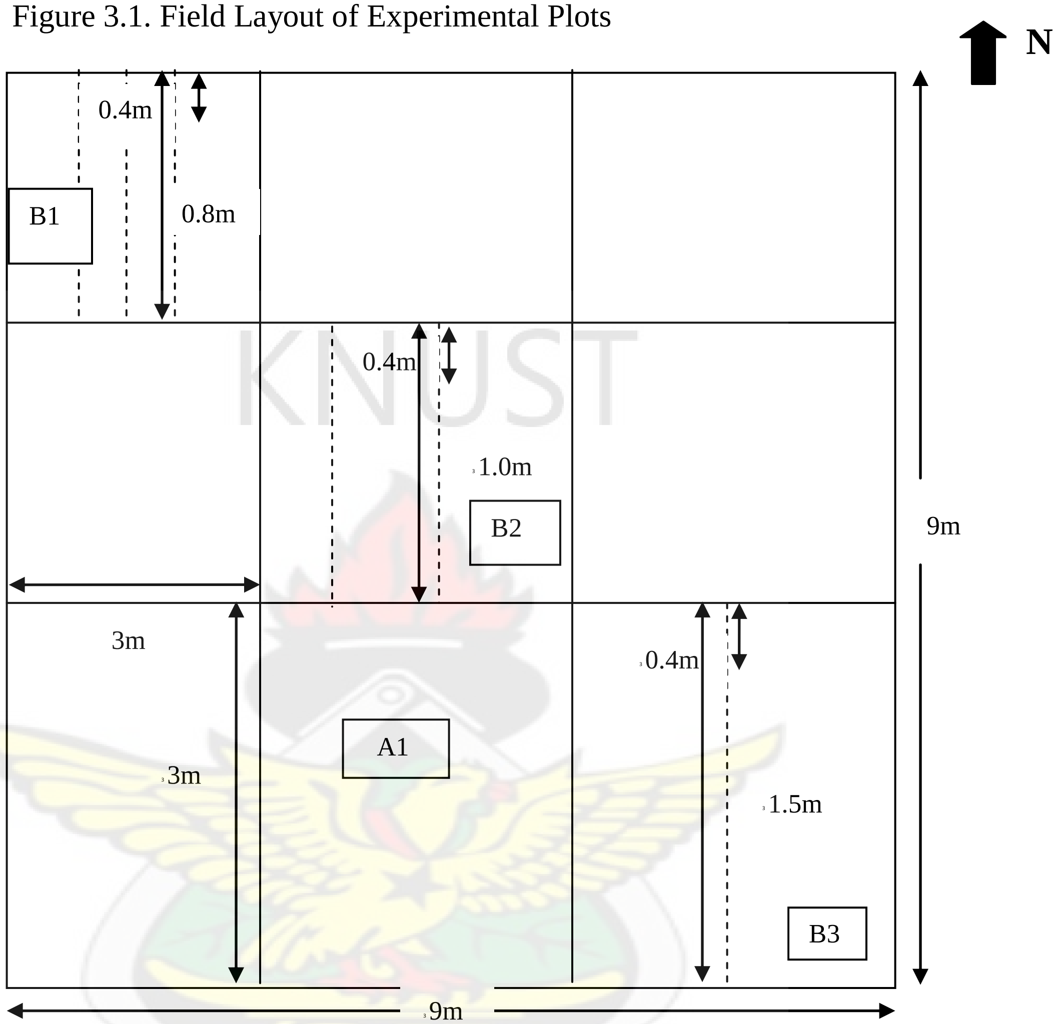
Volta series in the FAO/UNESCO classification is Dystric gleysol. These soils occupy valley bottoms or depressions. They are grey, poorly drained and slowly permeable, silty clays. They are extensive and cover the eastern part of the site. The soil is medium textured and has a high moisture retention capacity and becomes waterlogged during the rainy season and also able to retain moisture throughout the dry season if well protected by surface cover. Teak on Volta series is assessed to be highly suitable largely due to moisture availability throughout the year. However, it is necessary to control drainage so as to prevent water logging particularly during the initial stages of the plant growth.

Wenchi series in FAO/UNESCO classification is Dystric leptosol. It is shallow soils of less than 30cm. It consists of iron gravel with pan encountered at 30cm or less. This soil occurs in patches within the location of the Lima series area (Quansah, *et.al* 2001)

3.3 Experimental Layout

An experimental plot size of 10 x 30m was laid out on almost same soil level under each of the 200 by 500m Teak stands. Trees were established at 3 x3m spacing and range from ages; 1 to 3years. Each main plot was divided into 9 x 9m subplots and replicated three times. In each subplot, maize variety (Obaatanpa) was sown at spacing of; 40 x 80cm; 40 x 100cm and 40 x 150cm. and randomly distributed in a Complete Randomised Block Design (CRBD). Teak ages were designated; A_1, A_2 & A_3 and intercrop spacing designated; B_1, B_2 & B_3 (Figure 3.1)

Figure 3.1. Field Layout of Experimental Plots



A1 – Teak age 1 year

A2 – Teak age 2 years

A3 – Teak age 3 years

B1 – Maize intercrop spacing; 40 x 80cm

B2 – Maize intercrop spacing; 40 x100cm

B3 – Maize intercrop spacing; 40 x 150cm

Plate 1. One year old Teak Stand with Maize Intercrop

Plate 2. Two years old Teak Stand with Maize Intercrop

Plate 3. Three years old Teak Stand with Maize Intercrop

3.4 Field Operations

Experimental plots were cleared of weeds and soil clumps prepared to fine soil tilth under teak with a hand hoe. Teak trees within plots were uniformly pruned and plots kept weed free throughout the study period. Tree diameter at breast height was measured with clinometers at the start of the study and maize height measured with measuring a tape.

