IMPACT OF TOBACCO GROWING ON FLORA IN HOIMA DISTRICT-UGANDA

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DECLARATION

This thesis is entirely my original work and has not been presented for a degree in any other University

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DEDICATION

This work is dedicated to my late parents, beloved brothers, sisters and friends in recognition of their support.

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Abstract

Tobacco *(Nicotiana tabacum*, L) growing takes up soil nutrients at a much faster rate than many other crops, thus rapidly decreasing the fertility of the soil and consequently requiring regular inputs of chemical fertilizers. Tobacco crop is also prone to several diseases and insect pests especially in early stages and, therefore requiring pesticides application to ensure a good quality crop. However, the environmental impact of these requirements particularly on flora diversity is not well documented in Uganda. During the period of two growing seasons, weed prevalence in Kigorobya and Kitoba sub counties of Hoima district was studied using standard quadrat sampling method in plots managed under; (1) first tobacco after bush fallow, (2) two consecutive tobacco crops after bush fallow, and (3) three consecutive tobacco crops after bush fallow. A comparative study was made to elucidate whether similar patterns of change in the flora were evident under maize crops grown as active fallow after the various tobacco crops under similar agricultural regime. At the beginning of the experiment a survey of nearby bush fallow land was undertaken to act as control in assessing differences in vegetation dynamics.

Tobacco production incorporating the use of agro-chemicals did not have adverse effects on either diversity or prevalence of the common macro-flora. Most of the grass species failed to show any recovery by the third cropping cycle of tobacco and the maize fallow break after tobacco cultivation while the broad leafed weed species showed increase from bush fallow under tobacco cultivation. Prevalence scores of weeds species such as *E. floribundus, E. hirta, G. parviflora, M. merculiasis, D. velutina* and *C. benghalensis* remained unchanged under the maize fallow breaks. Total viable counts of bacteria, fungi and bean nodulating rhizobia were not significantly affected by tobacco growing or the subsequent maize fallow break.

CHAPTER ONE

INTRODUCTION

1.0 Origin distribution of tobacco

Natural occurrence of tobacco (*Nicotiana spp*) is restricted to the American continent, Australia and the South Pacific. The majority of species are confined to South America and this, with other geographical evidence, suggests a South American origin for this genus (Akehurst, 1968; Purseglove, 1988). In 1560, the Portuguese and Spanish introduced the tobacco to East Africa, from where it spread to central and West Africa (Purseglove, 1988). Tobacco was introduced into Uganda in the early 1920s and its formal cultivation dates back to 1927 when commercial farming was started under British American Tobacco (BAT) (Karugaba, 2002).

1. 1 Botany

Tobacco (*Nicotiana tabacum*, L) is normally grown as an annual but is potentially a woody, shrub-like perennial. The tobacco plant has a very shallow root system which provides poor anchorage for the more extensive above ground development. The *N. tabacum* types are one of the smaller species of *Nicotiana* spp. The leaves are the most economic valuable component of the plant and are given the most attention by botanists. Although there is variation in leaf size and shape among species, there is general uniformity, distribution, size and shape among cultivated types. The variable characters may include leaf shape, leaf angle to the stem, form of the leaf tip, attachment of leaf to the stem, structure of the attachment and leaf asymmetry. In *N. tabacum*, ovate or oblong-lanceolate shapes are the most common and the leaves are mainly usually borne directly (sessile) on the main stem. The leaf surface has a matte appearance. The calyx is seldom significant but the corolla extends much beyond it and is fairly characteristic (Akehurst, 1968)

Nicotiana tabacum has a uniquely high proportion of alkaloids occurring as nicotine and is considered to have survived as a species by man's protection. Evolution of new species through hybridization is a natural botanical occurrence and presumably *N. tabacum* arose as a natural hybrid, with *N. sylvestris* contributing one genome, but agreement on the other contributor is lacking (Akehurst, 1968). Artificial hybridization resulting in 'synthetic tobacco' bears very close genetic similarity to *N. tabacum*. However, cultivated tobaccos have changed immensely over time and it is unlikely that the forms of other species now available closely resemble the ancestral species (Akehurst, 1968)

Tobacco growth is restricted to latitudes approximately 60^{o} north to 45^{0} south, with the majority of the tobacco entering the world trade produced in the latitudes between 45^{0} north and 30^{0} south (Purseglove, 1988). The weather requirements vary according to the class of tobacco grown and growth is limited by the number of frost free days. Where as the optimum mean temperature for tobacco growing season is 18-27^{0}C, a minimum of 254 mm of well-distributed rain is needed (Purseglove, 1988). More critical in tobacco production is the sensitivity to small variations in soil fertility than any other crop and this determines the type and use of the leaf produced (Purseglove, 1988). For example, soils profoundly affect the flavour and aroma of the same cultivar. In addition, the crop requires adequately drained soils, moderate moisture retention and aeration and pH of 5-6.5 (Purseglove, 1988).

1. 2 Tobacco production

Tobacco production estimates worldwide showed that in 2006 Asia produced 63%, South America 17.7%, Europe 5.5%, Africa 9.4 %, North America and Australia 0.04% of the total tobacco leaf production (Table 1).

Table 1: World production of tobacco leaves

Region	Area harvested (Ha)	Yield (Kg/ha)	Production (Mt)
Africa	367594	930	341835
Asia	2473093	1728	4272453
Europe	212232	2248	477005
Australia	1417	2544	3605
South America	690144	1801	1242698
North America	151360	2518	381060
World	3896580	1724	6719314

Source: (FAO, 2006)

The worlds' leading producers are China, USA, India, Brazil, Turkey and Malawi, while Brazil, USA, Zimbabwe, Turkey, Malawi and Greece are the major exporters. In Uganda, BAT grows tobacco in four areas namely; West Nile, Bunyoro/Mubende, Rukungiri and Middle North (Lira, Gulu, Apac, Kitgum).

Tobacco is a labour intensive crop with farmers contracted by BAT devoting most of their time to tobacco growing. The company provides farmers with free agricultural extension services and interest free loans for agricultural inputs such as seed, fertilizers and chemical pesticides. In return, the farmers must sell their crop to BAT, which then recovers the loan from the money earned from the sale.

Tobacco ranks second as Uganda's cash crop earner, contributing approximately 8% (US $ 35 million) to annual government taxes and over 600,000 people derive their livelihood from the tobacco industry (Karugaba, 2002). The production trend of tobacco has increased over the past

10 years according to FAO, 2004 (Table 2); with increases in yield per hectare and new areas being planted. The application of mineral fertilisers (247kgha^{-1} nitrogen phosphorous and potassium (NPK) and 124 kgha^{-1} of 26%N calcium ammonium nitrate (CAN) and pesticides (Orthene 97%, 0.4-8kgha^{-1} in 80-400 litres of water) has intensified (B.A.T- Good Agricultural practices manual, 1997)

Table 2: Tobacco leaf production trends in Uganda

Year	Area of harvest (HA)	Yield (kg/ha)	Total production (Mt)
1996	7525	844	6349
1997	7525	1089	8195
1998	7525	1506	11333
1999	7525	2773	20,864
2000	9500	2404	22,837
2001	9500	2376	22572
2002	15000	2421	36310
2003	9500	3605	34250
2004	15000	2168	32520
2005	15000	2094	31413
2006	15000	2133	32000

Source: FAO, 2006

1. 3 Problem statement

Tobacco requires fertile land, and since it is a high value cash crop in the short term, farmers in Uganda tend to clear virgin land or land that has been under fallow for a long time such as forested land to reap great profits. Geist (1999a & b) noted that close to 200,000 ha of forests/woodlands are removed by tobacco farming each year of which 1.7% is in developing countries where the crop is cultivated. This implicitly leads to widespread declines in biological diversity.

The conversion of natural forests and/or grasslands into subsistence or cash crop farming drastically changes plant species composition, soil organic matter, soil structure, and soil fungi (Lalljee & Facknath, 1998). The site is largely cleared of multi-species, uneven-aged vegetation and normally planted with a single species of one age class.

Tobacco growing depletes nutrients, particularly nitrogen (N), phosphorous (P) and potassium (K), more heavily than many other crops thus making regular replenishment using mineral fertilizers imperative (Taylor, 1994). The removal of terminal buds (topping) from tobacco plants to stimulate leaf growth and increase nicotine content explains the high nutrient uptake (Taylor, 1994)

Besides, tobacco plants are prone to several diseases e.g. angular leaf spot and wild fire, black shank, black root rot, blue mold, frog eye leaf spot, fusarium wilt, rhizoctonia root rot, tobacco etch virus, tobacco vein mottling virus etc, and pests such as aphids, tobacco budworm, tobacco hornworm, stinkbug, vegetable weevil, white fringed beetle etc especially in early growth stages and therefore requires regular application of pesticides (Anon.1992). These chemicals are potential environmental pollutants and can harm non-target organisms. Protecting farmers' investment and avoidance of risk have been the driving forces for efficient pest and disease control in the tobacco fields. Many authorities e.g. Schulze & Mooney, (1993), Tilman & Downing (1994) and Mooney (1996) have indicated that the environmental problems arising from arable management are associated with changes in landscapes, plant and animal communities, and deterioration in soil, water and air. Several integrated crop management initiatives have reported that there are implications for biological diversity within fields from different approaches to cultivation and pest control and soil fertility enhancements (Clements *et al.*, 1994; Mayor & Dessaint, 1998).

