The potential of *Azadirachta indica* leave biomass as a nutrient source for maize cultivation in Tolon/Kumbungu District of Northern Ghana

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BY

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DECLARATION

I declare that except references to other people's research work to which due acknowledgement has been given, this thesis submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi for the Master of Science in Agroforestry, is the result of my own investigation and have not been submitted in any thesis for any award.

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ABSTRACT

Maize is the major staple food for most communities in Africa. For improved yield, high yielding varieties have been adopted by farmers. In spite of this, maize yields are dwindling. This is due to the extension of cultivation into drought prone, semi-arid areas, declining soil fertility, shortened fallow periods, high rates of erosion, leaching and removal of crop residues without adequate fertilization. Socio-economic studies was conducted in Tolon/ Kumbungu District while field and laboratory studies was conducted at Savanna Agricultural Research Institute in Nyankpala from July to November 2010. This was to evaluate the potential of *Azadirachta indica* biomass as a nutrient source for maize cultivation. A randomized complete block design (RCBD) was used. Six treatments used were: T1- 6t/ha of biomass, T2- 3t/ha of biomass, T3- 120kg of NPK fertilizer/ha, T4- 3t/ha of biomass with 60kg of NPK fertilizer/ha, T5- 4t/ha of biomass with 40kg of NPK fertilizer/ha and T6- control. The socio-economic survey indicated that, *Azadirachta indica* is located on farmland and infront of houses in Tolon-Kumbungu District. Is mainly used for roofing poles and fuelwood while pruning is adopted as the main management practice. Laboratory studies indicated that *Azadirachta indica* biomass contained nitrogen content of 2.07%, 0.12% of phosphorous, 0.20% of potassium, 0.61% of calcium and 0.22% of magnesium. Maize grain yield differed significantly among the treatments. One hundred and twenty (120) kg of NPK fertilizer/ha significantly produced the highest maize grain yield of 3t/ha than all the treatments. The same grain yield of 1.8t/ha was obtained for 6t/ha of biomass (T1), 4t/ha of biomass plus 40 kg of NPK fertilizer/ha (T5), and 3t/ha of biomass plus 60 kg of NPK fertilizer/ha (T4) which recorded the second highest maize yield. 3t/ha of biomass gave

maize yield of 1.2t/ha. All the treatments were significantly different from the control. The control had the least grain yield of 0.5t/ha. Highest level of NPK fertilizer application (120 kg/ha) significantly produced the highest maize height (170.2cm). Besides, 6t/ha of biomass (T1), 3t/ha of biomass with 60 kg of NPK fertilizer/ha (T4), 4t/ha of biomass with 40 kg of NPK fertilizer/ha (T5), were not significantly different but were significantly higher than 3t/ha of biomass (T2), and the control. In conclusion, despite the low yield recorded by either sole or combined application of neem leave biomass, small scale farmers who are mostly financially less resourced can adopt the combination of organic and inorganic fertilizers application to enhance nutrients use efficiency, increase the organic matter base of their farms which will enable farmers achieve sustainable yield.

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DEDICATION

To my wife and child Rahama and Zakiyya, parents Mr. and Mrs. Sumaila, uncle Mr. A. A. Ziblim and all my siblings.

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CHAPTER ONE

1.0 INTRODUCTION

Maize production is a key aspect of small-scale agriculture in West Africa. Is the most important among cereals as it forms a major staple food for most communities (Fosu *et al.*, 2004). In spite of the high-yielding varieties adopted by farmers in Africa (33 - 50% of Africa's maize producing area), average yields per hectare are low (Kumwenda *et al*., 1996). Average maize yields per unit land area has decreased in maize yields have been observed in Africa since the 1970's partially because maize cultivation has extended into drought prone, semi-arid areas and partly due to decreasing soil fertility (Gilbert *et al*., 1993). Besides, increase cultivation of the currently used lands has become essential in most farmer communities in West Africa due to pressure on the land (Whittome *et al*., 1995).

Declining soil fertility is now observed as a serious problem affecting agricultural output and environmental well-being in sub-Saharan Africa (Bationo *et al*., 2004). The soils of the major maize growing areas in Ghana are low in organic carbon, total nitrogen, exchangeable potassium and available phosphorus (Adu, 1995; Okalebo *et al*., 2003).

Thus, the non-availability of inorganic fertilizer aggravated by high prices prevents farmers from improving their yields. Moreover, required fallow periods of 5 – 10 years to restore soil fertility are now not practicable (Tarawali *et al*., 1999). The reduced fallow periods below 5 years coupled with high rates of erosion, leaching, removal of crop residues and continuous farming of the same land without ample fertilization has caused reduction of crop yields below tolerable levels (Berner *et al*., 1996; Sanchez and Jama, 2002).

For sustainable and improved crop yield, there is the need for farmers to adopt plant residues as a way of improving soil fertility and organic matter status of the soil. In farming systems, the addition of available plant materials to the farmer as fertilizer is viewed as a substitute to inorganic fertilizer. Organic resources available to the farmer such as manure (cow dung and poultry manure) are restricted especially in farming systems where the animals are not completely integrated. The large section of animals feed on extensive range land where it becomes difficult to gather the manure. Another limiting issue is the cost of transporting manure to farms. Crop residues also have other uses such as fodder, fuel and building materials for which there are no substitutes (Quedraogo *et al*., 2005).

Therefore organic resources such as high biomass producing plants are needed as soil amendments to address the decline in soil fertility under continuous cropping systems (Vanlauwe and Giller, 2006). The use of plant biomass for soil fertility replenishment also requires the identification of species found in the farm vicinity to reduce labour cost. Such plant species should have the ability to increase phosphorous availability to crops since organic inputs have low phosphorous contents (Palm *et al*., 1997).

Also, the plant material must be able to produce a large pool of mineral nitrogen before the period of rapid nitrogen uptake by a crop (Magdoff, 1991). This will mean application of large amounts of the plant material which may not be available. Therefore, combining plant biomass and mineral fertilizers may therefore provide an intermediate solution allowing the most efficient use of scarce resources (Vanlauwe *et al*., 2004).

For most of the studies on resource quality characterization, decomposition and nutrient release, attention have mainly concentrated on leguminous plant species which are considered as high quality materials (Cadisch and Giller, 1997). Non leguminous plant species such as *Azadirachta indica* are also capable of improving soil fertility and organic matter status of soils. Despite the considerable importance of non-leguminous plant species in improving soil fertility and organic matter status of soils, few attempts have been made to quantitatively determine the effects of neem leaves as a nutrient source for maize production.

In order to evaluate the effects neem plantation have on the yield of food crops, surface soil under 12 year old plantations of neem was used to grow food crops. The results indicated that two months after planting, the crops produce five times higher biomass on the soil from the neem plantation than on the control. The trees had favorable effects on soil fertility and therefore improved crop yield (Verinumbe, 1991). Studies in Burkina Faso has shown that mulching sorghum with neem leaves improved sorghum yields by up to 422% of the unmulched control (Tilander, 1993).

Azadirachta indica (Neem) is one of the most widely planted exotic species on nutrient deficient soils in Northern Ghana. Neem has acclimatized well throughout Northern Ghana, and is popular as a source of firewood and as poles and rafters for building construction as well as provision of shade. Neem extracts are also valued for their medicinal properties in treating malaria and as an insecticide for protecting grain. The leaves, together with the twigs, can be applied as mulch or incorporated into the soil as organic input to provide nutrients to crops.

Therefore, this research aims at assessing the potential of *Azadirachta indica* foliage biomass as a nutrient source for maize cultivation. Specifically the study seeks to assess: (i) farmers knowledge on the locations, use and management of *Azadirachta indica* in Tolon-Kumbungu District; (ii) the nutrient content of *Azadirachta indica* leave biomass; and (iii) the effect of different levels of *Azadirachta indica* leave biomass and fertilizer on maize height and yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Ecology of *Azadirachta indica* (neem)

Neem can grow in tropical and subtropical regions with semi-arid to humid climates. It can grow well in areas with annual rainfall of 400-1200 mm and at elevations from sea level to 1000 m. At higher altitudes (1000-1500 m), growth may be slow. Neem is best suited to deep, well drained and sandy soils (Schmutterer, 1995), however the range of soils on which it can grow is wide. Soil water availability is the most critical factor (Fishwick, 1970). Neem can grow on both alkaline and saline soils with a pH of 6.2 – 7.0, although pH of 5.9 and 10.0 may also be tolerated (Ogemah, 2003). Optimum temperatures for its growth range from 21-32^{0}C. However, it can tolerate temperatures as high as 50^{0}C, but low temperatures below 40^{0}C are unfavorable. Neem tree is drought-tolerant and thrives in many of the drier areas of the world. There is, therefore, considerable interest in neem as a means to prevent the spread of deserts and ameliorate desert environments in Saudi Arabia and Sub-Saharan Africa (Ahmed, *et al.*, 1989; National Research Council, 1992; Childs *et al.*, 2001).

2.2 Uses of *Azadirachta indica* (neem) in Ghana

Neem trees are used for the production of firewood and charcoal, but other potential uses remain under-exploited. The most common use of neem in Ghana is for medicinal purposes although other uses such as protection of crop pest in the field and storage crops, timber and poles have been reported (Childs *et al.*, 2001).