3.5 Data Collection and Analysis

SPSS statistical package was employed for analysis of experimental data. This presented cross tabulation and frequencies of treatment means. The statistical package showed ANOVA and correlation between experimental plots and predicted numerical outcomes.

3.5.1 Soil Sampling

Soil samples were systematically taken cross experimental plots from a soil profile of 30cm depth. Samples collected were bulked together air-dried and sieved with the 2 mm sieve. Small samples were then taken to the Soil Research Institute laboratory and analyzed for nutrients, acidity and organic matter before start and after crop harvest.

3.5.2 Teak Measurements

Within each plot a third of the trees were randomly sampled and diameters at breast height were measured using diameter tape and mean tree diameter per plot estimated. Tree heights were measured using clinometers and mean height per plot estimated.

3.5.3 Maize Measurements

In each experimental plot maize measurements taken were; crop height, leaf count, leaf area index were taken at regular intervals and grain yield measured after harvest. Crop height was measured with a measuring tape, leaf abundance was counted, leaf area index estimated as; ratio of cross-sectional area of largest crop leaf to area of overcast shadow by crop. Dry grain weight per intercrop spacing were measured with a weight scale after crop harvest.

CHAPTER FOUR

4.0 RESULTS AND ANALYSIS

4.1 Soil Analysis

Results from soil analysis have been presented in given table below showing soil condition before and after the study period (Table 4.1)

Table 4.1 Comparison of Soil Mineral Status before and after Maize intercrop under Teak

Soil Property	Before	After
PH (1:1 in H_2O)	5.00	6.00
Organic C (%)	0.66	1.02
Total N (%)	0.06	0.06
Available P (mg/kg)	20.80	22.50
Total Exchangeable Bases TEB (me/100g)	3.70	3.50
Exchangeable Acidity (me/100g)	0.80	0.60
Effective CEC (me/100g)	4.50	5.50

Soil pH and C slightly increased after the trials creating slightly acidic condition, possibly due to organic matter decomposition and mineralization. Similarly available P and cation exchange capacity CEC, slightly increased after intercrop. However, N, exchangeable bases and acidity reduced slightly

4.2 Stand Age and Intercrop Spacing effect on Maize Height

Analysis of results did not present any significant difference in maize heights under different Teak ages and intercrop spacing (Table 4.4). Highest mean crop height occurred under Teak age 2 at spacing; (40 x 150cm) and lowest Teak age 1 at; (40 x 80cm), (Table 4.2)

Table 4.2 Table of Means showing Crop height/cm at different spacing under Teak

Plot Numbers	Interactions	Mean Height/cm	Remarks
H_0	A_1B_1	50.3	Lowest crop height
H_1	A_1B_2	52.3	
H_2	A_1B_3	66.0	
H_3	A_2B_1	74.3	
H_4	A_2B_2	73.3	
H_5	A_2B_3	75.0	Greatest crop height
H_6	A_3B_1	54.1	
H_7	A_3B_2	60.6	
H_8	A_3B_3	66.4	
Grand Mean		60.4	
CV 1%		6.9	
LSD 5%		3.9	

Table 4.3 Treatment Means – Maize Height/cm

Row Totals A	Row Means A_x	Column Total B	Column Means B_x	Grand Totals	Grand Mean
169.0	56.3	162.3	54.1		
222.6	74.2	178.9	59.6	540.5	60.1
148.9	49.9	199.3	66.4		