1.4 Justification of the study

Land productivity for a crop is, largely determined by soil fertility; the latter being highly influenced by its organic matter content, basic cations and other nutrients stored in the soil (Vlek *et al.*, 1996). Assessment of soil fertility or quality is based on physical, chemical and biological indices (Stenberg, 1998). Chemical composition of soils varies with parent material; for example, soils dominated by minerals such as quartz are deficient in many nutrients required for plant growth. Clays and loam soils have enough, or all, the nutrients to support natural vegetation. However, when crops are introduced on a soil, nutrients diminish depending on soil types; all soils eventually require external fertiliser application in order to sustain crop productivity (Machacha & Gaboutloeloe, 1999).

According to Aniku (2001), the major limitation of soils in the Lake Albert crescent zone is their low natural fertility and consequently their management requires application of chemical fertilisers. Since tobacco growing is heavily dependent on chemical fertilisers and pesticides as the crop heavily depletes soil nutrients, prone to many pests and diseases, the use of these agrochemicals would be expected to impact on the ecosystems in the tobacco growing areas. In Tanzania, conversion of forest to tobacco farms caused disappearance of several local animal and plant species (Geist, 1999a&b). Additionally, there may be loss of primary productivity and cleansing potential for wastes and pollutants of soils (Tillman & Downing, 1994). These effects occur partly because the biological regulation of soil processes is altered, and these processes are often substituted by the use of mechanical tillage, chemical fertilisers and pesticides (Tillman & Downing, 1994).

Few studies have documented the impact of agrochemicals used in tobacco growing on the environment. Available data from other crops suggest that mineral fertilisers and chemical

pesticides differentially affect floral diversity depending on; regions, types and amounts of agrochemicals used (McLaughlin & Mineau, 1995). While many chemical pesticides and mineral fertilisers are used on tobacco fields in Uganda, their impact on non-target plant species is not well documented. Bridging this knowledge gap is imperative in controlling biodiversity loss and thus protection of the environment.

The overall goal of the present study therefore, was to determine the impact of tobacco production system on the flora in Kigorobya and Kitoba sub-counties of Hoima district.

1. 5 Specific objectives

- To determine the influence of tobacco production on composition and abundance of macro and micro flora in tobacco fields.
- To assess the residual influence of tobacco production on macro and micro flora in subsequent food crops grown as an alternate fallow crop with tobacco cropping cycles.

1. 6 Hypotheses

- The changes in the number of species of macro- and micro-flora, and/ or their abundance in tobacco production fields will not be different from bush fallows.
- The number of species of macro-and micro-flora, and/ or their abundance will not be different under subsequent food crops grown as an alternate fallow crop with tobacco cropping cycles.

CHAPTER TWO

LITERATURE REVIEW

2. 0 Factors that influence distribution of weeds in Uganda

In 1992, a baseline weed survey was conducted in Uganda primarily to identify the major weeds (Terry & Webb, 1992). Results showed that *Digitaria abyssinica (*A.Rich) Stapf; *Cyperus* spp; *Biden pilosa* L.; *Commelina benghalensis* L.; *Galisonga parviflora* cav; *Ageratum conyzoides* L.; *Oxalis latifolia* H.B.K.; *Amaranthus hybridus* L.; *Striga* spp.; *Cynodon* vanderrst; *Imperata cylindrica* (L.) Raeuschel; *Rottboelia cochnchinensis* (Lour.); *Panicum maximum* Jacq. and *Tagetes minuta* L were the major weeds of Ugandan agriculture. However, information specifically relating to weeds that are typically found in the tobacco growing fields in Uganda is not available.

Variation in weed assemblages may be caused by weed management (Doucet *et al*., 1999) but other studies have indicated that differences between fields may affect weed composition more than management practices. Variation in across fields can be due to the differing weed species composition on different types of soils, i.e., the proportion of strongly competitive species among the soil types (Milberg and Hallgren, 2000) and also a shift in competitive balance between the crop and weeds with soil type (McGiffen *et al*., 1997). Andersson and Milberg (1998) compared weed composition and density in three identical long-term field experiments and reported that variation across the three fields was greater than the effects of crop and nutrient management practices. Ugen and Wortman (1997) reported that weed management in most cropping systems of Uganda is less stringent than in the above-mentioned experiments and therefore with such laxity in

weed management, weed composition may be more related to soil characteristics than management programs (Swanton *et al.*, 1999). In Hoima, rainfall is sufficient thus weed growth often occurs through out the year. Conventional practices in Uganda for small scale annual crop production involve shallow tillage of weedy fields just before sowing, followed by occasional weed removal during the cropping season. During crop maturation and after harvest, weeds re-establish and continue to grow during the off- season period. These practices result in dynamic weed flora with an abundant supply of seeds and propagules (Ugen and Wortman (1997). However, edaphic and management factors affecting macro and micro flora composition and prevalence in tobacco growing fields of Hoima have not been studied.

2.1 Effect of chemical pesticides used in tobacco growing on flora

Tobacco is susceptible to many diseases and pests especially during early growth and therefore requires pesticides inputs .e.g. orthene, copper oxychloride etc, up to 16 applications of different pesticides are recommended during one growing period of three months (UN Environment Programme, 1992; California Department of Pesticide Regulation, 1994; EPA, 1997).

The effect of pesticides used in tobacco on macro and micro flora is not documented. However, basing on similar studies of other crop systems, the most direct and quantifiable negative impacts of pesticides on weed flora are due to habitat loss of weeds and decline in non-target species population (McLaughlin, 1994). Boutin *et al.*, (1994) observed in Quebec, Canada, reduced plant species diversity and cover measured along 5m transects from the field edge into hedgerows and woodland edges following herbicide application. Likewise, the application of pesticides reportedly impacted on microbial population (Ambrogioni *et al.*, 1987) either by stimulation or suppression possibly through modification of soil biological processes such as nitrification

(Heinonen-Tansk *et al.*, 1985), ammonification (Schuster & Schroeder, 1990a; b) and other soil processes which are essential for soil health, fertility status and crop production.

2. 2 Effects of tobacco growing on soil physical and chemical properties and their influence on weed flora

Tobacco growing affects soil nutrients by depleting nutrients at much faster rate than many other crops, thus rapidly decreasing the fertility of the soil. Goodland *et al.*, (1984) compared tobacco to some potential substitute crops (Table 3).

Table 3: Average annual depletion of soil nutrients in Africa by tobacco and other crops

Crop (1 tone /hectare)	Nutrient loss ($kgha^{-1}$)		
	Nitrogen	Phosphorous	Potassium
Tobacco	24.4	15.0	9.8
Coffee	2.2	14.4	2.5
Maize	1.9	0.4	46.4
Cassava	19.5	6.7	1.9

Source: Goodland *et al.*, 1984

Invariably, tobacco requires regular inputs of chemical fertilizers as it depletes N, P and K. Nitrogen management affects yield and quality of tobacco with lack of N resulting in cured leaf being pale and glossy with poor texture (Hardy *et al.*, 2005). The total N requirements for tobacco are based on plant needs, soil texture, soil depth, residual N levels, tobacco variety characteristics, and adjustments for leaching losses (Hardy *et al.*, 2005).