2.3 The role of neem in agroforestry systems

Neem has considerable potential within agroforestry systems; however, the species is thought to be under-utilized in many areas (Tilander, 1996). The good coppicing ability of the tree, as well as low mortality following coppicing, makes neem favorable for use in agroforestry systems (Chaturvedi, 1993).

The use of neem leaves as a mulch is among one of the species most important potential uses. Tilander and Bonzi (1997) studied the effects of neem leaf mulches and compost on sorghum yield. They found that neem was highly effective in reducing water loss and high soil temperatures, but that yield was increased when compost and neem leaf mulches were combined. Neem compared favourably to other agroforestry species such as *Leucaena leucocephala, Albizzia lebbeck* and *Acacia holocericea* due to the high nutrient content of the leaves and decomposition rates. The use of mulches to conserve soil moisture and increase nutrient status of the soils is thought to be especially pertinent to semi-arid areas where growth is often limited. The fact that neem keeps its leaves during drought periods increases its significance as a source of biomass for mulching (Tilander and Bonzi, 1997).

2.4 Maize production in Ghana

Maize is the most important cereal crop in most parts of West Africa (Fosu *et al*., 2004). International Maize and Wheat Improvement Center (1990) observed that in the past two decades maize cultivation has spread rapidly into the most savannas, replacing traditional cereals crops like sorghum and millet, particularly in areas with good access to fertilizer inputs and market. In Ghana, maize is the major staple food especially in the savanna agro-ecological zone where it is even replacing sorghum and millet which were the major staples some years ago. Maize is used for the following purposes:

(i) It is milled to prepare meals such as “Tuo-zaafi”, “Banku”, “Kenkey” and porridge (Okoruna, 1995).

(ii) It is eaten fresh when grilled or cooked (Okoruna, 1995).

(iii) The stalk is used to feed animals (Salunkhe *et al*., 1985).

(iv) It features prominently in infant weaning foods (Okoruna, (1995).

(v) The grains are used to prepare animal and poultry feeds.

(vi) It is used as raw material for the production of alcohol, starch and corn oil (Salunkhe *et al*., 1985).

The increasing demand for maize as food in the country shows its potential of becoming an important non-traditional export crop (Rosegrant, 2001). However, maize has low protein content with little vitamin A but higher in vitamin B (Abbiw, 1990). In general, maize contains 90% carbohydrate and 10% proteins (Ofori and Kyei-Baffour, 1993).

The major maize growing areas in Ghana are the forest, savanna and transition agro-ecological zones. Ghana Produces about 1, 100,000 metric tonnes of maize annually over an area of 755, 300 hectares (SRID, MOFA, 2007). Maize yields on the average are 1.5 metric tonnes per hectare compared to an immense potential yield of up to 7.5 tonnes per hectare if the crop is properly managed.

2.5 Major constraints to maize production in Ghana

In Ghana, maize is produced predominantly by smallholder resource poor farmers under rain–fed conditions (Savanna Agricultural Research Institute, 1996). Low soil fertility and low application of external inputs are the two major reasons that account for low productivity of maize. The soils of the major maize growing areas in Ghana are low in organic carbon (<1.5%), total nitrogen (<0.2%), exchangeable potassium (<100 mg/kg) and available phosphorus (<10 mg / kg) (Adu, 1995).

Estimates showed negative nutrient balance for all crops in Ghana. Available nitrogen declines rapidly once cereal cropping is commenced, from O.2% (0.5 cm depth) to 0.04% after four years of maize cropping without addition of external input. Fertilizer nutrient application in Ghana is low, approximately 8 kg ha^{-1}. However, it has been reported that moist savanna soils require 15 kg N/ha and 2 kg P/ha for each tonne of maize grain produced (Van Keulen and Van Heemst, 1982; Lal, 1989; FAO, 2005).

2.6 Farming systems in Northern Region

The prevailing farming systems in northern region can be described generally as subsistence with low or minimum external input. The average field size is about 1.1 hectare (Albert, 1996). The main system of farming was shifting cultivation, which involves the mixed cropping of the drought resistant principal crops such as millet and guinea corn with yam, pulses, vegetables and other crops. This is done to minimize soil erosion, maintain ecological stability, optimize utilization of the different soil nutrients, and enhance food security and a balanced diet. This migratory farming system is now modified into Bush and Compound farming systems in response to the growing pressure on the land (Gyasi, 1995).

Compound farming is relatively permanent mixed cropping system centered on the home compound. Soil fertility is regenerated by techniques traditionally involving mainly refuse and manure from the livestock kept by virtually every household. The land immediately surrounding the compound is the most intensively cropped. Crops such as millet, guinea corn, maize and vegetables are usually grown. It is permanently cropped without fallow periods due to increasing population pressure (Gyasi, 1995).

The bush farming system involves intercropping among natural economic trees on a rotational basis 1 – 6 kilometers from the home compound. It comprises of lowland bush fallow farms, upland bush fallow, flood land and irrigated farming. The flood land and irrigated farming involves swamp rice cultivation in naturally flooded areas, artificial irrigation farming and vegetable farming in naturally moist valleys and other depressions. Maize, sorghum, millet, groundnut, cowpea and yam are usually grown in this system (Gyasi, 1995).

2.7 Nature of soils of Northern Region

The main geological formation of Northern Region is the Voltaian, comprising sandstone, shale and mudstone with a characteristic layer of ironstone at shallow depths (Bates, 1962). One major form of soil degradation in Ghana is the formation of plinthite, which hardens irreversibly to petroplinthite in upland agriculture soils (Asiamah, 2002).

Formation of plinthite is facilitated by the removal of vegetation cover, leading to erosion of top soil and subsequent enrichment of iron oxide, the main constituent of plinthite. Three broad groups of soils can be distinguished in northern region. These include the reddish well-drained upland sandy loams on the upper voltain sandstones where agricultural activity is mainly concentrated; the yellowish imperfectly drained sandy loams on slopes close to the valley bottoms; and in-situ alluvial soils of valley floors (Overseas Development Institute, 1999).

The upland soils are generally shallow and gravely with plinthite and iron stone. They occur as different soil units classified as Lixisols, Regosols, Leptosols, and Plinthosols. They are light textured at the surface and as a result they dry up quickly after rainfall. Additionally, most of the sub soils have impeded drainage. At the valley bottoms are various soil units namely, Vertisols, Gleysols and Fluvisols, which are deep and non-concretionary (Fosu, 1999).

Soils of northern region of Ghana have ranging pH values of 4.5 – 6.7, organic matter content of 0.6 – 2. 0%, total nitrogen of 0.02 – 0.05%, available phosphorus of 2.5 – 10 mg/kg of soil and Ca ranging from 45 - 90 mg/kg of soil (Soil Research Institute, 2001). Low organic matter level and phosphorus reserve, occurrence of plinthite and erodible sandy top soils make the soils inherently infertile. Soil fertility in northern Ghana has been on the decline in the last two decades (Abatania and Albert, 1993).

The causes are mainly attributed to bush burning, continuous cropping, monocropping and overgrazing. This has resulted in low crop yields: 0.5 – 1.0 tha^{-1} for maize, 0.75 - 1.0 tha^{-1} for sorghum and 0.2 – 0.5 tha^{-1} for groundnuts. The soils are characterized by widespread lateritic concretions (Owusu–Bennoah *et a*l., 1991; Abatania and Albert, 1993). In the top soil, there are only a few aggregates existing and therefore storage of plant available water in the soil is not only limited by an unfavorable pore size distribution but also by low infiltration. Having a low aggregate stability, they are extremely susceptible to surface sealing by rains and to soil erosion. However, during wet periods, these soils have the advantage of a good drainage (Hauffe, 1989).

2.8 Biomass transfer

The integration of trees in the conventional land use systems has one of its prime objectives as soil fertility maintenance. This is always looked at by considering several practices and systems and their associated benefits with minimum cost, ease of adaption and acceptability by farmers and within their environment. Biomass transfer is also called cut and carry mulching or tree-litter mulching. In this system, trees are grown as a separate block, possibly on less fertile parts of the farm. Leaf material is cut from the tree, transported and added to the crop land. The trees may be natural forest or planted and may have other productive functions. This system minimizes tree-crop competition, as there may be no tree-crop interface at all (Young, 1997).

Through the collection of biomass from the natural vegetation, this system is seen as an indigenous practice. In Nepal, leaves are gathered from natural forest and placed onto cropped terraces. In Zambia, farmers collect litter from *Brachystegia Julbernardia,* stall-fed to cattle and later applied the manure-litter mixture to crop fields (Nyathi and Campbell, 1993).

Biomass transfer allows trees to be grown on poorer soils on farms not suitable to crops, on poor drain sites and on stony hillsides. The trees can be managed in their own right- coppiced, pruned or allowed to grow tall. However, no benefit is obtained from dieback of roots. The utilization of marginal soils for biomass transfer to improve nutrient status of another site makes it a key factor for consideration in soil fertility maintenance and above all in soil management.

2.9 Effects of leave biomass application on the yield of crops

Litter production is a major process by which carbon and other nutrients are transferred from vegetation to the soil. A study report showed that tree/shrubs pruned at young stages and added to soils raised nutrient status of those soils compared to natural forest. Therefore, the results might be due to accumulated nutrients in the leaves at the young stage which were not translocated prior to harvesting. Hence, the stage of pruning is very crucial in biomass transfer for maximum benefits to the soil from green manuring. Litter quality determines the rate of decomposition and the release of nutrients from organic residues (Young, 1997).