Figure 4.1 Mean maize height/cm against weeks of growth under Teak

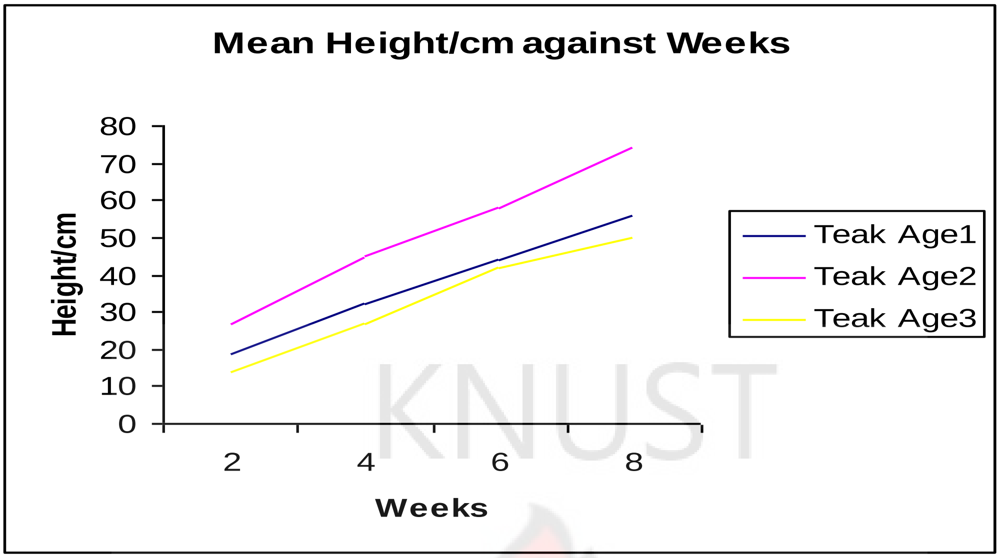


Table 4.4 Analysis of Treatment Variance (Maize Height)

Variation	Degrees of Freedom	Mean Square	$F_{0.95}$
V_B=323.5	2	161.7	0.654
V_A=39.5	2	19.8	0.079
V_E =988.3	4	247.1	
V =1351.3	8		

F distribution, at 2,4 degrees of freedom; $P \leq 0.05$

4.3 Stand Age and Intercrop Spacing effect on Maize Leaf Count

Analysis of results did not present any significant difference in maize leaf count under different Teak ages and intercrop spacing (Table 4.7). Highest mean crop leaf count occurred under Teak age 2 at spacing; (40 x 80cm) and lowest Teak age 1 at; (40 x 80cm), (Table 4.5)

Table 4.5 Table of Means showing Crop leaf count at different spacing under Teak

Plot Numbers	Interactions	Mean Heights/cm	Remarks
C_0	A_1B_1	10	
C_1	A_1B_2	11	
C_2	A_1B_3	10	
C_3	A_2B_1	12	Highest count
C_4	A_2B_2	11	
C_5	A_2B_3	11	
C_6	A_3B_1	9	Lowest count
C_7	A_3B_2	11	
C_8	A_3B_3	11	
Grand Mean		11	
CV 1%		6.9	
LSD 5%		0.72	

Table 4.6 Treatment Means – Maize Leaf Count

Row Totals A	Row Means A_x	Column Total B	Column Means B_x	Grand Total	Grand Mean
31.6	10.5	32.0	10.6		
36.1	12.0	33.3	11.1	99.6	11.1
31.9	10.6	32.3	10.7		

Figure 4.2 Mean Maize Leaf Count against Weeks of Growth under Teak

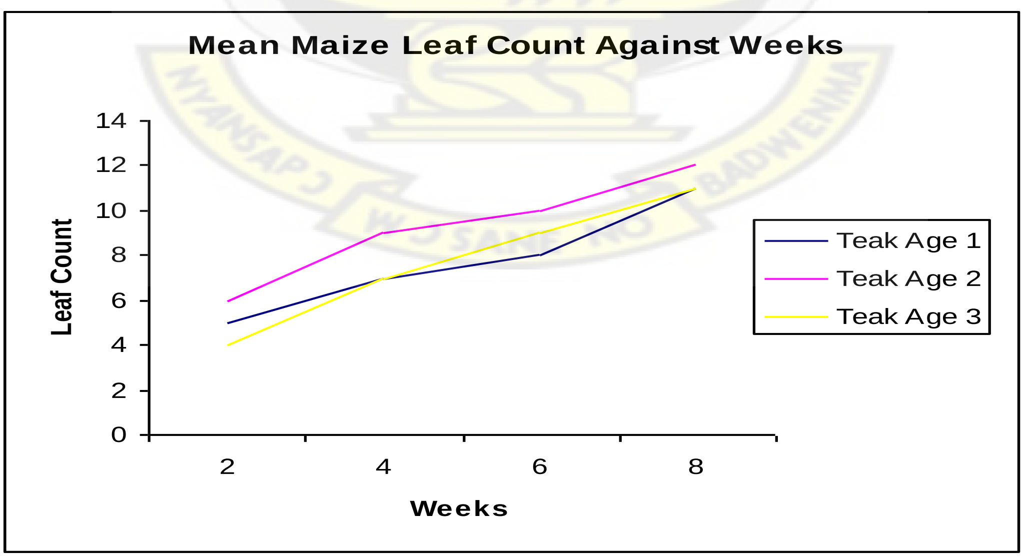


Table 4.7 Analysis of Treatment Variance (Maize Leaf Count)

Variation	Degrees of Freedom	Mean Square	$F_{0.95}$
V_B=1.42	2	0.71	0.327
V_A=0.41	2	0.205	0.094
V_E =8.66	4	2.165	
V =10.49	8		

F distribution, at 2,4 degrees of freedom; P≤0.05

4.4 Stand Age and Intercrop Spacing effect on Maize Leaf Area Index

Analysis of results did not present any significant difference in maize leaf area index under different Teak ages and intercrop spacing (Table 4.10). Highest mean crop leaf area index occurred under Teak age 2 at spacing; (40 x 150cm) and lowest Teak age 3 at; (40 x 80cm), (Table 4.8)

Table 4.8 Table of Means showing Crop leaf Area Index at different spacing under Teak