Weed flora and change in weed species composition may be influenced by soil properties (Froud-Williams, 1988) and other environmental factors such as location, weather fluctuation, soil management (Altieri and Liebman, 1988). Weed species occurrence and relative density can vary

ith soil nutrient availability. In a study of 37 weed species by Andreasen and Streibig (1991) the-stribution of 18 species varied with organic matter, 11 species with exchangeable potassium, and species with pH, Phosphorous, magnesium or manganese. Long-term fertilizer use has been hked to weed shifts which consequently have either negative or positive effects on organisms gh up in trophic level especially arthropod herbivores. Fertilization alters nutrient availability hich affects not only crop growth but also composition and growth of associated weeds (Theaker *al.*, 1995; Jørnsgård *et al.*, 1996; O'Donovan *et al.*, 1997). However, nitrogen is usually onsidered the most important factor stimulating germination and biomass production of weed pecies (Freyman *et al.*, 1989). Andersson and Milberg (1996) found *Stellaria media* (L.) Vill. to e associated with N-fertilized plots and *Equisetum arvense* L. with non-N fertilized ones. Pawar & Yaduraju, (1998) reported that *Avena fatua* L. was dominant in N-fertilized plots and *Melilotus ndicus* (L.) was prevalent in plots receiving no N-fertilizer)

In addition, other studies have indicated that repeated applications of inorganic nutrients can suppress organisms that produce certain enzymes such as amidase crucial in the N cycle (Dick, 992). It is argued that biological diversity within ecosystems, including agro-ecosystems, provides a range of biological functions, such as nutrient cycling and pest control (Altieri, 1999). The activity of soil microbes normally influences nutrient availability either directly or indirectly particularly in the break down of organic matter with subsequent release of nutrients used not only n cell building and maintenance processes but making 'extra' nutrients available to plants. The microbial biomass is a relatively labile fraction of the soil organic matter. Indirect effects esulting from the interaction of microbial by-products on P availability are well documented (Doran and Werner, 1990). Therefore, systems that increase below-ground C and N inputs through nclusion of legumes and /or fibrous rooted crops in rotations often increase microbial population and activity to greater extent than conventional systems using commercial fertilizers (Altieri, 1999). Immediately a leaf, stem, stalk or animal (or any other organic material) falls to the soil, it

is subjected to a coordinated attack by animals that live on dead and decaying plant and animal tissues (Lalljee & Facknath, 1998). Fig. 1 illustrates the food webs in the soils ecosystem.

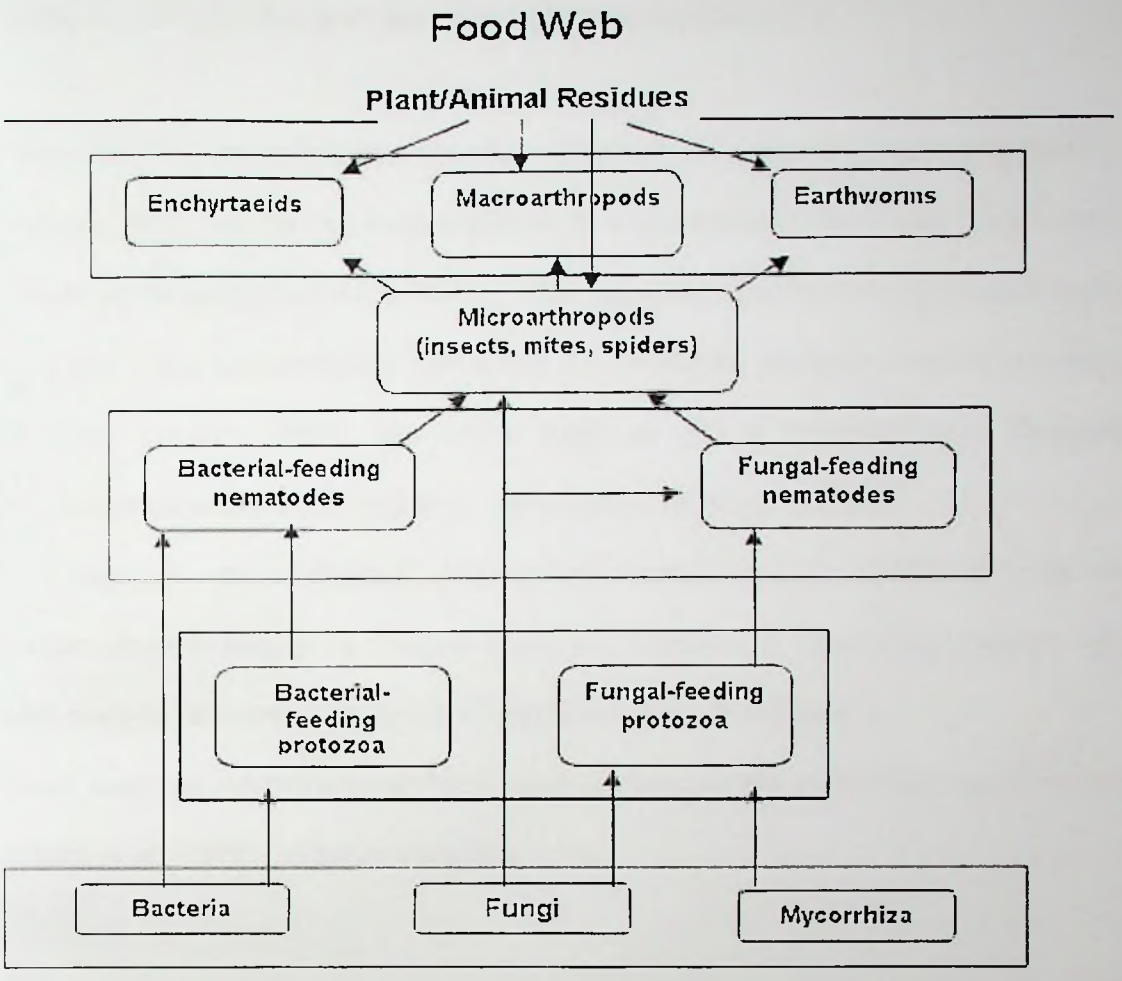

Fig. 1: The soil food web; Source: Lalljee and Facknath (1998)

The primary consumers, which include insects, other arthropods, molluscs, nematodes and earthworms (macrofauna) chew or tear holes in the tissue and open it up to more rapid attack by the secondary consumers, the microfauna (small animals) and microflora (small plants). While the action of the macrofauna is physical and chemical, that of the micro fauna and micro flora is essentially biochemical (enzymatic) (Lalljee & Facknath, 1998). The soil organisms ingest the organic matter, which is digested and assimilated. The undigested residue, combined with the enzymes and nitrogenous waste products are excreted. The excreta of soil organisms is rich in

nitrogenous compounds, bacteria and enzymes, and adds to the fertility of the soil (Lalljee & Facknath, 1998). Additionally, the nutrients released by the process of decomposition of organic matter are available for plant growth (Lalljee & Facknath, 1998).

Although fungi are much less abundant (between 10^4 and 10^6 fungal propagules g^{-1} soil) than bacteria, fungi are the major contributors to soil biomass and account for as much as 70% by weight of the biomass (Lynch, 1983). Most fungi are opportunistic; they grow and conduct their activities when environmental conditions e.g., nutrients, moisture, temperature and aeration) are favorable (Lynch, 1983). The acidic range of pH is generally more favorable for fungi multiplication and growth (Schinner, 1995; Vargas & Hungria, 1997)

Soil fungi are very versatile in decomposing organic residues (Lalljee & Facknath, 1998) Soil fertility depends largely on moulds, since they continue to decompose complex organic material after bacteria and actinomycetes have essentially ceased to function.

Some fungi can solubilise insoluble phosphorus into soluble phosphates readily taken up by plants (Zhang *et al.*, 1998; Lalljee & Facknath, 1998)

Soil bacteria are single-cell organisms and are the simplest and smallest life form. The number of bacteria occurring in soils is usually higher than those of other groups. Typically, there are between 10^6 and 10^9 bacteria per gram of soil; however because of their small size in relation to the large cell size and extensive filaments of the other groups, bacteria account for less than half of the total microbial mass in the soil (Alexander, 1977). Bacteria as a group participate vigorously in all of the organic transformations so vital if a soil is to support higher plants. They often exceed both fungi and actinomycetes in this aspect (Lalljee & Facknath, 1998). Through nitrogen oxidation (nitrification), bacteria oxidize (e.g, *Nitrosomonas sp*) ammonium compounds, including fertilizers, into nitrites, and then other species (e.g *Nitrobacter Sp*) complete the oxidation to

nitrates (Lynch, 1983). Since nitrate is the most preferred form of nitrogen for plant growth, the nitrification process has implications for plant nutrition (Lalljee & Facknath, 1998). Bacterial oxidation and reduction of inorganic ions such as iron and manganese influence the availability of these elements (Lalljee & Facknath, 1998). The excreta of soil macro fauna is culture substrate for huge numbers of bacteria and hence form sites of intensive bacterial activity (Tian *et al*, 1995).

A very small proportion of species of bacteria however have been identified as diazotrophs or organisms that can fix nitrogen (Dixon & Wheeler, 1986; Zahran *et al.*, 1995). Dinitrogen fixation can be carried out by bacteria in soils independent of plants, e.g. *Azotobacter*, but the amount of nitrogen fixed is much greater if the bacteria are intimately associated with plant roots (symbiotic nitrogen fixation), e.g. by *Rhizobium*.