Scientific trials involving biomass transfer have used planted fast-growing trees, mostly nitrogen-fixing. The species most commonly used are *L. leucocephala, G. sepium* and *S. sesban*. In contrast to hedgerow intercropping, *Leucaena* can be freely used in biomass transfer, because of the absence of competitive effects.

Large crop-yield increases are nearly always reported on biomass studies. In a trial at La Montana, Costa Rica, mean maize yields over a year on unfertilized plots increased from

2100 kg ha^{-1} on the un-mulched control to 2700 kg ha^{-1}, 2800 kg ha^{-1} and 3200 kg ha^{-1} for high rates of mulching with *G. sepium, Gmelina arborea* and *E. poeppigiana* respectively (Pinto *et al*., 1993).

In a two year trial involving biomass transfer of *Cajanus cajan* with maize in Bako Agricultural Research Center, Oromia Regional State Ethiopia, mulching with *Cajanus cajan* at rates of 2 t ha^{-1}, 4 t ha^{-1}, and 6 t ha^{-1} gave maize yields of 3208.5 kg/ha, 5279.15 kg/ha and 4802.88 kg/ha respectively (Abebe *et al*., 2005). In a three year biomass study in dry sub humid environment in Burkina Faso, plots were mulched with *A. indica* at three rates, corresponding to nitrogen applications of 25 kg ha^{-1}, 50 kg ha^{-1} and 75 kg ha^{-1}. The highest rate corresponded to 3.7 t ha^{-1}. Mean sorghum yields at the highest rate were 203%, 364% and 422% higher than those of the controls, with successive years (Tilander, 1993).

Additionally a trial with *Tithonia diversifolia* at five sites in Malawi revealed that the average yield of maize increased by 2.55 t/ha (216%) using 4.5 t/ha of biomass compared to the control plot (Ganunga and Kabambe, 2000). In Malawi, biomass transfer with *G. sepium* and *L. leucocephala* showed significant results and increased maize yields by 104% and 86% respectively (Chilimba *et al*., 2004). Also a reported yield increase of onion by 40 t/ha (183%) and 51 t/ha (143%) were obtained when 8 t/ha and 12 t/ha biomass of *G. sepium* was applied respectively. Similarly, the yields of cabbage was increased by 9 t/ha (145%), 6 t/ha (145%) for garlic and 7 t/ha (92%) for green maize when 8 t/ha *G. sepium* biomass was used (Mafongoya *et al*., 2006).

In a study to determine the effect of plant biomass, manure and inorganic fertilizer on maize yield in the central highlands of Kenya within four growing seasons; sole application of *Calliandra calothyrsus, Leucaena trichandra, Crotalaria ochroleuca,* and *Tithonia diversifolia* gave significantly ($p \leq 0.05$) higher maize grain yields than the control. These treatments gave maize yields of 3.2 t ha^{-1}, 2.6 t ha^{-1}, 1.4 t ha^{-1}, and 2.8 t ha^{-1} respectively compared to the control value of 1.2 t ha^{-1} (Mugwe *et al.*, 2007). Similarly, applying a 'cake' of *A. indica* blended with urea granules significantly increased cane yield on an alluvial soil in Bihar, India (Yadav and Singh, 1991).

Conversely, applying 80 kg N ha^{-1} of fertilizer and *Leucaena* leaves in Chandigarh, India, showed no clear differences in maize yield (Mittal *et al*., 1992). Contrastingly, in a trial with wheat in Pakistan, *Leucaena* prunings were more effective than equivalent nitrogen, phosphorus and potassium rates applied as fertilizer (Hussain *et al*., 1988). However, in a pot trial, 5 t ha^{-1} of *S. sesban* had the same effect as 75 kg ha^{-1} inorganic nitrogen (Gutteridge, 1992), and Similarly; application of 10 t ha^{-1} of fresh *Leucaena* prunings had the same effect on maize yield as the addition of 100 kg N ha^{-1} (Kang *et al.*, 1981).

In an on farm research, green manure from *Tithonia* and *Lantana* were applied to a cropping area at rates of 5, 10, and 20 tonnes per hectare. Other plots were treated with commercial fertilizer (NPK) at 12.5, 25 and 50 kilogram per hectare. Control plots received neither fertilizer nor green manure. The increase in maize yields in response *to Tithonia* or *Lantana* application was significant compared to the control. Plots with commercial fertilizer (NPK) had maize yields of 250 - 300 kilograms per hectare higher than the control plot but where *Tithonia* or *Lantana* was applied, maize yields were more than 1000 kilogram per hectare higher than the control plot. After it had been applied, the residual or lasting effect of this biomass transfer increased yields into the next succeeding seasons after application (Wanjau *et al.*, 1997).

Residual effects in some trials have contributed to crop yield. In a *Leucaena* versus fertilizer trial at Chandigarh, India, residual effects on wheat yield were attributed to better soil physical conditions from organic mulch (Mittal *et al*., 1992). Most of the nutrient released through the short term path of litter decomposition are taken up by crops or lost by leaching in the year of application. As such the residual effect could arise either from improvement of soil physical conditions or delayed nutrient release from partly humified organic matter. The potentials for residual yield improvement are important, since it decreases the land requirement of the biomass transfer system (Young, 1997).

An eight-year alley cropping trial in Southern Nigeria showed that using *L. leucocephala* prunings only, could maintain maize yield at a "reasonable" level of 2 t ha^{-1}, as against 0.66 t ha^{-1} without *Leucaena* prunings and fertilizer. Supplementing the prunings with 80 kg N ha^{-1} increased the maize yield to over 3.0 t ha^{-1} (Kang *et al*., 1990 cited by Nair, 1993). Furthermore, to increase the yield of maize alley cropped with *Cassia siamea, G. sepium*, and *F. macrophylla* to an acceptable level, addition of nitrogen was recommended (Yamoah *et al.* 1986 cited by Nair, 1993).

2.10 Nutrients composition of multipurpose trees and shrubs

Multipurpose trees and shrubs refers to trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service; the retention or cultivation of these trees is usually economically but also sometimes ecologically motivated, in a multiple-output land-use system. Alternatively, it refers to the use of trees for more than one service or production function in an agroforestry system (Burley and Wood, 1991).

Most of the plants used for green manure, improved fallows, and even for improved animal manure production are leguminous species. Under favourable conditions, they can provide a practical way of securing nitrogen supply via biological nitrogen fixation. There is, however, evidence that several non-leguminous plants accumulate as much nitrogen in their leaves as legumes and also have very high levels of phosphorus. This is most probably because these, often indigenous, species are better adapted to the area, have a greater root volume and a special ability to recover scarce nutrients from the soil. When their biomass is transferred from where it has been produced to where it can be used it provides extra nutrient input of great benefit to crop producers (Wanjau *et al.*, 1997).

A number of multipurpose trees/shrubs have been used in biomass transfer. These include *Acacia mangium*, *Gliricidia sepium*, *Leucaena leucocephala*, *Acacia auriculiformis*, *Gmelina arborea*, *Calliandra calothyrsus*, *Cassia siamea*, *Flemingia macrophylla*, and *Tithonia diversifolia*. Tree prunings, which consist mostly of leaves and woody parts of many woody perennials used, have high amounts of nutrients (Nair, 1993). These prunings, when applied to the field, results in increased available nitrogen levels for the associated crops. A number of laboratory studies has confirmed that, tree prunings are generally high in nutrients especially nitrogen (Table 2.10).

Table 2.10: Nutrient content of some multi-purpose trees and shrubs pruning's

Tree species	Nutrient concentration (%)					Source
	N	P	K	Ca	Mg	
Alchornea cordifolia	3.29	0.23	1.74	0.46		Kang *et al*., 1984
Gliricidia sepium	4.21	0.29	3.43	1.40		Kang *et al*., 1984
Leucaena leucocephala	4.33	0.28	2.5	1.49		Kang *et al*., 1984
Dactyldenia barteri	2.57	0.16	1.78	0.90		Wilson *et al*., 1986
Erythrina poeppigiana	3.3	0.18	1.16	1.52		Russo and Budowski, 1986
Inga edulis	3.1	0.2	0.9	0.7		Szott *et al*., 1991
Cassia siamea	2.52	0.27	1.35			Nair, 1993
Acacia auriculiformis	2.29	0.10	1.10	1.46	0.22	Giashuddin *et al*., 1993
Acacia mangium	2.04	0.14	1.18	0.93	0.23	Giashuddin *et al*., 1993
Tithonia diversifolia	3.2	0.2	3.0	2.1	0.6	Mugwe *et al*., 2007
Calliandra calothyrsus	3.3	0.2	1.2	1.0	0.4	Mugwe *et al*., 2007
Leucaena leucocephala	3.6	0.2	1.8	1.4	0.4	Mugwe *et al*., 2007

Tilander (1993) reported nutrient content of 2.0% N, 0.076% P, and 1.7% K for *A. indica* and 2.8% N, 0.11% P, and 1.3% K for *Albizia lebbeck*. Also, a study reported that although *Tithonia diversifolia* is not a legume, the fresh leaf biomass has levels of N as high as those found in N-fixing legumes. *Tithonia diversifolia* is also rich in P and K.