Plot Numbers	Interactions	Mean Heights/cm	Remarks
A_0	A_1B_1	0.75	
A_1	A_1B_2	0.82	
A_2	A_1B_3	0.81	
A_3	A_2B_1	0.83	
A_4	A_2B_2	0.85	
A_5	A_2B_3	0.91	Greatest LAI
A_6	A_3B_1	0.71	Lowest LAI
A_7	A_3B_2	0.73	
A_8	A_3B_3	0.75	
Grand Mean		0.79	
CV 1%		0.23	
LSD 5%		0.13	

Table 4.9 Treatment Means – Maize Leaf Area Index

Row Totals A	Row Means A_x	Column Total B	Column Means B_x	Grand Total	Grand Mean
2.43	0.81	2.31	0.77		
2.58	0.86	2.37	0.79	7.12	0.79
2.10	0.70	2.43	0.81		

Figure 4.3 Mean Maize Leaf Area Index against weeks of growth under Teak

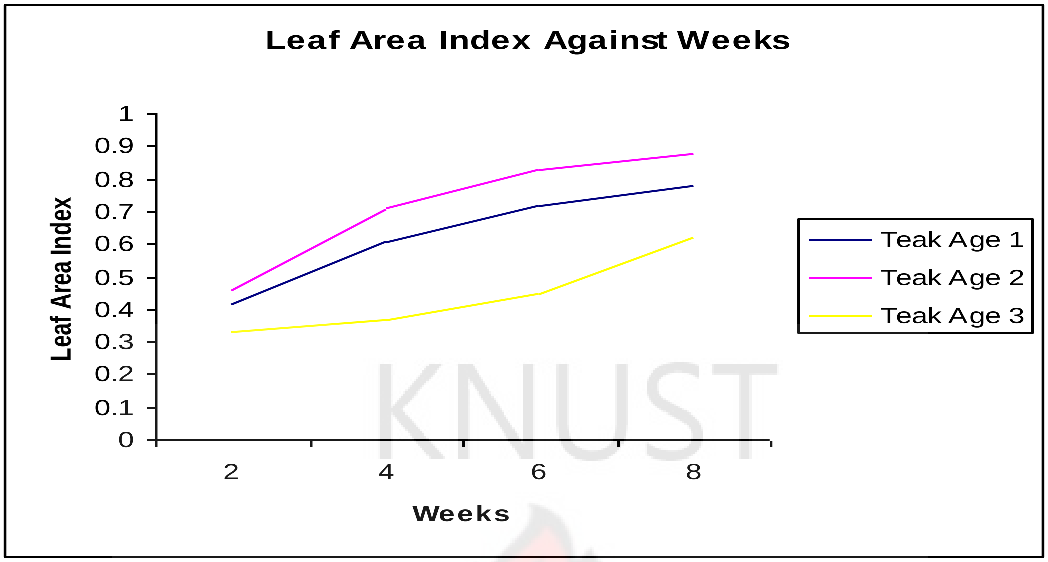


Table 4.10 Analysis of Treatment Variance (Maize LAI)

Variation	Degrees of Freedom	Mean Square	$F_{0.95}$
V_B=0.01	2	0.0002	0.02
V_A=0.001	2	0.0004	0.04
V_E =0.0438	4	0.0195	
V =0.045	8		

F distribution, at 2,4 degrees of freedom; P≤0.05

4.5 Stand Age and Intercrop Spacing effect on Dry Grain Weight

Analysis of results did not present any significant difference in estimated grain dry weight (tons/ha) under different Teak ages and intercrop spacing (Table 4.13). Highest estimated grain dry weight (tons/ha) occurred under Teak age 1 at spacing; (40 x 150cm) and lowest Teak age 3 at; (40 x 80cm), (Table 4.11)

Table 4.11 Table of Means showing Dry Grain Weight (tons/ha) at different Intercrop spacing under Teak

Plot Numbers	Interactions	Mean Yields tonnes/ha	Remarks
Y_0	A_1B_1	1.93	
Y_1	A_1B_2	2.08	
Y_2	A_1B_3	2.68	greatest yield
Y_3	A_2B_1	1.76	
Y_4	A_2B_2	1.75	
Y_5	A_2B_3	1.61	
Y_6	A_3B_1	0.65	Lowest yield
Y_7	A_3B_2	0.94	
Y_8	A_3B_3	1.13	
Grand Mean		1.61	
CV 1%		0.08	
LSD 5%		5.11	

Table 4.12 Treatment Means – Estimated Maize Yield (tons/ha)

Row Totals A	Row Means A_x	Column Total B	Column Means B_x	Grand Total	Grand Mean
6.69	2.23	4.38	1.46		
5.10	1.70	4.77	1.59	14.53	1.61
2.70	0.90	5.40	1.80		

Table 4.13 Analysis of Treatment Variance (Dry Grain Weight)

Variation	Degrees of Freedom	Mean Square	$F_{0.95}$
V_B=0.0896	2	0.448	0.832
V_A=0.058	2	0.029	0.054
V_E =2.153	4	0.538	
V =3.107	8		