2. 3 Effect of plant type on soil micro organism diversity

Plant roots release a wide variety of compounds into the surrounding soil, including ethylene, sugars, amino acids, organic acids, vitamins, polysaccharides, and enzymes. These materials create unique environments for the microorganisms living in association with plant roots, in the rhizosphere. The rhizosphere was first described by Hiltner (1904) as the volume of soil surrounding plant roots influenced by the living root. Bacteria respond differently to the compounds released by the plant root, and thus different compositions of root exudates are expected to underpin different rhizosphere communities. On the other hand, rhizosphere bacteria will also influence plants, as wide ranges of bacteria in the rhizosphere can promote plant growth via chemical signals such as auxins, gibberellins, glycolipids, and cytokinins. Genera such as *Pseudomonas, Agro bacterium, Bacillus, Variovorax, Phyllobacterium*, and *Azospirillum* are among the most efficient plant growth-promoting bacteria (Bertrand *et al.*, 2001). For example, *Azospirillum brasilense* can exert a positive effect on the growth of common bean and soybean.

and *Agro bacterium tumefaciens* can have a strong effect on plant root development (Burdman *et al.*, 1997; Molla *et al.*, 2001).

2. 4 Effect of agricultural management regime on soil microbial communities

Several recent studies have shown that soil-management practices, such as crop rotation, tillage, fertilizer, compost, manure, pesticide applications and/or irrigation greatly affect soil microbes (Anderson & Gray, 1990; Sparling *et al.*, 1994; Omay *et al.*, 1997; Schönfeld *et al.*, 2002). In as much as the effects of the treatments are complex, the outcome is often not easily explainable. For instance, Bossio *et al.*, (1998) showed that different farming regimes, i.e., organic, low-input, and conventional or high-in put, influence soil phospholipid fatty acid (PLFA) profiles. In particular, mono-unsaturated fatty acids increased with organic input in organic and low-input systems. In addition, the relative importance of environmental variables on the PLFA profiles was determined. Tiedje *et al.*, (1999) compared the responses of microbial communities in three soils of different history to the application of 2, 4-D [2, 4-dichlorophenoxyacetate] and reported that the same population of 2, 4-D degraders became dominant in three soils of different land use history, indicating that 2, 4-D was a stronger selector than was soil use history. Steenwerth *et al.*, (2003) evaluated soil microbial community structure for nine land uses, including irrigated and non-irrigated agricultural sites, nonnative annual grassland and relict, and never-tilled or old field perennial grassland and the results showed a distinct grouping of microbial communities from different treatments and suggesting that land use may be associated with a unique microbial community. The impact of long-term grassland management regimes (N-fertilizer application and soil drainage) on microbial community structure was assessed by Clegg *et al.*, (2003) using PCR-DGGE and PLFA profiling and concluded that Nitrogen fertilizer exerted a significant impact on

the total bacterial and actinomycete community structures, whereas soil drainage had a significant impact on the actinomycete and pseudomonad communities.

2. 4. 1 Effect of Soil Acidity on nitrogen fixing bacteria

Soil acidity constrains symbiotic N_2 fixation in both tropical and temperate soils (Munns, 1986), limiting *Rhizobium* survival and persistence in soils and reducing nodulation (Brockwell *et al.*, 1991; Graham *et al.*, 1982; Ibekwe *et al.*, 1997) but rhizobia with a higher tolerance to acidity also exist (Graham *et al.*, 1982). These strains usually but not always perform better under acidic soil conditions in the field (Munns, 1986).

The inability of some rhizobia to persist under such conditions is one cause of nodulation failure (Bayoumi *et al.*, 1995; Carter *et al.*, 1994; Graham *et al.*, 1982), but poor nodulation can occur even where a viable *Rhizobium* population can be demonstrated (Graham, 1992; Graham *et al.*, 1994). Evans *et al.*, (1980) found that nodulation of *P. sativum* was 10 times more susceptible to acidity than was either rhizobial multiplication or plant growth. Some legumes, e.g., *Trifolium subterranean*, *T. balansae*, *Medicago murex*, and *M. truncatula*, showed tolerance to soil acidity as indicated by dry-matter yield; however, the establishment of nodules was more sensitive to soil acidity in most of these plants than was indicated by the relative yields of dry matter (Evans *et al.*, 1990).

High pH (6.0 and up to 10.0) totally inhibited the nodulation of some lupins (Tang & Robson, 1993), and the authors suggested that pH values above 6.0 have a specific effect in the impairment of nodulation of lupins. However, rhizobia appear to be more tolerant to alkalinity than do their legume hosts. The number of *R. leguminosarum* bv. *trifolii* cells was greater in carbonate-treated soil (Evans *et al.*,1988); increasing the soil pH resulted in both an increased rate at which rhizobia colonized the soil and the frequency of nodule formation. It has also been reported (Rao *et al.*,

1994) that while germination of pigeon pea was decreased at pH values of 8.8, growth of rhizobia was unaffected up to pH 11.5. These authors also found that uninoculated pigeon pea plants nodulated as well as those grown from plant seeds inoculated with *Rhizobium* in reclaimed alkaline (pH 10) soils in a greenhouse study.

2. 4. 2 Effect of fertilizer application on the activity of nitrogen fixing bacteria

The N_2 - fixing activity is confined to areas with low NO_3^- availability (Becana & Sprent, 1987). Nitrate may allow the plant to conserve its energy, since in overall terms more energy is required to fix N_2 than to utilize NO_3^- thus the plant is able to detect the presence and level of NO_3^- in the rooting medium and adjust its N_2 fixation accordingly.

2. 4. 3 Effect of pesticide application on nitrogen fixing bacteria

The use of a vast array of pesticides to overcome the economic losses in agriculture exerts varied environmental stresses on non-target organisms present in the soil. The maximum benefits of biological nitrogen fixation (BNF) may not be achieved if other constraints are placed on the system. One of the most important and potentially limiting factors to BNF is the use of fungicides, and other pesticides. The effect of agrochemicals used in tobacco growing such as orthene, oxychloride, confidor etc on rhizobia is not documented. Studies elsewhere (Hamdi, 1999) with different goals from this study reported that rhizobia showed varied in-vitro growth under pesticide treatment, and that some pesticides are not detrimental to the growth of rhizobia when applied at field rates (Martensson, 1992; Mogollon *et al.*, 1986; Torralba Redonde *et al.*, 1986), whereas other pesticides were toxic to rhizobia when applied at low rates (Ruiz-Sainz *et al.*, 1984). Certain strains of rhizobia could resist high levels of pesticides by adaptation (Kanta *et al.*, 1987); however, these pesticide-adapted rhizobia may be genetically modified (Ruiz-Sainz *et al.*,

1984). Recently, the effects of four pesticides on four legume species, (Abu-Gharbia, 1996) showed that the growth of free-living and symbiotic rhizobia is sensitive to pesticide treatment.

CHAPTER THREE

3. 1 Materials and methods

3. 1. 1 Location

Field surveys were conducted in Kigorobya and Kitoba sub counties Hoima District ($1^{0}00'$N and $2^{0}00'$N; $30^{0}30'$E and $31^{0}45'$E) (Fig.2) to select the study sites with help of resident British American Tobacco Uganda staff. The area has two rainfall seasons with wet peaks in April/May and August/September corresponding with the crop growing seasons for tobacco and maize crop fallow breaks respectively.

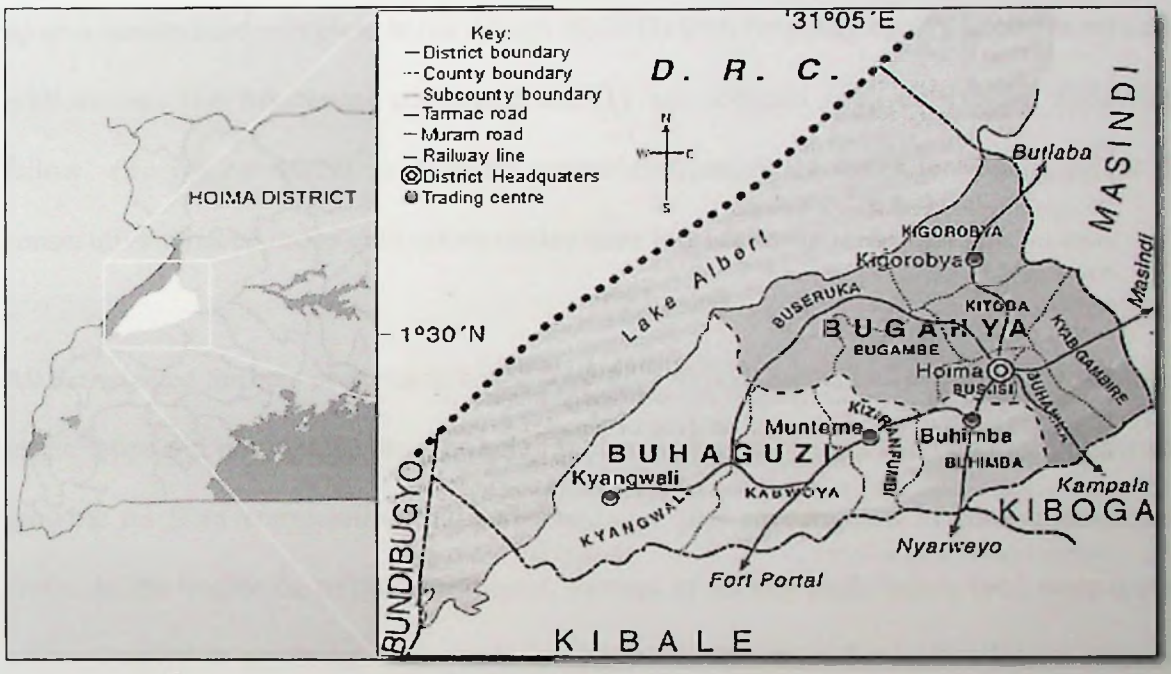

Fig.2: Map of Hoima district showing the study area

The soils of the study area are rhodic and lithic Ferralsols (FAO-UNESCO systems, 1994) with moderate productivity

3. 1. 2 Social baseline surveys in the study area

A social baseline survey was conducted in the study area. Questionnaires were administered to 50 farmers from each sub-county using a pre-tested questionnaire purposively to assess the land-use, cultural practices, agrochemical use and land management history.