The fresh leaves contain 3.5% N, 0.3% P and 3.8% K (Gachengo, 1996). Thus, the phosphorus levels in the shrub are about 0.15% - 0.20% higher than those found in legumes commonly used in agroforestry (Palm, 1995).

2.11 Effects of biomass on soil

Leave biomass has been reported to have many positive effects in tropical agriculture in general. For example, it can ensure the slow and continuous release of nutrients (Budelman, 1988), increase P availability (Hagger *et al.*, 1991), conserve soil moisture, reduce soil temperature fluctuations, prevent weed seed germination (Tilander, 1993) and decrease soil erosion (Young, 1989).

Because of soil variability and time required, there are only limited data on soil changes resulting from tree-litter biomass mulching. Most results have either been neutral (no change over time or no difference from control) or positive. At Turrialba, Costa Rica, there were no significant differences between soil properties under controls and heavily mulched plots of three species over nine years, although the mulch treatments had given consistently higher yields. Thus this can be taken as evidence of sustainability (Pinto *et al.*, 1993).

In a semiarid climate in Burkina Faso, 2 years of mulching with *A. indica* and *A. lebbeck* produced small but significant improvements in soil organic matter, nitrogen and potassium (Tilander, 1993). The most frequently observed beneficial effects involve soil organic matter and properties dependent upon it: physical properties and organic nitrogen. After 9 years in Costa Rica, soil carbon and nitrogen were higher under hedgerow systems (Mazzarino *et al*., 1993).

The effects of alley cropping with *Leucaena leucocephala* and incorporation of its prunings on the phosphorus status of an andosol at Mbeya, Rwanda, were studied. The results of soil analysis over a period of 11 years indicated plots receiving *L. leucocephala* prunings in combination with nitrogen fertilizer had organic matter content significantly higher than the control plots (Mnkeni *et al*., 1995).

In on-station and on-farm trials at Ibadan, Nigeria; soil carbon, nitrogen and phosphorous increased in proportion to volume of prunings applied (Larbi *et al*., 1993). One of the clearest positive results comes from Malawi, where after 3 years of intercropping with four hedge species, soil properties related to organic matter were much improved, as compared with controls. The crop control had organic carbon, total nitrogen and cation exchange capacity values of 0.87%, 0.05% and 6.13m.e.% respectively while the hedgerow treatments also had organic carbon, total nitrogen and cation exchange capacity values ranging from 1.02% - 2.01%, 0.07% - 0.08% and 9.24 - 21.6m.e.% respectively (Khonje, 1989 cited by Young 1997).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The study was conducted in Tolon/Kumbungu District in the Northern Region of Ghana. The District is located in the Guinea Savanna Zone and lies between latitude 10° -20° N and, longitude 10° - 50° W. The characteristic vegetation of the Guinea Savanna Zone consists of short deciduous, widely spaced, fire- resistant trees. These do not form a closed canopy and overtop an abundant ground flora of grasses and shrubs of varying heights (Taylor, 1952). The raining season is monomodal, starting in April or May and ending in October, with an annual rainfall varying between 900 to 1100 mm (Tsigbey and Clottey, 2003).

3.2 Socio – economic survey

A purposive sampling technique was used to determine the presence, use and management of Neem in the District. Sixty farmers were interviewed using semi structured questionnaire in twenty communities. Three farmers were interviewed from each community. The survey instrument for the farmers considered questions under farmers' personal information (age, educational level, sex, and marital status), farmers knowledge on the type of organic manure they use, types of crops grown, locations, uses and management of Neem, benefits, and reasons for pruning Neem.

3.3 Field experimentation

3.3.1 Experimental site

The study was carried out on the research field of Savanna Agricultural Research Institute, (SARI) Nyankpala. The land has a gentle slope of about 2% and it's strongly disturbed by sheet erosion. It is a well drained Voltaian sandstone soil unit locally referred to as *Tingoli* series, classified as ferric Luvisol (FAO/UNESCO, 1997). The climate of Nyankpala is warm, semi-arid with monomodal annual rainfall varying between 900 to 1100 mm, starting from April or May and ending in October. This is then followed by five or six months of dry season, which is characterized by the dry Hamattan winds with high risk of uncontrolled bushfires resulting in the loss of vegetative cover of the soil. The average monthly atmospheric temperatures range from a minimum of 26 °C to a maximum of 39 °C with an annual mean of 32 °C.

3.3.2 Experimental design and procedure

A field experiment was conducted on the research field of Savanna Agricultural Research Institute (SARI) to determine the effect of different levels of *A. indica* biomass with and without fertilizer on maize grain yield. The land was ploughed and harrowed with tractor. *Azadirachta indica* leaves were harvested from a Neem plantation near the SARI research field. The fresh weight of these leaves was determined. Leave samples were oven dried to constant weight.

Moisture content was determined to be 40% and was then factored into quantities of treatments applied. The treatments were applied based on 2.07% of nitrogen content in neem leaves biomass. Leaves were applied on dry matter basis. Leaves were evenly spread over the plots and slightly incorporated by hoeing at time of planting. Planting was done on the 31st of July 2010 using the Maize variety Obatampa with 2 seeds per hill at a spacing of 0.3 m x 0.9 m with plant population per hectare of 74074.

The inorganic fertilizer, N P K (15: 15:15), was applied two weeks after planting. Weeding was done 3 weeks after planting and when necessary manually with a hoe. There were six treatments with four replicates in a randomized complete block design. A plot size was 5 m x 5 m with 2 m spaces between plots and 3 m between blocks. The total plot size was 1,160m^2. A layout of the experiment is shown in figure 3.1.

The treatments were;

T1- 6t/ha of neem leave biomass

T2-3t/ha of neem leave biomass

T3 -120kg N ha^{-1} of NPK fertilizer

T4-3t/ha of neem leave biomass+60kg N ha^{-1} of NPK fertilizer

T5-4t/ha of neem leave biomass+ 40kg N ha^{-1} of NPK fertilizer

T6- Control with no inputs

Plot 1 T3	Plot 1 T5	Plot 1 T6	Plot 1 T2
Plot 2 T5	Plot 2 T1	Plot 2 T4	Plot 2 T1
Plot 3 T2	Plot 3 T4	Plot 3 T5	Plot 3 T6
Plot 4 T1	Plot 4 T2	Plot 4 T1	Plot 4 T4
Plot5 T4	Plot 5 T3	Plot 5 T3	Plot 5 T5
Plot 6 T6	Plot 6 T6	Plot 6 T2	Plot 6 T3
BLOCK I	BLOCK II	BLOCK III	BLOCK IV

Figure 3.1: Field layout of the experimental plots.

3.3.3 Data collection

Data was collected on plant height and maize yield using plants in the middle rows (harvestable area) of each plot. Plant height at harvest was measured from the base of the plant to the flagship leaf using a linear tape. Five different plants were sampled in each plot for data collection. Plants with the same treatments but in different blocks were added which gave sampled plants of twenty (20) in each of the treatments. Maize grain yield was determined for the one growing season. The crop was harvested in November 2010, from a harvestable area of 3m x 3m per plot. The maize cobs were shelled after harvesting and the grains were sun dried for three days. Samples of the sun dried grains were collected in equal weight and dried in an oven at 60 ºC to a constant weight. Soil chemical properties such as OC, N, P, K, Ca, Mg, pH and foliar nutrients content such as N, P, K, Ca, Mg were determined in the laboratory.

3.4 Foliar sampling and analysis of *A. indica*

To determine the nutrient content of *A. indica*; foliage samples were taken from Neem plantation near Savanna Agricultural Research Institute (SARI) research field. Foliage biomass (young and matured) was collected from four different trees. On each tree, samples were taken from four different compass directions. Samples from each tree were bulked into one composite sample. The four samples collected, were taken to Savanna Agricultural Research Institute (SARI) laboratory where N, P, K, Ca and Mg in the biomass were determined using methods described in sections 3.4.1.

3.4.1 Laboratory analysis

Nitrogen

Total nitrogen was determined by the Kjeldahl method in which plant material was oxidised by sulphuric acid and hydrogen peroxide with selenium as a catalyst. The nitrogen present was converted into NH_4^+. The ammonium ion, which reacts with the excess of sulphuric acid to form ammonium sulphate, was distilled off in an alkaline medium into boric acid.

$$NH_3 + H_3BO_3 \longrightarrow NH_4^+ + H_2BO_3^- . \qquad \text{Equation 3.1}$$

The $H_2BO_3^-$ that was formed was titrated with standard hydrochloric acid back to H_3BO_3.

About 20 g oven-dried plant samples was ground in a stainless steel hammer mill with a sieve mesh of 0.5 mm, and mixed well to ensure homogeneity. Following this, 0.5 g plant sample was digested in a 10 ml concentrated sulphuric acid with selenium mixture as a catalyst. The clear digest obtained was transferred into a 100 ml conical flask and made to the mark with distilled water. Five millilitres each of a blank and sample were pipetted separately into the Kjeldahl distillation apparatus. To this, 5 ml solution of 40 % sodium hydroxide was added and distilled. Ammonia evolved was trapped in a 25 ml of 2 % boric acid-indicator solution. The ammonium borate formed was titrated with 0.1 *N* HCl with bromocresol green-methyl red indicator to determine the amount of nitrogen in the sample.