F distribution, at 2,4 degrees of freedom; $P \leq 0.05$

CHAPTER FIVE

5.0 DISCUSSIONS

Soil test results showed slight differences in levels of mineral content after maize intercrop (Appendix 5). Across the experimental plots, pH records ranged from 5.0 to 6.0 indicating moderate acidicity making area suitable for cultivation of teak and cereals cultivation (Asubonteng, *et al*, 1995).Organic matter (OM) - (organic carbon) levels were generally moderate considering the climatic and vegetation condition of the area. A greater number of samples gave OM values in the range from 0.5 to1.5% in the topsoil, this confirms studies by Jose and Koshy (1972) that organic matter content in Teak plantations correlated with stand age till after 30 years. They observed that soils beneath plantations less than 30 years had showed higher bulk densities, lower amount of pore space and water holding than older plantations and natural forests. Total nitrogen (N) levels were (less than 0.1%) for greater number of samples. The moderately high organic matter could compensate for the low nitrogen levels after decomposition and mineralization.(Table 4.1)

Available phosphorus (P) levels of the site ranged from 1.0 to 22.7 ppm^{p} in the topsoil and potassium (K) values ranged from 45 to 233 ppm^{k} for the topsoil (0.20cm).

Exchangeable bases (Calcium, magnesium and sodium) levels were generally moderate in all the samples and in some cases high. calcium (Ca) and magnesium (Mg) were above 3.0 me/100g and 0.5 me/100g soil respectively. Exchangeable potassium levels were also (above 0.2 m.e per 100g soil). These are reportedly good for teak which takes up lots of potassium and other bases (Asubonteng, *et al,* 1995).

Cation exchange capacity (CEC) showed moderate to high values (above 5.0 me/100g). This also indicates high fertility of the soil which could support the growth of crops for a couple of years. This is supported by studies of Hosur and Dason (1995) on effect of Teak on soil chemical properties.

Due to the high base status and the high pH levels of the soils, the exchangeable acidity (Al + H) levels were low (less than 0.5me/100g soil). This offset any foreseeable problem of acidity and aluminum toxicity which requires liming.

From ANOVA; tables 4.4, 4.7, 4.10, & 4.13 the study did not present significant difference in treatment means; ($p \leq 0.05$), thus Teak age and intercrop spacing did not have remarkable effect on maize growth and dry grain yield. Results indicated that; maize height, leaf count and leaf area index were greatest under 2 year stand than under the 1 or 3 year old stands. The study also revealed that intercrop spacing of; 40 x 150cm resulted to higher maize heights, leaf area index and dry grain yield. This is confirmed by Porras and Luyano (1974), that cereal cultivation under two year rows of treecrop enhances crop growth and yield and proves an economic approach to landuse.

Results showed that dry grain weight tons/ha of maize was higher under Teak year 1 than under year 2 and 3. The observed trend of reduced maize yield with increasing Teak age could be accounted for by relatively higher competition for soil water and nutrient as a result of increasing root densities. This is supported by crop trials by (Kasoa-ard1981).

Tree foliage somehow impaired maize growth and yield, from mean values of crop growth higher effects was observed by closeness of crops to individual rows of trees, hence intercrop spacing; 40 x 80cm was relatively in proximity to rows of trees than spacing; 40 x 100cm and 40 x 150cm. Although all trees were uniformly pruned at the start of study, tree foliage regrowth and coverage was greater with increasing stand age, hence overhead shade was cast on intercrops resulting to low growth and yield. This explains the growth and yield responses of tree-crop interphase where increasing distances from tree bases give good intercrop growth and yield (Khan and Ehrenreich 1994).

The study of tree intercrop growth and yield responses also confirms the relative influence of living roots and canopy cast by the Teak trees on yield of intercrop maize. The study revealed that competition for light was significant after 2 weeks following crop germination, thus resulting to elongated height growth. When combined with root competition, stunted growth was evident in maize. Shading also substantially reduced total dry weight of grains per cob ($p<0.01$). Living roots alone did not have significant effect on maize height growth, total dry matter production, grain yield, number of cobs per plant, mean cob weight and mean grain weight per cob. ($p>0.05$) (Agbede 1985).

However, a combination effect of shade and living roots of Teak trees appreciably reduced total dry matter yield and mean cob weight per maize plant, this confirms the study results that; intercrop spacing of 40 x 150cm under Teak age1 gave the best maize biomass growth and dry grain yield. This is supported by (Agbede and Adedire, 1989).

Kang *et, al.* (1981) attributed low yields of maize rows adjacent to *Leucaena* hedgerows to shade. Neumann and Pietrowicz (1989) studied competition in agroforestry combination of *Grevillea robusta*, maize and beans in Rwanda, reported that shade cast by *Grevillea* appeared more important than other effects of the trees. Since crops differ in their responses to poor nutrition. Competion for light or water may either be reduced or amplified by shortage nutrients (Cannell, 1983).