3.1. 3 Establishment of On-farm trials

The study was conducted on 4 separate farms in each of the two sub-counties in an experiment set up as a randomized complete block design (RCBD) with cropping cycles as treatments and sites as replications. The treatments comprised of; (1) one tobacco crop cultivation following a bush fallow, (2) two consecutive tobacco crops cultivation cycles after bush fallow (3) three consecutive tobacco crops cultivation cycles after bush fallow.

All the selected farmers used maize as the food crop to rest the land after harvesting tobacco. All the maize crops did not receive any agricultural chemical application. The residual impact of tobacco growing on flora composition and /or abundance was investigated in subsequent maize fallow crops. At the beginning of the experiment, surveys of nearby bush fallow land were undertaken to act as controls in assessing differences in vegetation dynamics for both tobacco crop cycles and the maize fallow breaks. The experiments were conducted during the growing seasons of 2004B, 2005A, and 2005B.

At all the sites, farmers' fields which were at least one acre were selected as experimental fields. In each selected farm, a plot measuring $20m^2$ was randomly selected for macro and micro flora sampling. Within this plot, 10 subplots of $1m^2$ were randomly selected for sample collection using

the modified count quadrat method (Cox, 1990). Weed prevalence was determined by expressing the number of $1m^2$ quadrats in which a particular species existed as a fraction of the total number of the ten 1 m^2 quadrats. A tobacco cultivar, Burley which is recommended by BATU was grown on all the sites and the farmers followed the recommended agronomic practices of applying 24.7 $kgha^{-1}$ N; 49.4$kgha^{-1}P_2O_5$; 49.4$kgha^{-1}$ of K as a basal application and CAN (26%N) equivalent to 32.24$kgha^{-1}$N of mineral fertilisers, as top dressing to boost the nitrogen at one and half months after planting regardless of the status of soil fertility, and pesticides treatment using Orthene 97% at 0.4$kgha^{-1}$ whenever pests or their symptoms were evident.

Soil samples were collected at transplanting stage in case of tobacco cropping cycles and at emergence for maize fallow breaks and was continued at two month intervals averaged over the growing period while in the bush control sampling was done at the beginning of the experiment. Samples were taken from 0 - 15cm depths in the plots and a 1kg composite soil sample from each of the 10 quadrats per plot were collected. One half of the composite soil samples were stored at 4^0C until they were analysed for populations of selected micro organisms while the other was used for chemical analysis using Okalebo *et al.*, (2002) method and the soil water content was determined using the gravitational method ((Dirksen, 1999; Mullins *et al.*, 2001).

A space-for-time approach for the classical but more costly long-term experiments (Pickett, 1988; Johnston and Powlson, 1994) was used. Trends over time from a systematic comparison of fields with different cycles of tobacco or maize fallow cultivation were inferred.

The hypothesis was that all fields had similar characteristics when first cropped (Triomphe,1996).

3. 2 Enumeration of bacteria and fungal colony forming units (CFU)

Bacteria and fungi were isolated from soil samples and enumerated using the dilution plate technique (Wollum, 1982; Schinner *et al.*, 1995). Nutrient agar modified by addition of $30\mu gmL^{-1}$ Amphotericin B (antifungal) and Malt extract Agar also modified by adding $67mgL^{-1}$ of rosebengal and $40mgL^{-1}$ of Streptomycin (antibacterial) were preferentially used for culturing bacteria and fungi respectively.

The inoculated petri-dishes were inverted and incubated at 30 ^{o} C in the dark. Periodically they were examined for colony formation. After 7 days of incubation, plates with discreet colonies numbering between 30 and 300 were selected for enumeration. Using the colony counter, bacterial or fungal units were obtained. The results for total fungi and bacteria were expressed as Colony Forming Units (CFU) per unit weight of dry soil (Ingham, 1994; Parkinson, 1994; Schinner *et al.*, 1995) which gives an indication of the number of either bacteria or fungi capable of growing on experimental media used.

$$\text{Population } g^{-1} \text{ of dry soil} = \frac{Number\ of\ colony\ for \min g\ units \times Dilution\ factor}{Dry\ weight\ of\ soil}$$

3. 2. 1 Determination of bean nodulating bacteria

Bacteria nodulating common beans (*P. vulgaris)* were determined by the Most Probable Number method (Somasegaran & Hoben, 1985). From each soil suspension sample 10 fold serial dilutions were made and aliquots of 1ml of the soil suspension from 10^{-3} to 10^{-5} were used to inoculate four bean seedlings in previously grown in paper pounches per dilution series. The inoculated seedlings were left to grow for 4 weeks in a growth room set at 22^{0}C and 12h photoperiod of

6850 lumens light intensity and then the nodulation was assessed and the MPN of cells per unit of dry weight of soil was computed using the following formula (Somasegaran & Hoben, 1985);

Most Probable Number of rhizobia cells per gram of soil = mxd/v where;

d = Lowest serial dilution factor,

m = Figure in the MPN tables corresponding with the number of total positives (nodulated) and the dilution series, e. g ten-fold,

V = volume of aliquot used for inoculation.

3. 3 Data analysis

The macro-and micro-flora data were subjected to arcsine and log transformations respectively and averages per treatment were subsequently determined. Zero count plates (no CFU visible on the plate) would give 0 $CFUg^{-1}_{dry\ soil}$ and infinite when log-transformed. Log ($CFU^{-1}_{dry\ soil}$) was set at 0 for the zero count plates. All data collected were subject to analysis of variance using the GENSTAT Computer Package to determine whether there were differences in macro and micro flora composition and/or abundance among treatments. Where significant effects occurred, means were separated using Fishers' Protected Least Significant Difference (LSD) at 5% probability level (Gomez & Gomez, 1984).

Data from the baseline survey were analyzed using the Statistical Package for Social Scientists (SPSS) to generate frequencies for the different land uses, cultural practices and agrochemical use.

CHAPTER FOUR

4. 0 Results and discussion

4. 1.1 Social demographic profile of farmers interviewed in Kigorobya and Kitoba sub counties

The results of social-economic characteristics of farmers are presented in Table 4

Table 4: The social-economic characteristics of farmers interviewed in the study area

Character	N	Minimum	Maximum	Mean ± S.D
Age (years)	98	20	72	38.97 ± 11.95
Education (years in formal school)	88	0	13	6.85 ± 2.72
Experience of farming (years)	95	1	67	18.84 ± 13.27
Experience of tobacco farming (years)	98	1	54	9.29 ± 8.98
Farm size (ha)	97	0.407	14.2	2.88 ± 2.23
Fallow period (years)	76	1	5	2.24 ± 2.27

N = no. of respondents interviewed for each character

Age of interviewees ranged from 20 to 72 years with the mean age of approximately 39 years implying that tobacco growing in this region is done by adults. Farmer education ranged between no formal education and those with 13 years of education and an average of 7 years. The respondents' farming experience ranged between one year and 32 years with an average of 19 years, while the experience in tobacco growing ranged between one year and 18 years with an average of 9 years equivalent to nine seasons of tobacco growing. Implicitly most farmers apart from having experience in growing crops, lack the scientific basis for the management practices in their fields due to lack of either sufficient education or farming experience or both. Therefore, most of the innovations for conservation of biodiversity have to be delivered by extension officers. The average farm size was 2.88 ha indicating that there was not much land to allow long term

fallow periods and thus fallows of only about 2 years were encountered. This implies that farmers who had bigger land could afford longer fallow periods for their resting land compared to ones with smaller pieces of land.