Calculation:

$$\% \text{ N/DM} = \frac{(a-b) \times M \times 1.4 \times \text{mcf}}{w} \qquad \text{Equation 3.2}$$

Where

a = ml 0.1 M HCl used for sample titration

b = ml 0.1 M HCl used for blank titration

M = Molarity of HCl

1.4 = 14 × 0.001 × 100% (14 = atomic weight of nitrogen)

w = weight of sample in mg.

Phosphorus

A 5.0 ml aliquot of the filtrate above was taken into a 25 ml volumetric flask. Following this, 5.0 ml of ammonium vanadate solution and 2.0 ml stannous chloride solution were added and made to the 25 ml mark with distilled water. The solution was allowed to stand for 10 minutes for full colour development. A standard curve was developed concurrently with phosphorus concentrations ranging from 0, 1, 2, 5, 10 to 20 mg P per kg. The absorbance of the sample and standard solutions were read on the spectrophotometer (Spectronic 21D) at a wavelength 470 nm. A standard curve was obtained by plotting the absorbance values of the standard solutions against their concentrations. Phosphorus concentration of the samples was determined from the standard curve.

Potassium

Potassium in the ash solution was determined using a Gallenkamp flame analyser. Potassium standard solutions were prepared using the following concentrations: 0, 10, 20, 40, 60 and 100 mg K per litre of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission values against their respective concentrations.

Calcium and Magnesium

A 10.0 ml aliquot of the ash solution was put in an elementary flask. Potassium cyanide and potassium ferrocyanide solutions were added to complex (remove) interfering cations Cu and Fe. In calcium + magnesium determination, the solution was titrated with 0.01 M EDTA solution in the presence of Eriochrome Black T murexide indicator. To determine calcium content, potassium hydroxide was added to raise the pH to about 12. At this pH magnesium, is precipitated leaving calcium in solution. The solution was titrated again with EDTA using as the murexide indicator. The difference between the first and the second titrates represents magnesium concentration in the solution.

3.5 Soil sampling and analysis

Soils were sampled before planting and after harvesting. The soil samples were collected from 0 -15 cm depth of profile from all plots using an Eldelman auger. Five sub samples were collected from each plot and were mixed thoroughly to obtain composite samples. This resulted in 6 composite samples for the treatments. The samples were air dried and crushed in a mortar using a porcelain-capped pestle. The crushed and pulverized soil was sieved through a 2 mm sieve and stored in clean labeled containers for subsequent analysis. Soil chemical properties N, P, K, Ca, Mg, pH and Organic Carbon were determined at Savanna Agricultural Research Institute laboratory.

3.6.1 Laboratory analysis

Soil pH

Soil pH was determined using a H1 9017 Microprocessor pH meter in a 1:2.5 suspension of soil and water. A 20 g soil sample was weighed into plastic pH tube to which 50 ml water was added from a measuring cylinder. The suspension was stirred frequently for 30 minutes. After calibrating the pH meter with buffer solutions at pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

Soil organic carbon

A modified Walkley and Black procedure was used in the determination of organic carbon (Nelson and Sommers, 1982). One gram of soil sample was weighed into an Erlenmeyer flask. Included too were a reference sample and a blank. Ten milliliters of 1.0 *N* (0.1667*M*) potassium dichromate was added to the sample and the blank flasks. Concentrated sulphuric acid (20 ml) was carefully added to soil from a measuring cylinder, swirled and allowed to stand for 30 minutes in a fume cupboard. Distilled water (250 ml) and 10 ml concentrated orthophosphoric acid were added and allowed to cool. A diphenylamine indicator (1 ml) was then added and titrated with 1.0 m ferrous sulphate solution.

Calculation

The organic carbon content of the soil was calculated as:

$$\%\ \text{Organic carbon} = \frac{M \times 0.39 \times \text{mcf} \times (V_1 - V_2)}{w}$$ Equation 3.3

Where

M = molarity of ferrous sulphate

V_1 = ml ferrous sulphate solution required for blank

V_2 = ml ferrous sulphate solution required for blank

w = weight of air – dry sample in gram

mcf = moisture correcting factor (100 + % moisture) / 100)

0.39 = 3 × 0.001 × 100% × 1.3 (3 = equivalent weight of carbon, 1.3 = Compensation factor for incomplete oxidation of the organic carbon)

Total nitrogen

This was determined by the Kjeldahl digestion and distillation procedure. A 0.5 g soil sample was weighed into a Kjeldahl digestion flask. To this 5 ml distilled water was added. After 30 minutes, concentrated sulphuric acid (5 ml) and selenium mixture were added and mixed carefully.

The sample was then digested for 3 hours until a clear digest was obtained. The digest was diluted with 50 ml distilled water and mixed well until no more sediment dissolved and allowed to cool. The volume of the solution was made to 100 ml with distilled water and mixed thoroughly. A 25 ml aliquot of the solution was transferred to the reaction chamber and 10 ml of 40 % NaOH solution added followed by distillation. The distillate was collected in 2.0 % boric acid and was titrated with 0.02 *N* HCl using bromocresol green as indicator. A blank distillation and titration was also carried out to take care of the traces of nitrogen in the reagents as well as the water used.

Calculation:

The % N in the sample was expressed as:

$$\% \mathrm{N} = \frac{N \times (\mathrm{a} - \mathrm{b}) \times 1.4 \times \mathrm{mcf}}{\mathrm{w}} \qquad \text{Equation 3.4}$$

Where

N = concentration of HCl used in titration

a = ml HCl used in sample titration

b = ml HCl used in blank titration

w = weight of air-dry soil sample

mcf = moisture correcting factor (100% + moisture)/100)

1.4 = 14 × 0.001 × 100% (14 = atomic weight of N)

Available phosphorus (Bray's No. 1 phosphorus)

The available phosphorus was extracted with Bray's No. 1 extraction solution (0.03 *M* NH_4F and 0.025 *M* HCl. Phosphorus in the extract was determined by the blue ammonium molybdate method with ascorbic acid as the reducing agent using a 21 D spectrophotometer. A 5 g soil sample was weighed into a shaking bottle (50 ml) and 35 ml of extracting solution of Bray's No. 1 added. The mixture was shaken for 10 minutes on a reciprocating shaker and filtered through a Whatman No. 42 filter paper. An aliquot 0f 5 ml of the blank, the extract, and 10 ml of the colouring reagent (ammonium molybdate and tartarate solution) were pipetted into a test tube and uniformly mixed. The solution was allowed to stand for 15 minutes for the blue colour to develop to its maximum. The absorbance was measured on a spectronic 21 D spectrophotometer at a wavelength of 660 nm at medium sensitivity. A standard series of 0, 1,2,3,4 and 5 mg P/1 was prepared from 20 mg/1 phosphorus stock solution.

Calculation:

$$\text{P (mg/kg soil)} = \frac{(a-b)\times 35\times 15\times \text{mcf}}{w} \qquad \text{Equation 3.5}$$

Where

a = mg/1 P in sample extract

b = mg/1 P in blank

mcf = moisture correcting factor

35 = ml extracting solution

15 = ml final sample solution

w = sample weight in gram

Exchangeable cations

Exchangeable bases (calcium, magnesium, and potassium) in the soil were determined in 1.0 *M* ammonium acetate extract. A 5 g soil sample was weighed into a leaching tube and leached with 100 ml buffered 1.0 *M* ammonium acetate solution at pH 7

Calcium and Magnesium

To analyze for calcium and magnesium, a 25 ml aliquot of the extract was transferred into an Erlenmeyer flask. To this were added 1 ml portion of hydroxylamine hydrochloride, 1 ml of 2.0 % potassium cyanide, 1 ml of 2.0 % potassium ferrocyanide, 10 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution.

The solution was titrated with 0.01 *M* EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour. A 25 ml aliquot of the extract was transferred into a 250 ml Erlenmeyer flask and the volume made up to 50 ml with distilled water. Following this, were added 1 ml hydroxylamine, 1 ml of 2.0 % potassium cyanide and 1 ml of 2.0 *M* potassium ferrocyanide solution. After a few minutes, 5 ml of 8.0 *M* potassium hydroxide solution and a spatula of murixide indicator were added. The resultant solution was titrated with 0.01 *M* EDTA solution to a pure blue colour.

Calculation:

$$\text{Ca} + \text{Mg}\,(\text{or Ca})\ (\text{cmol/kg soil}) = \frac{0.01 \times (\text{Va} - \text{Vb}) \times 1000}{\text{w}} \qquad \text{Equation 3.6}$$

Where

w = weight (g) of air – dried soil used

Va = ml of 0.01 *M* EDTA used in sample titration

Vb = ml of 0.01 *M* EDTA used in blank titration

0.01 = concentration of EDTA

Exchangeable potassium

Potassium (K) in the leachate was determined by flame photometry. A standard series of potassium was prepared by diluting 1000 mg/1 solution to 100 mg/1. In doing this, 25 ml portion of solution was taken into 250 ml volumetric flask and made up to the volume with distilled water. Portions of 0, 5, 10, 15, 20 ml of the 100 mg/1 standard solution was put into 200 ml volumetric flask. One hundred millilitres of 1.0 *M* NH_4OA_C solution was added to the flask and made to volume with distilled water. This resulted in standard series of 0, 2.5, 5.0, 7.5 and 10 mg/1 for K. Potassium was measured directly in the leachate by flame photometry at wavelength of 766.5.