The study hence showed that the topsoil under Teak age 2 appeared more mineralized with plant biomass than under Teak age 1. Low maize growth and yield under Teak age 3 could be attributed to limiting light availability due to canopy formation, hence low photosynthetic activity in maize. This confirms Haggar and Beer (1993) on the study of the effect on maize growth of the interaction between increased nitrogen availability and competition with trees in alley cropping. Spatial variability in soil nitrogen mineralization and mulch nitrogen release did not explain any difference in growth or nitrogen uptake with respect to the trees. They hypothesized that the slower growth of maize next to *Erythrina* after 2 months of sowing is due to increasing light and nutrient competition by the tree as the trees recover from pollarding. The apparent lack of competition from *Gliricidia* may be due to different rates of regrowth or different shoot and root architecture.

Results suggest possible enhanced soil nutrient availability under Teak age 2 and 40 x 150cm intercrop spacing promoted high crop biomass growth and grain yield (Tables; 4.2 & 4.11) this is in line with Korwar and Raddar (1994) findings on the influence of root prunings and cutting interval of *Leucaena* hedgerows on the performance of alley cropped rabi sorghum, in which they concluded that; root prunings of *Leucaena* increased grain and stover yields of alley cropped rabi sorghum by 33% and 17% over unpruned hedgerow roots. Similarly shorter cutting intervals of 1 to 2 months increased crop yields as compared with longer cutting intervals of 3 to 6 months. Growth in height and dry matter was similarly influenced.

From table 4.13, Teak age and intercrop spacing did not show any significant difference in maize growth and grain yield. Grain yield was highest under Teak age 1 at 40 x 150cm spacing and lowest under Teak age 3 at 40 x 80cm spacing (Table 4.11). Maize yield of dry grain yield per experimental plots ranged from; 0.65 to 2.68 tons/ha. This is in line with Ramdial (1980a) findings that; average yield of cereals under modified Teak taungya systems ranged from 5.0 – 6.6 tons/ha and from 2.3 – 3.9 tons/ha under pines.

Karim *et al.* (1993) also concluded from their crop trials in Sierra Leone, that alleys of 2 to 4m wide planted no closer than 0.50m within rows resulted in more than twice the yields of maize, than in the 8m alleys planted at 0.25m within rows, once the hedgerows were well established and were being managed.

Moreover, Khan and Ehrenreich (1994) also concluded that proximity of wheat crops to trees under irrigated conditions adversely affected the crop tillers/m^2 and weight/1000 grains and the yield of wheat planted up to a distance of about 8.5m from the trees. Plant height and grain/spike were least affected. In general they concluded that the growth and yield of wheat improved as distance from the trees increased. Tree size did not affect wheat height, tillers/m^2; grain (spike or weight/1000 grains). The grain yields were slightly lower near the largest trees of diameter 50-54.9cm dbh.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study investigated Teak age and intercrop spacing effect on maize growth and yield. Grain yield was estimated per unit plot as dry grain weight per hectare after crop harvest. The study involved soil sampling and laboratory analysis to compare nutrient levels, organic matter, pH as well as cations and bases exchanges under Teak. Soil samples were not necessarily analyzed for variances between treatment means.

From table 4.1, there was slight differences in pH, exchangeable bases, cation exchange capacity, organic matter and available phosphorous. However total nitrogen and exchangeable acidity remained fairly unchanged before and after trials.

The study did not conclude any significant effect of Teak stands from 1 to 3 years on soil mineral status within the period of study. This is supported by the findings of Marquez *at. al* (1993), that Teak chronosequence; 2, 7 and 12 years. They observed that Ca, Mg, pH and CEC were significantly higher in the 12 year than in both the 2 and 7 year old stands. Moreover Jose and Koshy (1972), research on soil physical properties under Teak concluded that organic matter content and soil bulk densities correlated with stand age.

From tables; 4.4, 4.7, 4.10, & 4.13 analyses of treatment variances did not present any significant difference of Teak age and intercrop spacing on maize biomass growth and grain yield. From mean tables; 4.2, 4.5, 4.8, & 4.10 highest crop height and leaf area index was recorded under Teak age 2 at 40 x 150cm intercrop spacing. Highest dry grain yield was estimated under Teak age 1 at 40 x 150cm, hence best intercrop spacing which promoted good crop growth and dry grain yield per hectare was; 40 x 150cm.

Karim *et al.* (1993) concluded that alleys of 2 to 4m wide planted no closer than 0.50m within rows resulted in more than twice the yields of maize, than in the 8m alleys planted at 0.25m within rows, once the hedgerows were well established and were being managed. This somehow supports the study results.

Moreover, Khan *et al.* (1994) also concluded that proximity of wheat crops to trees under irrigated conditions adversely affected the crop tillers/m^2 and weight/1000 grains and the yield of wheat planted up to a distance of about 8.5m from the trees. Plant height and grain/spike were least affected. In general they concluded that the growth and yield of wheat improved as distance from the trees increased. Tree size did not affect wheat height, tillers/m^2; grain (spike or weight/1000 grains). The grain yields were slightly lower near the largest trees of diameter 50-54.9cm dbh.