4.1.2 Cultural practices

Table results of various cultural practices in the tobacco growing areas are presented in Table 5

Table 5: Cultural practices in tobacco growing areas (No. farmers =100)

Cultural practices	Percentage
-Mulch garden	21
-No mulching of garden	79
-Carry out crop rotation	99
-Do not rotate crops	1
-Carry out intercropping	88.7
-Do not intercrop	11.3
-Fallow their land	80.2
-No fallowing land	19.8

The farmers employed various cultural practices in their land and these include crop rotations, intercropping etc among others; mainly to maintain soil integrity and also avoid carry over of diseases from one season to the next (Averre *et al.*, 1991; Karlen *et al.*, 1994; Clark *et al.*, 1998). Furthermore, on average, most farmers permitted less than three years fallow periods in this study area leading to more soil exhaustion. Many authorities, for example; Conway & Barbier, 1990; Reganold *et al.*, 1990 suggest that sustainable agricultural production in sub-Saharan Africa is threatened by resource degradation stemming from increased population pressure and intensified use of land which is at the advanced stage of weathering.

4.1.3 Impact of tobacco cropping cycles and maize fallow crop on soil properties

The results of soil properties averaged at each of the growing cycles of tobacco and the maize crop fallows are presented in Table 6

Table 6: Average soil property values of tobacco cropping cycles and maize fallow crops

Cropping cycles	Soil parameters									
	Soil pH	P_{av} (mgkg^{-1})	%N	Exc. Bases (mgkg^{-1})				% Sand	% Clay	% Silt
				K	Ca	Na	Mg			
A: Tobacco										
Bush fallow	5.50	3.75	0.21	0.40	4.52	0.03	1.73	56.1	30.50	13.38
1A	5.76	5.08	0.24	0.44	6.53	0.04	4.62	60.3	23.17	16.00
2A	5.41	6.07	0.28	0.68	5.4	0.04	4.24	57.2	25.00	17.83
3A	5.51	5.70	0.29	0.44	7.79	0.03	5.58	60	24.83	15.17
$LSD_{0.05}$	NS	NS	0.06	NS	2.46	NS	1.84	NS	4.45	NS
CV%	6.5	45.0	26.3	66.6	49.2	55.9	55.2	12	20.8	31.2
B: Maize										
1B	6.21	4.03	0.27	0.55	6.93	0.04	3.13	63.2	20.2	16.50
2B	5.91	6.31	0.28	0.35	4.78	0.03	2.19	61.0	21.5	17.25
3B	6.19	4.43	0.27	0.47	6.48	0.05	3.13	62.8	20.8	15.75
Critical value[†]	5.5	15	0.2	0.40	4.0	<1.0	0.50			
$LSD_{0.05}$	0.43	NS	NS	NS	NS	NS	NS	NS	8.33	NS
CV %	6.9	61.1	26.4	75.8	40.5	64.6	66.5	16.6	34.8	28.0

1A-3A= variuos tobacco cycles: 1B-3B= various maize fallow breaks after tobacco harvest NS = not significant at P > 0.05; [†]General soil critical values based on Okalebo *et al.*, (2002) for soil fertility; Soil type = Ferralitic; Soil texture class = Sandy Clay loam

The results of soil properties showed that tobacco growing cycles were not significantly different from the maize crop fallows implying that soil fertility was adequate according to the critical values.

4. 1. 4 Agrochemical usage

Most farmers (89.4%) that were interviewed used pesticides in tobacco growing (Table 7).

Table 7: Agrochemical use information (No. farmers =100)

Practice	Percentage
- Using pesticide	89.4
- Not using pesticide	10.6
Types of pesticide used	
- Use Orthene	92.8
- Use copper oxychloride	1.2
- Use both	4.8
- Use other chemicals	1.2
Evaluation of knowledge of fertilizer importance	
- Know importance of fertilizer importance	88
- Do not know fertilizer importance	12
Use of fertilizers	
- use fertilizers in farming	37.4
- non use of fertilizers in farming	14.1
- Use only on tobacco	48.5
Use of organic fertilizers	
-Use of organic fertilizers	29.2
- Non use of organic fertilizers	70.8
Types of organic fertilizers used	
- Use compost	50
- Use green	30.8
- Use farm yard	19.2
Use of inorganic fertilizers	
- Use of inorganic fertilizers	90
- Non use of inorganic fertilizers	10
Types of inorganic fertilizers used	
- Use NPK only	58.7
- Use CAN only	2.2
- Both NPK and CAN	39.1

The pesticides applied included; Orthene (insecticide), copper oxychloride (fungicide) and, Confidor (suckeride). Most of the farmers (92.8%) use Orthene at a rate of 0.4-0.8kgha^{-1} in 80-

400L of water in their tobacco crop production because it is a broad spectrum systemic insecticide and it is applied either as a foliar insecticide or directly on the soil during the growth of cycle of tobacco. The farmers applied fertilisers in their tobacco production system at various rates for example nitrogen, phosphorous, and potassium [NPK (10:20:20)] at a rate of 247kgha^{-1} and calcium ammonium nitrate [C.A.N (26%N)] at 124 kgha^{-1}. NPK was applied as a basal fertilizer while CAN was applied as top dressing in the growth cycle of tobacco if the tobacco plants showed signs of N-deficiency per season of tobacco growing. However, not all the farmers apply the two fertilisers; for instance 60% of the farmers applied only N.P.K in their tobacco fields because they wanted to save on cost of inputs since it is deducted from their sales. The implication is that in some fields the nutrients applied may not be enough because based on the formulation (10:20:20), two applications of N would be necessary at the given rates above in order to produce good yields. However, results from soil analysis did not show that N was below the critical values under the tobacco cropping cycles.

This study found that some farmers use crop residues as fertilisers or manures on their land especially under the food crops. These are cheaper compared to the inorganic fertilisers. In addition, these organic manures provide a range of nutrients though it would be difficult for the farmers to raise the amounts that would provide the same amount of nutrients as mineral fertilisers.

4. 1. 5 Farmers' perceptions of land productivity

Most farmers (63.5%) perceived the productivity of their land to have decreased, while only a few (14.6%) thought that it had increased from the time they started farming (Table 8).

Table 8: Farmer perception of productivity of their fields (No. of farmers = 100)

Farmer perception	Percentage
Land productivity	
- increased	14.6
- decreased	63.5
- no change	21.9
Cause of productivity decline	
- weather fluctuation	37.4
- Soil exhaustion	17.6
- Increased pests and diseases	8.8
- Inadequate extension services	2.2
- Indequate agrochemicals	11
- any combination of above	23

The farmers principally attributed declining land productivity to fluctuation of weather conditions and secondly to soil exhaustion. However, from the soil analysis results (Table 6), the soils had nutrients above the critical levels (with the exception of available phosphorous) for optimum crop growth under both tobacco and the subsequent maize fallow crops.

4. 2 Meteorological data

The weather data for the study area are shown in Fig. 3

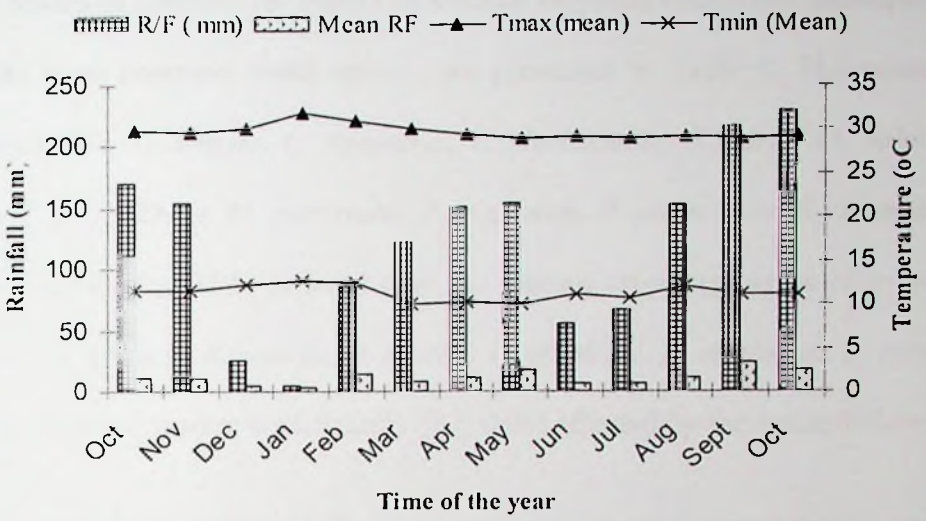

Fig. 3. Weather data for study area (October 2004-October 2005)

Source: Bulindi Zonal Agricultural Research and Development Institute

The weather data for the study area indicated that the monthly maximum temperature ranged between 29^0C to 31.8^0C while minimum temperatures between 10^0C to 12.7^0C during the course of the study and the rainfall was normal. These weather conditions reflected adequate tobacco growing conditions and supported a dynamic weed population with an abundant supply of seeds and propagules (Purseglove, 1988 and Ugen & Wortman, 1997)

4. 3 Impact of tobacco cropping cycles and maize fallow break crops on the most common weed species occurrence

The results of analysis for impact of tobacco cropping cycles and subsequent maize fallow breaks on the most common weed species are presented in Table 9. The occurrence of *A. zygia, C. benghalensis, C. trigyna*, C. *Rotundrus*, *E. floribundus, E. hirta, D. velutina, G. parviflora, G. scabra, I. cylindrica, M. mercrialis*, *P. maximum*, *P. purpuleum*, *S. rhombifolia* and *Triumfetta sp* significantly ($P \leq 0.05$) differed over the various cropping cycles of tobacco while *A. zygia, B. pilosa C. trigyna*, C. *Rotundrus*, *G. scabra, I. cylindrica*, *P. maximum*, *P. purpuleum*, *S. rhombifolia* and *Triumfetta sp* were significantly ($P \leq 0.05$) affected by the maize fallow breaks.