Exchangeable K (cmol/kg soil) = $\frac{(a-b) \times 250 \times mcf}{10 \times 39.1 \times w}$ Equation 3.7

Where

a = mg/1 K or Na in the diluted sample percolate

b = mg/1 K or Na in the diluted blank percolate

w = weight (g) of air-dried sample

mcf = moisture correcting factor

3.6 Data analysis

The data collected from the socio - economic survey was examined from the completed questionnaires through quality control measures such as sorting, editing, and coding to identify and eliminate errors, omissions, incompleteness and general gaps in the collected data. The refined data were analyzed using Statistical Package for Social Sciences (SPSS) and Excel, to facilitate data description and analysis. Descriptive statistics such as cross tabulation and frequencies were employed to summarize and present the quantitative aspect of the data in the form of tables, and chats. The qualitative aspect of the data was summarized in the form of text, quotes and extracts.

The quantitative data obtained from the soil parameters, height and yield of maize were subjected to Analysis of Variance (ANOVA) using GENSTAT to test the effect of different treatments on maize height and yield. Furthermore, quantitative data from the foliar analysis were analyzed using Excel and results presented in tables.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socioeconomic survey

Demography of respondents

Majority (85%) of the respondents were men while (15%) were women with age's ranging from 30 - 60 years. None had tertiary education, with majority (60%) of them having no formal education. Ten percent (10) had primary education, 20% had middle school level certificate and 10% had Junior Secondary School education (Table 4.1).

Table 4.1: Demography of respondents in Tolon/Kumbungu District of Northern Region

Characteristics	No. of respondent (N=60)	Percentage (%)
Sex		
Male	51	85
Women	9	15
Education level		
Primary level	6	10
Middle school level	12	20
Junior secondary school	6	10
None	36	60

N represents total number of respondents for each demographic data.

The location of Neem (*Azadirachta indica*)

Azadirachta indica (Neem) locations in the district were classified into two groups. These are on farmland, and infront of houses. The study showed that 40% of Neem in the district were located on farmland while 60% were located infront of houses (Figure 4.1).

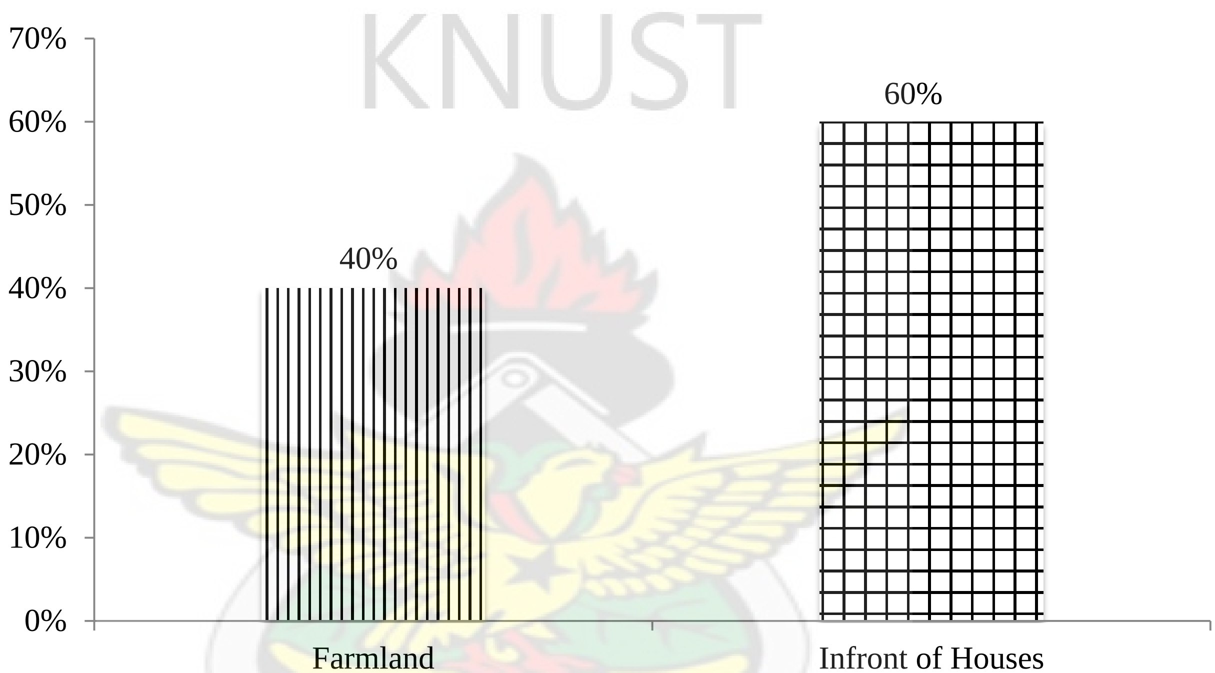

Figure 4.1: The Locations of Neem in Tolon/ Kumbungu District of Northern Region.

Uses and management of *Azadirachta indica*

Main uses of Neem in the district were generally classified as service use (soil fertility, shade), products use (timber, fuel) and amenities (recreation). The study revealed that 48% of farmers use organic manure while 52% of them do not use organic manure (Table 4.2). Out of the number who uses organic manure, 22% use animal manure while 26% use plant manure.

The animal manure used was poultry and livestock droppings. The plant manure is mostly crop residues left after harvest. Organic manure is mostly applied to agricultural crops including: cereals, vegetables and other crops. About 45% of farmers use organic manure on cereals while 10% use it on both vegetables and cereals, 21% on vegetables only and 24% use it on other crops. On the use of Neem biomass as organic manure, 23% of farmers use Neem as organic manure while 77% of farmers do not use it. However majority of farmers (80%) knew it potential usage as organic manure while 20% were not aware of its organic manure potential.

The high awareness on the potential usage of Neem biomass as organic manure among farmers accompanied with its low usage in the district could be attributed to the timming of pruning. Pruning is mostly done in the dry period where poles are used for construction (roofing) purposes at which period there are no farming activities. Other uses of Neem in the district include poles, fuel wood, shade and Neem seed oil. On tree management, the main management technique employed is pruning. Pruning frequency ranges from once per year to once in 2 years. Fifty seven percent of farmers prune Neem for only poles, 38% for both poles and fuel wood and 5% prune for both poles and growth enhancement (Fig 4.2).

Table 4.2: Uses and management of Neem in Tolon/Kumbungu District

Characteristics	Response
Organic manure use	
Yes	29 (48%)
No	31 (52%)
Type of organic manure used	
Animal manure	13 (22%)
Plant manure	16 (26%)
Crops which organic manure is applied	
Cereals	13 (45%)
Vegetables and cereals	3 (10%)
Vegetables	6 (21%)
Others	7 (24%)
Use of Neem biomass as organic manure	
Yes	14 (23%)
No	46 (77%)
Knowledge on Neem biomass as organic manure	
Yes	48 (80%)
No	12 (20%)
Benefits of Neem tree	
Poles	20 (33%)
Fuelwood	15 (25%)
Shade	10(17%)
Stakes	10 (17%)
Neem seed oil	5 (8%)
Frequency of pruning	1 per year –1 per 2 years