6.2 Recommendation

The study mainly focused on young Teak stand effect on soil physical and chemical properties within the period of study. Although results did not present any significant differences in soil treatment means, samples were not necessarily analyzed for variations in soil physical and chemical properties between Teak plantation blocks. Moreover it must be pointed out that the trial period for this study was quite short to allow full transformation of soil physical and chemical properties under Teak. Hence it is worthwhile to consider analyzing soil samples under the stand at regular time intervals till end of the 30 year plantation rotation. Since soil condition remained fairly unchanged within 1 to 3 years of Teak establishment, it may be worthwhile analyzing soil samples at intervals of 5 years and comparing results with that from control plots to assess any variation in samples.

Moreover intercropping Teak with maize till tree canopy closure and analyzing soil samples to ascertain any difference in chemical composition which may have contributed to reduced growth in crops could be helpful to allay the notion that Teak plantations impoverish soil making it unsuitable for intercropping (allelopathy).

Further research trials if pursued could be beneficial to provide Bosomkyekye village community and beyond with useful information about good Teak and maize intercrop cultivation practices.

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APPENDICES

Appendix 1

Stand Age and Intercrop Spacing effect on Mean Maize height/cm.

Age (A) (Years)	Weeks After Germination			
	2	4	6	8
1	19.0	32.3	44.4	56.4
2	27.2	45.1	58.5	74.2
3	14.4	27.2	42.5	50.7
Spacing (B)				
1	23.0	38.0	52.5	66.4
2	19.1	37.3	48.1	60.8
3	19.0	29.3	44.9	54.1
Grand Mean	20.37	34.88	48.5	60.1
LSD 5%	2.56	6.21	5.8	3.9
C.V. %	13.33	18.88	12.6	6.9

Appendix 1a.

Stand Age and Intercrop Spacing Interaction effect on Mean Maize Height.

Age (A) (Years)	Intercrop Spacing			Mean
	1	2	3	
1	50.7	52.3	66.0	56.3
2	74.3	73.3	75.0	74.2
3	37.3	53.3	58.3	50.6
Mean	54.1	60.6	66.4	60.3
Grand Mean				60.4
LSD 5%				3.9
CV 1%				6.9

Appendix 2

Stand Age and Intercrop Spacing effect on Mean Maize Leaf Count.

Age (A) (Years)	Weeks after Germination			
	2	4	6	8
1	5.1	6.9	8.0	10.5
2	5.9	8.7	9.7	12.0
3	4.3	6.6	8.6	10.7
Spacing (B)				
1	5.2	7.3	7.8	10.7
2	4.3	7.3	8.8	11.1
3	4.3	7.4	9.7	11.4
Grand Mean	5.2	7.4	8.7	11.1
LSD 5%	0.75	0.91	0.89	0.72
C.V. %	15.3	13.06	10.8	6.9

Appendix 2a

Stand Age and Intercrop spacing Interaction effect on Mean Maize Leaf Count

Age (A) (Years)	Weeks After Germination											
	4				6				8			
	Spacing				Spacing				Spacing			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
1	7.3	7.7	5.7	6.9	6.3	9.3	8.3	7.9	10.0	11.3	10.3	10.5
2	9.0	7.7	9.3	8.6	9.6	8.6	10.7	9.6	12.7	11.7	11.7	12.0
3	5.7	6.7	7.3	6.5	7.3	8.3	10.0	8.5	9.3	10.3	12.3	10.6
Mean	7.3	7.3	7.4	7.3	7.7	8.7	9.6	8.6	10.6	11.1	11.0	11.0
Grand Mean				7.4				8.7				11.1
LSD 5%				0.91				0.89				0.72
CV 1%				13.1				10.8				6.9

Appendix 3

Stand Age and Intercrop Spacing effect on Mean Maize Leaf Area Index

Age (A) (Years)	Weeks After Germination			
	2	4	6	8
1	0.42	0.61	0.74	0.78
2	0.46	0.71	0.83	0.88
3	0.33	0.37	0.45	0.62
Spacing (B)				
1	0.43	0.63	0.71	0.74
2	0.32	0.61	0.72	0.76
3	0.34	0.58	0.76	0.82
Grand Mean	0.36	0.60	0.73	0.77
LSD 5%	0.29	0.22	0.26	0.21
C.V. %	0.24	0.29	0.25	0.13

Appendix 3a.

Stand Age and Intercrop Interaction effect on Mean Maize Leaf Area Index

Age (A) (Years)	Weeks After Germination											
	4				6				8			
	Spacing				Spacing				Spacing			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
1	0.61	0.59	0.60	0.60	0.68	0.72	0.76	0.72	0.76	0.83	0.83	0.81
2	0.75	0.77	0.69	0.74	0.77	0.81	0.84	0.80	0.84	0.86	0.90	0.86
3	0.35	0.34	0.42	0.37	0.44	0.42	0.73	0.53	0.71	0.69	0.70	0.77
Mean	0.57	0.56	0.57	0.57	0.63	0.65	0.77	0.68	0.77	0.79	0.81	0.81
Grand Mean				0.56				0.68				0.80
LSD 5%				0.24				0.29				0.23
CV 1%				0.29				0.25				0.13

Appendix 4

Stand Age and Intercrop Spacing Interaction effect on Estimated Mean Maize Yield in Tons per Hectare