Mean prevalence scores of the most common species over tobacco cropping cycles and the subsequent maize fallow breaks are presented in Table 10. The weed species responded significantly ($P<0.05$) differently across tobacco cropping cycles and the subsequent maize fallow breaks. *B. pilosa* was not affected by tobacco production while *I. cylindrica*, *Pennisetum purpuleum, G. scabra*, and *A. zygia S. rhombifolia, P. maximum*, *E. floribundus* and *Triumfetta sp* significantly ($P<0.05$) decreased and failed to recover across consecutive tobacco cropping cycles. *C. benghalensis*, *C. trigyna, C. rotundrus D. velutina, G. parviflora, M. merculiasis,* and, *E. hirta* species showed a recovery beyond the levels recorded in bush fallow (Table 9). In the maize fallow breaks, *A. zygia I. cylindrica, P. purpuleum, B. pilosa* and, *P. maximum* showed a significant ($P < 0.05$) decline while *S. rhombifolia, C. trigyna, G. scabra, Triumfetta sp* and *C. rotundrus* showed a significant ($P < 0.05$) recovery over the same period.

However, weed species such as; *E. floribundus, E. hirta, G. parviflora, M. merculiasis, D. velutina* and, *C. benghalensis* were not significantly changed from the bush fallow.

Table 9: Analysis of Variance for the impact of tobacco cropping cycles and maize fallow breaks on the most common weed species

Sources of variation	DF	Weed flora mean squares														
A: Tobacco																
		B.pilo	*C.beng*	*D.velt*	*E.flor*	*E.hirt*	*G.parv*	*I.cy*	*M.mer*	*P.max*	*P.pur*	*S.rho*	*Trium*	*G.scab*	*C.trig*	*A.zy*	*C.rot*
Location	3	0.037	0.101	0.071	0.160	0.034	0.275	0.059	0.079	0.230	0.106	0.029	0.005	0.217	0.198	0.028	0.016
Cropping cycles	3	0.238ns	0.302*	0.583***	0.387***	0.135***	0.258**	1.276***	0.366*	0.512***	0.648***	0.149*	0.241****	0.194*	0.121ns	0.092***	0.202**
Error	57	0.094	0.082	0.095	0.030	0.019	0.058	0.023	0.094	0.030	0.017	0.044	0.040	0.052	0.064	0.004	0.041
Total	63																
CV (%)		81.6	82.1	84.9	168.5	176.7	159.1	63	128.5	108.4	128.4	126	106	116.9	190	147.7	132.5
B: Maize																	
Location	3	0.131	0.102	0.139	0.298	0.094	0.142	0.145	0.098	0.075	0.053	0.106	0.025	0.121	0.063	0.012	0.016
Maize fallows	3	0.351**	0.094ns	0.095ns	0.077ns	0.139ns	0.100ns	0.498***	0.124ns	0.243***	0.324***	0.168*	0.139*	0.157*	0.125*	0.050***	0.011ns
Error	25	0.069	0.092	0.091	0.084	0.096	0.095	0.018	0.050	0.021	0.019	0.040	0.035	0.054	0.041	0.004	0.017
Total	31																
CV (%)		79.8	102.5	108	131.4	184	171.1	51.4	137.4	92.2	137.1	91.3	94.4	128.2	204	163.7	165.9

* = Significant at P < 0.05, ** = Significant at P < 0.01, *** = Significant at P < 0.001, NS= not significant at P > 0.05

Full names of weeds according to families;
Mimosaceae: *Albizia zygia Durazz*
Amaranthaceae: *Celocia trigyna* L
Compositeae: *Erigeon floribundus* L; *Biden pilosa* L; *Galisonga parviflora* Cav
Commelinaceae: *Commelina benghalensis* L
Cyperaceae: *Cyperus rotundrus* L
Euphorbiaceae: *Euphorbia hirta* L; *Micrococca merculiasis* Benth.
Graminaea: *Digitalia velutina* L; *Imperata cylindrica* (L) Rausch; *Pennisetum purpuleum* L; *Panicun maximum* L
Malvaceae: *Sida rhombifolia* L
Tiliaaceae: *Triumfetta sp*

Table 10: Change in the occurrence of the most common weed flora species over tobacco cropping cycles and the maize fallow breaks

Plant species	Weed flora prevalence (%)										
	Bush fallow	1A	2A	3A	LSD	CV%	1B	2B	3B	LSD	CV%
Biden pilosa L.	0.34*	0.30	0.31	0.56	NS	81.6	0.57	0.36	0.07	0.27	79.8
Commelina benghalensis L.	0.21	0.25	0.49	0.44	0.20	82.1	0.24	0.27	0.46	NS	102.5
Digitalia velutina (Forssk) P.Beauv.	0.15	0.27	0.47	0.57	0.22	84.9	0.27	0.41	0.29	NS	108
Erigeon floribundus L.	0.34	0.04	0.00	0.04	0.12	168.5	0.18	0.26	0.11	NS	131.4
Euphorbia hirta L.	0.03	0.05	0.02	0.22	0.10	176.7	0.32	0.24	0.10	NS	184.6
Imperata cylindrical (L.) Reauschel	0.63	0.29	0.03	0.03	0.11	63	0.19	0.07	0.16	0.14	51.4
Micrococca mercurialis Benth	0.03	0.28	0.27	0.38	0.22	128.5	0.22	0.10	0.30	NS	137.4
Panicum Maximum Jacq.	0.42	0.15	0.02	0.06	0.12	108.4	0.05	0.10	0.07	0.15	92.2
Pennisetum purpuleum L.	0.40	0.00	0.00	0.00	0.10	128.4	0.00	0.00	0.00	0.14	137.1
Galisonga parviflora Cav.	0.03	0.11	0.33	0.14	0.17	159.1	0.21	0.29	0.20	NS	171.1
Sida rhombifolia L.	0.30	0.07	0.14	0.16	0.15	126	0.36	0.03	0.20	0.21	91.3
Triumfeta spp	0.36	0.08	0.13	0.18	0.14	106.6	0.21	0.04	0.18	0.19	94.4
Guizolia scabra	0.35	0.19	0.08	0.17	0.16	116.9	0.04	0.25	0.10	0.24	128.2
Celocia trgyna	0.03	0.11	0.17	0.23	0.18	190	0.01	0.08	0.28	0.21	204.1
Albizia zygia	0.16	0.00	0.01	0.01	0.05	147.7	0.0	0.0	0.0	0.07	163.7
Cyprus rotundus	0.10	0.06	0.14	0.31	0.14	132.5	0.08	0.03	0.11	0.13	165.9

* Proportion of quadrats that contained the weed flora species; 1A-3A = various tobacco cropping cycles; 1B-3B = Various Maize fallow breaks after tobacco crop NS = not significant at $P > 0.05$

The most common species in the tobacco cropping cycles as well as subsequent maize fallow breaks were Albizia zygia, *B. pilosa, C. benghalensis, C. trygina, Cyperus rotundrus, E. floribundus. E. hirta, D. velutina, Guizolia scabra G. parviflora, I. cylindrica, M. merculiasis, P. maximum, P. purpuleum, S. rhombifolia* and *Triumfetta sp.* Similarly, Terry & Webb (1992) reported that *Digitalia spp, B. pilosa, C. benghalensis, I. cylindrica*, and *P. maximum,* were the major weeds of Uganda.

The natural bush fallow was predominantly covered by grasses such as *I. cylindrica, P. maximum* and *P. purpuleum, Triumfetta sp, Guizolia scabra,* and *E. floribundus* (Table 10). The rest of the weed flora species were overshadowed by these more dominant grass species.

The prevalence of most weed flora was generally low in the first cropping cycles of tobacco and the first maize fallow break compared to the next cropping cycles due to low seed numbers of these species from the preceding bush fallow. Ikuenobe & Angelifo (2003) reported low weed abundances for species such as *B. pilosa* and *C. benghalensis* under the first cycle of cropping from bush fallow.

The weed flora species that showed increases in prevalence at the second cropping cycle of both tobacco and the maize fallow break must have produced vast quantities of seeds from the first cropping cycle that establish during the second and third cropping cycles (Rasmussen, 1998 and Ikuenobe & Angelifo, 2003).