Percentage values in parenthesis

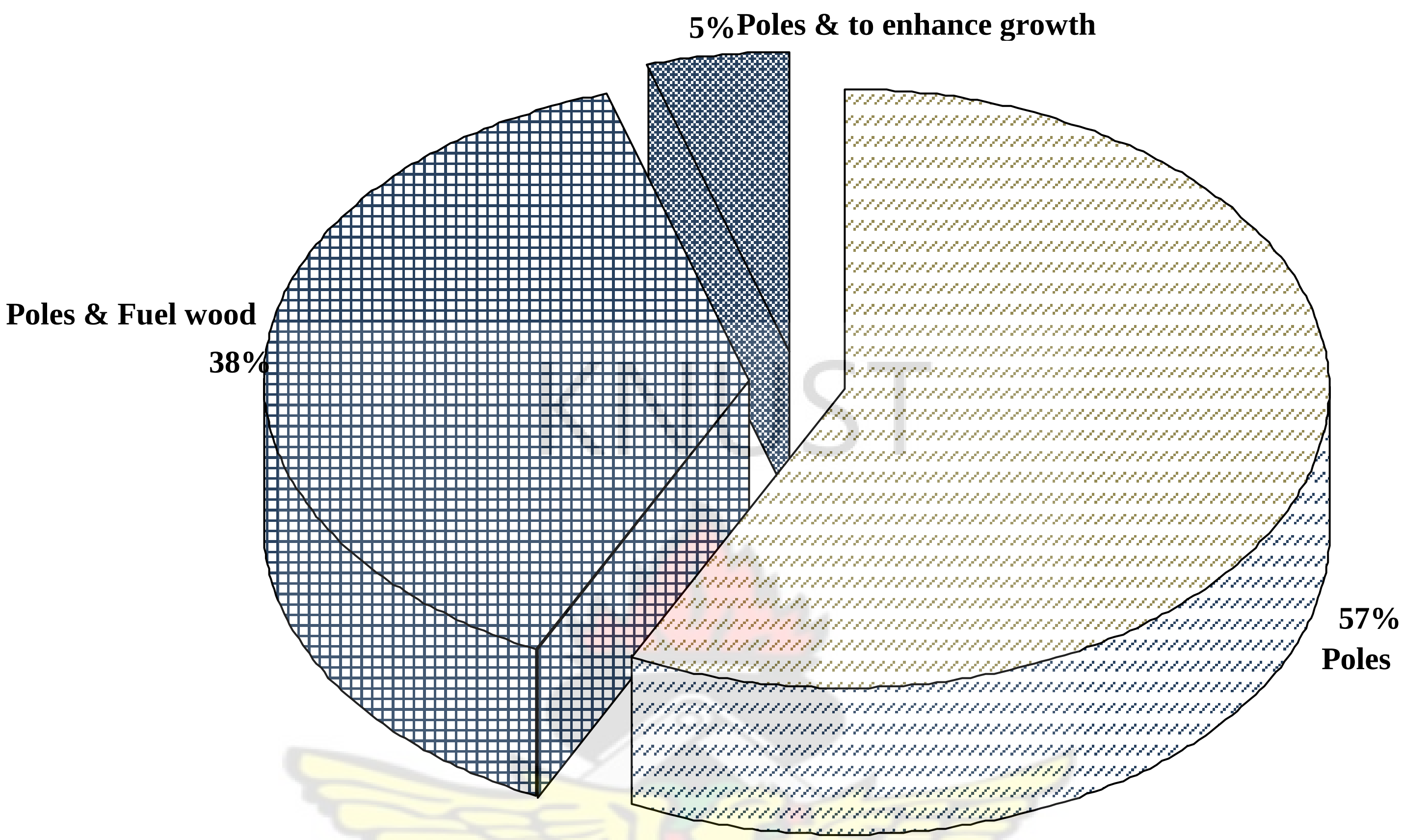

Figure 4.2: Reasons for pruning Neem in Tolon/kumbungu District.

4.2 Laboratory and field studies

4.2.1 Rainfall

The amount of rainfall recorded during the experimental period and its distribution are presented in Figure 4.3. Total amount of rainfall received was 1,348.5 mm. Rainfall amounts varied with the months. The highest rainfall 330.8 mm was recorded in August. April, June to October were the wetter months of the year while the rains commenced in February. November, December and January recorded no rains.

4.2.2 Chemical composition of Neem leaves

Table 4.3 shows the mean nutrient composition of Neem leaves applied. Nitrogen level was 2.07%, 0.12% for total P and 0.20% for Exchangeable K. Also Calcium and Magnesium values were 0.61% and 0.22% respectively. Although, not a leguminous tree, an appreciable nitrogen level of 2.07% was obtained which is similar with the findings of Tilander (1993) who reported 2.0% of nitrogen level in Neem leaves. However, the P and K values were different from the report of Tilander (1996) who reported 0.076% and 1.7% for P and K respectively. Besides, the Mg value obtained (0.22%) was consistent with the findings of Giashuddin *et al*.,(1993) when *Acacia auriculiformis* was tested while the Ca value (0.61%) was almost similar to the report of Szott et al., (1991) who reported Ca value of 0.7% for Inga edulis.

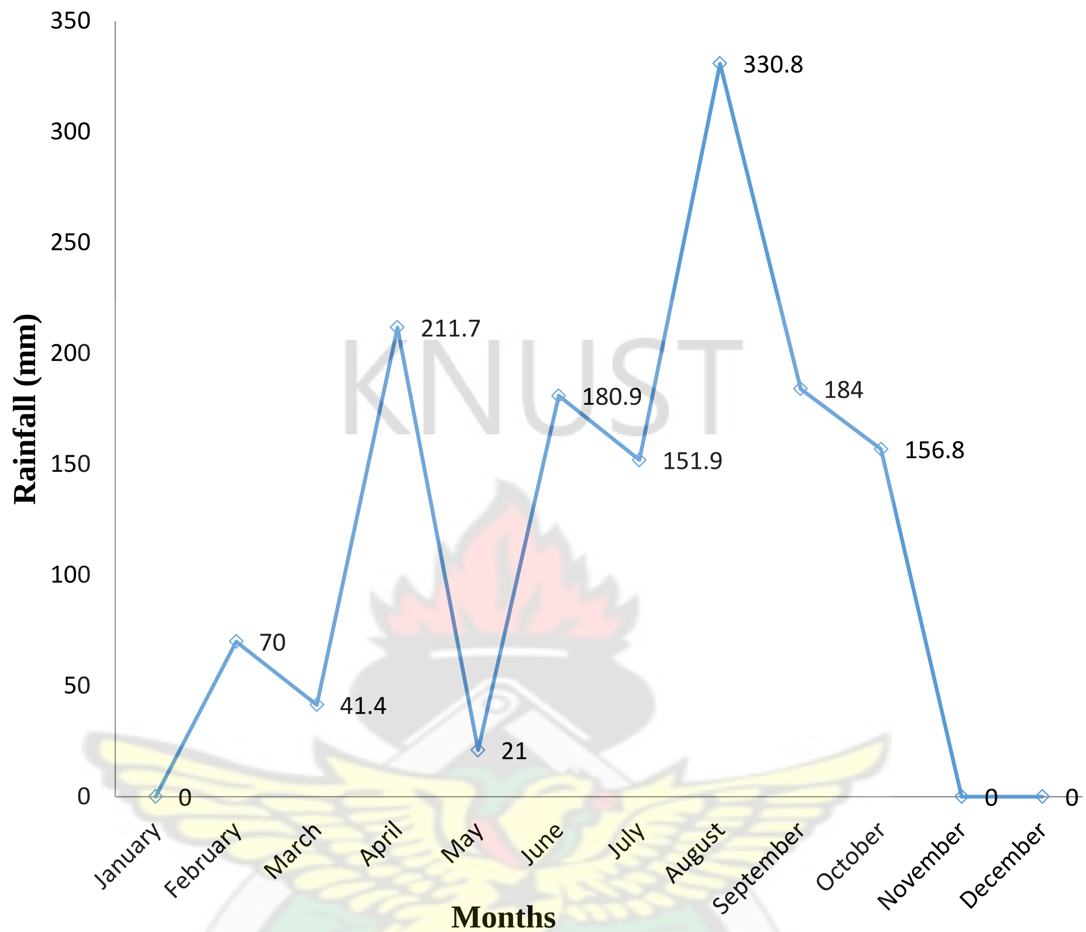

Figure 4.3: Rainfall pattern for the experimental site from January - December 2010

The focus of soil fertility research in recent years have shifted towards the combined application of organic and inorganic nutrient sources to reverse the negative nutrient balances in cropping system in agriculture in Sub-Saharan Africa (Vanlauwe et al., 2001). While mineral fertilizers supply plant nutrients, organic residues are a precursor of soil organic matter which maintains the physico-chemical properties of soil contributing to soil fertility such as cation exchange capacity and soil structure.

Organic materials differ considerably in their ability to supply nutrients to the soil and crop. These differences are controlled in part by the resource quality of the material. The analysis of *Azadirachta indica* in this study indicates that they contain nutrients which suggest their suitability for soil fertility management.

Table 4.3: Comparison of nutrient composition of Neem and other multipurpose trees

Tree species	Nutrients Concentration (%)					Source
	N	P	K	Ca	Mg	
Azadirachta indica	2.07	0.12	0.20	0.61	0.22	
Alchornea cordifolia	3.29	0.23	1.74	0.46		Kang *et al*., 1984
Dactyldenia barteri	2.57	0.16	1.78	0.90		Wilson *et al.*, 1986
Erythrina poeppigiana	3.3	0.18	1.16	1.52		Russo and Budowski1986
Cassia siamea	2.52	0.27	1.35			Nair, 1993
Acacia auriculiformis	2.29	0.10	1.10	1.46	0.22	Giashuddin *et al.*, 1993
Acacia mangium	2.04	0.14	1.18	0.9	0.23	Giashuddin *et al.*, 1993

4.2.3 Soil chemical properties

The pH of the initial soil was slightly acidic with a value of 5.97. Organic carbon, available P and K values were 0.81 %, 7.04 mg/kg and 41.55 mg/kg respectively and total nitrogen was 0.071 %. Calcium and Magnesium values recorded were 142.45 mg/kg and 60.36 mg/kg respectively (Table 4.4).

Soil chemical properties of the treated plots after harvest showed no significant improvement (Appendix 3) in soil nutrients after harvest relative to the initial levels (Table 4.4). Soil pH (5.81-6.35) remained slightly acidic. Total nitrogen (0.046% - 0.086%) was very low while organic carbon (0.54% - 0.93%) and available phosphorus (3.44mg/kg - 4.76mg/kg) were low after harvest. Available Potassium ranged from low–moderate. No significant increase in Mg and Calcium values was obtained for all the treatments. The results is in agreement with results which indicated that, the soils of the major maize growing areas in Ghana are low in organic matter (< 1.5%), total nitrogen (< 0.2%), available potassium (< 100mg/kg) and available phosphorus (< 10mg/kg) (Adu, 1995).