Plant Age(A)	Intercrop Spacing			Mean
	1	2	3	
1	1.93	2.08	2.68	2.23
2	1.76	1.75	1.61	1.70
3	0.65	0.94	1.13	0.90
Mean	1.46	1.59	1.80	1.61
Grand Mean				1.60
LSD 5%				0.08
CV %				5.11

Appendix 5

Sample (cm)	PH (1:1)	C (%)	OM (%)	Total N (%)	Avail. P (mg/kg)	Exchangeable Cations						Effective CEC (me/100g)
						Ca	Mg	K	Na	Al	H	
A_0 0-10	5.0	0.87	1.51	0.08	19.5	3.20	1.00	0.02	0.03	0.40	1.00	5.65
A_0 10-20	5.0	0.66	1.10	0.06	18.2	2.60	1.40	0.02	0.03	0.60	0.80	5.25
A_1 0-10	5.0	0.72	1.28	0.06	26.3	2.80	0.80	0.02	0.03	0.80	0.80	5.65
A_1 10-20	5.3	0.74	1.00	0.05	11.3	2.40	0.40	0.01	0.03	0.60	0.60	4.65
A_2 0-10	5.7	0.76	1.61	0.09	11.8	2.80	0.60	0.02	0.04	0.40	1.00	5.24
A_2 10-20	5.5	0.84	1.28	0.07	15.4	2.80	1.00	0.02	0.03	0.40	0.60	5.65
A_3 0-10	5.9	0.94	1.38	0.06	19.4	3.80	0.80	0.02	0.03	0.20	0.80	5.05
A_3 10-20	5.8	0.74	0.97	0.08	18.2	3.00	1.20	0.05	0.03	0.20	0.80	5.69
A_4 0-10	5.6	0.72	0.95	0.06	24.9	3.20	1.20	0.02	0.03	0.60	1.00	4.85
A_4 10-20	5.8	0.90	1.42	0.05	19.5	3.80	3.60	0.01	0.03	0.40	0.80	4.65

Appendix 5 (contd).

Sample (cm)	PH (1:1)	C (%)	OM (%)	Total N (%)	Avail. P (mg/kg)	Exchangeable Cations						Effective CEC (me/100g)
						Ca	Mg	K	Na	Al	H	
B_0 0-10	5.7	0.76	1.31	0.08	22.0	3.00	1.20	0.04	0.03	0.06	1.00	5.87
B_0 10-20	5.6	0.52	1.90	0.06	16.9	3.20	0.40	0.03	0.03	1.00	1.00	5.66
B_1 0-10	5.4	0.76	1.31	0.07	18.2	3.00	0.60	0.03	0.03	0.80	1.20	5.66
B_1 10-20	5.4	0.86	1.48	0.07	19.5	3.40	0.80	0.03	0.03	1.20	1.20	8.06
B_2 0-10	5.3	0.56	0.97	0.08	23.6	4.40	1.00	0.06	0.06	1.20	1.20	6.66
B_2 10-20	5.3	0.30	0.52	0.08	19.5	3.80	1.60	0.02	0.02	1.00	1.20	5.65
B_3 0-10	5.5	0.70	1.21	0.10	22.0	3.80	1.20	0.04	0.04	0.80	1.00	7.05
B_3 10-20	5.5	0.40	0.69	0.06	15.4	3.00	1.20	0.03	0.03	0.60	1.20	6.06
B_4 0-10	5.4	0.70	1.21	0.07	18.2	3.00	1.00	0.02	0.02	1.00	1.20	6.28
B_4 10-20	5.6	0.80	1.48	0.07	24.9	3.20	2.00	0.03	0.03	0.60	1.20	6.88

Appendix 5 (contd).

Sample (cm)	PH (1:1)	C (%)	OM (%)	Total N (%)	Avail. P (mg/kg)	Exchangeable Cations						Effective CEC (me/100g)
						Ca	Mg	K	Na	Al	H	
C_0 0-10	5.3	0.46	0.79	0.07	15.4	2.80	1.20	0.03	0.03	0.04	1.00	5.67
C_0 10-20	5.1	0.42	0.72	0.06	11.8	3.00	1.60	0.02	0.03	1.02	1.10	5.66
C_1 0-10	5.3	0.46	0.79	0.07	13.1	3.00	0.60	0.04	0.02	0.80	1.00	6.67
C_1 10-20	5.2	0.34	0.59	0.06	14.3	2.40	2.00	0.06	0.02	1.30	1.00	6.08
C_2 0-10	5.2	0.40	0.69	0.07	19.5	3.20	1.60	0.04	0.03	0.50	1.20	5.89
C_2 10-20	5.0	0.80	1.38	0.07	18.2	4.00	1.00	0.05	0.04	0.60	1.20	7.04
C_3 0-10	5.2	0.58	1.00	0.10	13.1	4.00	0.40	0.03	0.06	1.00	1.00	6.67
C_3 10-20	5.1	0.82	0.79	0.07	13.1	4.00	1.40	0.02	0.04	0.80	1.20	5.97
C_4 0-10	5.0	0.66	1.41	0.06	19.5	3.00	1.20	0.04	0.03	0.60	1.20	6.56
C_4 10-20	5.4	0.60	1.03	0.08	13.1	2.80	1.40	0.02	0.02	0.06	1.00	7.09