Table 4.4: Chemical properties of the surface soil at 0-15cm before and after harvest

Treatments	Nutrient Concentration					
	pH (H_2O)	%O.C	%N	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
Initial soil	5.97	0.81	0.071	7.04	41.55	142.45	60.36
T 1	5.81	0.58	0.049	3.56	62.51	188.94	60.87
T 2	6.35	0.54	0.046	3.44	53.89	168.53	58.98
T 3	6.05	0.62	0.053	3.78	84.27	111.36	59.68
T 4	5.93	0.89	0.076	4.50	42.52	158.67	94.56
T 5	5.99	0.62	0.059	3.87	96.35	144.59	74.52
T 6	6.12	0.93	0.086	4.76	81.69	156.42	90.68
LSD Values	0.80	0.49	0.05	4.00	55.20	78.00	36.10

T1-6t/ha neem leave biomass T4- 3t/ha neem leave + 60kg NPK fertilizer/ha

T2-3t/ha neem leave biomass T5- 4t/ha neem leave + 40kg NPK fertilizer/ha

T3-120kg NPK fertilizer/ha T6- control

4.2.4 Effect of Neem leave biomass and fertilizer on maize height and yield

Analysis of variance (ANOVA) table (Appendix 2) showed significant differences in maize height among treatments. One hundred and twenty (120) kg /ha of fertilizer (T3) significantly ($p<0.05$) produced the highest maize height (170.2 cm) than all other treatments. This notwithstanding, maize heights were similar for T1 (130.0 cm), T4 (142.1 cm), T5 (144.0 cm) but were significantly higher than T2 (111.8 cm) and T6 (100.5 cm) (Table 4. 5). The low level of the major nutrients on control plots could account for the low maize height. As such, the low maize height recorded in T1, T4 and T5 compared to T3 could arise from nutrient immobilization, lack of synchrony in nutrient release and crop demand and probably slow decomposition of leaves biomass (Young, 1997).

Table 4.5: Maize height response to the application of neem leaves and their combination with NPK fertilizer

Treatment	N	Mean height (cm)
T1 = 6t/ha of neem biomass	20	130.0^{b}
T2 = 3t/ha of neem biomass	20	111.8^{c}
T3 = 120kg of NPK fertilizer/ha	20	170.2^{a}
T4 = 3t/ha biomass + 60kg of NPK fertilizer	20	142.1^{b}
T5 = 4t/ha of biomass + 40kg of NPK fertilizer	20	144.0^{b}
T6 = control	20	100.5^{d}

LSD = (0.05)

Means followed by same letters in a column are not significantly different at 0.05 probability levels. N= Number of samples.

Furthermore, analysis of variance (Appendix 1) of maize grain yield differed significantly among the treatments (Table 4.6). One hundred and twenty (120 kg) of fertilizer / ha (T3) produced significantly higher maize grain yield of 3t/ha than all the other treatments. The same grain yield of 1.8t/ ha was obtained for 6t/ha of biomass (T1), 40 kg/ha of NPK fertilizer plus 4t/ha of biomass (T5); and 60 kg of NPK fertilizer plus 3t/ha of biomass applied (T4). The control had the lowest grain yield of 0.5t/ha.

Table 4.6: Maize grain yield response to Neem leave application and their combination with NPK fertilizer

Treatments	N	Mean t/ha
T1 = 6t/ha of biomass	4	1.8^{b}
T2 = 3t/ha of biomass	4	1.2^{c}
T3 = 120kg of fertilizer (NPK)/ha	4	3.0^{a}
T4 = 3t/ha of biomass+ 60kg of NPK fertilizer/ha	4	1.8^{b}
T5 = 4t/ha of biomass + 40kg of fertilizer (NPK) /ha	4	1.8^{b}
T6 = control	4	0.5^{d}

LSD (0.05)

Means followed by same letters in a column are not significantly different at 0.05 probability levels. N= Number of samples.

The initial soil chemical properties of the study site which represent conditions on the control plots had low level of major nutrients such as total nitrogen, available phosphorous and potassium (Table 4.4). Consequently, all the treated plots had significantly higher grain yield than the control. This could indicate that neem leaves biomass had some positive effect on maize grain yield.

The low level of the major nutrients on control plots could account for the low yield in maize. Nutrient availability in the right quantities, ratios and in synchrony with crop demand is important for good crop yields. *Azadirachta indica* leave biomass applied resulted in significantly ($p<0.05$) lower maize grain yield either as sole treatment or in a combination with fertilizer compared to the yield of 3t/ha obtained for sole fertilizer application (120 kg/ha). As such, the low crop yield in biomass transfer could probably arise from nutrient immobilization, lack of synchrony in nutrient release and crop demand and probably slow decomposition of Neem leave biomass (Young, 1997). Similarly, a study reported of depressed maize yield in the first year which was attributed to slow decomposition of the biomass applied and nutrient immobilization (Mugwe et al., 2007). As such, residual effects on crop yields have been reported from biomass trials which were attributed to delayed nutrient release from partly humified organic matter (Mittal *et al*., 1992; Tilander 1993). Hence, low maize yields in response to Neem leaves biomass application could be attributed to delayed nutrients released from partly humified organic matter. Besides, Neem leaves biomass were observed to be partly decomposed on all treated plots after the study.

Despite the high yield (3t/ha) recorded by inorganic fertilizer, this yield may not be sustainable considering nutrients losses through leaching, volatilization and soil erosion. Also the high prices of inorganic fertilizers are beyond the purchasing power of small scale farmers. The low yield recorded by either sole neem leave biomass application or its combination with inorganic fertilizer (NPK) would be more sustainable than the sole fertilizer application. The addition of neem leave biomass increases organic matter status of soils which in turn improves nutrients use efficiency, soil physical properties leading to lower soil bulk density and balance between fine and coarse pores. In addition nutrients availability, cation exchange capacity of soil is also enhanced. Moreover applied leave biomass on soil also increases soil biological activity leading to nutrients release from decay of litter (Young, 1997).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The study sought to determine the uses, management and location of Neem in Tolon – Kumbungu District; nutrient content of Neem leaves biomass and the effect of the biomass and its combination with fertilizer on the yield and height of maize. At the end of the study, it was revealed that Neem tree was predominantly found infront of houses and on farmlands. Neem was mainly used for poles and as fuel wood. Moreover, majority of farmers were aware of the potential of Neem biomass as organic manure. Farmers in the district should be educated on the potential of Neem leaves biomass on maize production. Pruning was the main management practice adopted by farmers in the management of the tree species.

Resource analysis of *A. indica* biomass revealed appreciable quantities of 2.07% N, 0.12% P, 0.20% K, 0.61% Ca, and 0.22% Mg. Thus, *A. indica* biomass could serve as a potential source of nutrients which could support maize cultivation.

On maize yield, the application of Neem leaves biomass showed significant differences between treatments and the control. Sole application of fertilizer (T3 = 120kg/ha) gave the highest maize yield of 3t/ha. Furthermore, sole application of Neem leaves biomass (T1 = 6t/ha) and Neem leaves biomass combined with inorganic fertilizer at different levels (T4= 3t/ha of biomass with 60 kg of NPK fertilizer/ha and T5= 4t/ha of biomass with 40 kg of NPK fertilizer/ha) produced the same yield of 1.8t/ha. Also, 3t/ha of biomass (T2) recorded the third highest yield of 1.2t/ha with the no application of biomass and NPK fertilizer (T6) recording the lowest maize yield of 0.5t/ha.

The treatments had significant effect on maize plant height. Sole application of fertilizer (T3) recorded the highest maize height of 170.2 cm while 6t/ha of Neem leaves biomass (T1), 3t/ha of biomass with 60 kg of NPK fertilizer/ha (T4) and 4t/ha of biomass with 40 kg of NPK fertilizer/ha (T5) had similar maize height of 130.0 cm, 142.1 cm and 144.0 cm. Three tonnes (3t/ha of biomass, T2) recorded the next highest maize height of 111.8 cm with the control recording the lowest maize height of 100.5 cm.

The neem leave biomass, and NPK fertilizer combined with neem leave produced lower maize height and yield compared to the sole fertilizer (NPK). Despite this observation, neem leave biomass application or its combination with inorganic fertilizer (NPK) can produce sustainable yield. The addition of neem leave biomass increases organic matter status of soils which in turn improves nutrients use efficiency, soil physical properties leading to lower soil bulk density and balance between fine and coarse pores. In addition nutrients availability, cation exchange capacity of soil is also enhanced. Moreover applied leave biomass on soil also increases soil biological activity leading to nutrients release from decay of litter.

Therefore, small scale farmers could adopt the combination of organic and inorganic fertilizers applications to enhance nutrient us efficiency. Based on these conclusions, it is recommended that;

(i) Further research should be carried out beyond one year to determine the effect of Neem leaves biomass on maize yield and soil fertility.

(ii) This research should also be carried out on other agricultural crops such as vegetables since farmers in the district are into vegetable cultivation.

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APPENDIXES

Appendix 1: Anova table of soil samples before and after harvest

Source of Variation	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F value	P value
Treatment	6	900.7526	150.1254	0.04	0.9996
Error	42	145810.4273	3471.6768		
Total	48	146711.1799			

Appendix 2: Anova table of maize plants height

Source of Variation	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F value	P value
Treatment	5	4569.27	913.85	10.21	0.001
Blocks	3	926.98	308.99	3.45	
Error	15	1343.07	89.54		
Total	23	6839.32			

Appendix 3: Anova table of maize grain yield

Source of Variation	Degree of freedom	Sum of Squares	Mean Sum of Squares	F value	P value
Treatment	5	668846	133769	3.16	0.038
Blocks	3	5981112	199371	4.72	
Error	15	634160	42277		
Total	23	1901118			