Although diversity (i.e. number of species) of the most common broad-leafed weeds and grass weeds changed overtime during consecutive cultivations, some of them especially grass weeds would perhaps return to the original state when allowed enough fallow time ($\geq$ 5 years). In most cases those that had decreased on first cultivation, started recovering over time of cropping cycles. This study and others done else where (Dvorak, 1993; Roder *et al.*, 1997, 1998) have shown that increasing cropping cycles can lead to increased or decreased density or composition of particular weed species.

The high coefficients of variation (Cvs) for the different weed species in this study imply that the prevalence of the weed species across tobacco and the subsequent maize fallow break fields was probably influenced also by other factors such as initial cultivation and subsequent weeding besides cycles of cropping because in most of the weed species, most of

the variability was unexplained. Other studies (Andersson and Milberg, 1998) have indicated that variation across fields in terms of differing weed species composition on soils of different types (Milberg and Hallgren, 2000), i.e., the proportion of strongly competitive species might vary. Also the competitive balance between the crop and weeds can shift with soil type (McGiffen *et al.*, 1997) may affect weed composition more than the effects of crop and nutrient management practices. However, results of soil analyses showed that the soils were closely similar (Sandy clay loam) implying that any variation due soil differences would be minimal. Legere & Samson, (1999) reported that weed community shifts are influenced by multiple abiotic and biotic factors as opposed to a single factor. Albrecht and Auerswald (2003) and Dieleman *et al.*, (2000) reported that density and species composition both vary in response to underlying environmental variation while other studies relate it to shifts in agricultural management practices such as tillage (Anderson *et al.*, 1998; Dorado *et al.*, 1999; Clements *et al.*, 1996), crop rotation (Moonen and Barberi, 2004, Cardina *et al.*, 2002), and weed management (Barberi *et al.*, 1998; Menalled *et al.*, 2001).

4. 4 Impact of tobacco cropping cycles and maize fallow breaks on soil microbial populations

The results for total viable colony counts of fungi, bacteria and total viable cell counts of bean nodulating rhizobia across tobacco cropping cycles and the maize fallow breaks are presented in

Table 11.

Table 11: Total viable colony and cell counts of soil micro flora over cropping cycles of tobacco and the maize fallow breaks

Cropping cycles	Fungi (CFU gm^{-1} dwt soil) x 10^{-4}	Bacteria (CFU gm^{-1}dwt soil) x10^{6}	Bean nodulating rhizobia (Cells g^{-1} d wt soil)
A: Tobacco			
Bush fallow	2.4	6.9	151.4
1A	7.0	4.4	446.7
2A	6.1	4.1	109.7
3A	3.6	4.6	512.9
LSD (0.05)	NS	NS	NS
%CV	11.3	7.5	35.9
B: maize			
1B	9.4	7.7	295.1
2B	7.4	10.6	213.8
3B	6.5	8.9	416.9
LSD (0.05)	2.44	NS	NS
%CV	7.9	7.3	36.7

1A-3A= variuos tobacco cycles: 1B -3B= various maize fallow breaks after tobacco harvest; NS = Not significant at $P > 0.05$.

The selected micro flora were not significantly affected by tobacco cropping cycles suggesting that tobacco production incorporating the use of agro-chemicals had no negative impact on the bacteria, fungi and bean nodulating rhizobia density over the course of the study. Similar results were recorded in the maize fallow break, except in the case of fungi which were significantly ($P<0.05$) increased in the fields which had already under gone two

tobacco crops followed by maize crop. Boerner *et al.*, (1996) and Boddy, (1999) reported that fungal species were highly stable in time but may become unstable in space.

Bacteria population density was stable both in time and space. Similar results were reported by Finlay *et al.*, (1999). Like many other soil micro organisms, bacteria exhibit temporal heterogeneity resulting from their ability to form resistant and/or resting structures and the highly dynamic nature of substrate availability in soil helps to maintain the metabolic integrity of the soil (Domsch, 1970).

Significance of the difference of total viable counts of bean nodulating rhizobia cells under both tobacco cropping cycles and the maize fallow breaks was not evident (Table 11). Katarina *et al.* (2004) suggested that some soil organisms may be selectively inhibited as a result of land use practice including the use of agrochemicals but other organisms of the same group rapidly appear to replace the affected types hence restoring the stability in numbers with time. Clearly this micro organism group is not sensitive enough to indicate changes in the soil environment.

For evaluation of the impact of tobacco growing on soil quality, other organisms such as soil invertebrates should be included in such a study since invertebrates particularly macrofauna also regulate soil biological and physical processes (Pankhust, 1997). Soil fauna enhance the bio-degradation and humification of organic residues (i) by comminuting them and increasing their surface area for microbial activity and interaction and (ii) by producing enzymes that break down complex biomolecules into simple compounds to form humus. In addition, they improve the environment for general microbial growth (Shinner, 1995; Ayuke, 2000).

Communities of microorganisms can be described in different ways: the taxonomical composition of a biomass component, metabolic activities of this component or its biochemical and genetic characteristics (Kunc, 1994). There are some general limitations in studying fungal and bacterial diversity in soils. These problems are due to both methodological limitations and a lack of sufficient taxonomical knowledge (Kirk *et al.*, 2004; Trevors, 1998). The plate count, using different media, is a widely accepted technique in enumerating viable soil microorganisms (Wollum, 1982). Two major characteristics of soil microorganisms, their enormous numbers and their microscopic size, make it necessary to make some assumptions (Zuberer, 1994). A major assumption which brings some important limitations with it, is that all viable cells will produce a visible colony which is never completely true. Plate counts estimate only those cells that are tolerant of the medium and incubation conditions and only those that are able to divide and produce recognizable colonies (Zuberer, 1994). Further, this assumption does not take into account that cells will interact with each other (Wollum, 1982). Competition, production of antibiotics and other antagonisms certainly do exist between soil organisms (Wollum II, 1982; Kirk *et al.*, 2004). A third assumption is that for each organism or organisms under study, a suitable medium exists. However, only few media exist that are specific to only one generic group of microorganisms and only sometimes can a selected chemical or physical environment contribute to this specificity (Wollum II, 1982). Further, the microorganisms with fast growth rates in a certain media are usually favored in plate growth (Dix and Webster, 1995). Selecting media and growth conditions such as temperature and pH can thus be an important limitation (Kirk *et al.*, 2004). Despite the well known bias, such as overwhelming number of

non-cultivable microorganisms which are not considered by these techniques, CFU counts on more or less specific solid media are still useful to compare the effects of soil treatments on those bacteria or other microorganisms that are recoverable under the conditions of the experiment (Zuberer, 1994) and informative (Janvier *et al.*, 2007)

The above limitations and assumptions imply that the results obtained by this study did not isolate a substantial fraction of microorganism community. Therefore complementing results from this study and those from biochemical and genetic characteristic of soil biomass and, invertebrate studies would express the population and structural dynamics of the soil organisms better as influenced by soil treatment or other land use practices.

CHAPTER FIVE

5. 0 CONCLUSIONS AND RECOMMENDATIONS

Most of the grass species failed to show any recovery by the third cropping cycle of tobacco or the subsequent maize cultivation fields while the broad leafed weed species showed increase from bush fallow under continuous tobacco cultivation. However, some weed species such as; *E. floribundus, E. hirta, G. parviflora, M. merculiasis, D. velutina* and *C. benghalensis* were not significantly changed under the various maize fallow break fields due to the dense crop cover established when maize was in the field.

More emphasis should be directed towards understanding the interactions between the crop type and other crop management variables such as tillage and weeding. The use of other techniques such species diversity, species evenness should be explored to express weed flora dynamics and the use of weed biomass changes or differences should be explored to understand wether there is any difference between the weed flora under tobacco cultivation fields and the food crop fallow breaks.

Tobacco production, incorporating the use of agro-chemicals had no negative impact on the bacteria, fungi and bean nodulating rhizobia density over the course of the study. A comparative study suggested that the impact of tobacco cultivation on these floras did not significantly differ from that of the maize fallow break.

Complementing results from this study with others like those from biochemical techniques and soil invertebrates would give a better expression of the changes in the microbial population due to soil treatment effects or the impact of other land use practices. There is

also a need to consider cropping systems holistically including agro-ecosystem constraints such as changes weather and to conduct further in-depth research on the effect of other crop management practices on soil micro-flora communities, their structure and activity in addition to density.

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APPENDICES

Appendix 1: ANOVA table of impact of tobacco cropping cycles on soil properties

Soil property	Sources of variation	DF	SS	MS	F	P-value
N	Replication	3	0.008	0.003	0.60	
	Cropping cycle	3	0.051	0.017	3.79	0.017
	Error	41	0.183	0.005		
	Total	47				
P_{av}	Replication	3	1.445	0.482	0.09	
	Cropping cycle	3	37.542	12.514	2.32	0.089
	Error	41	220.735	5.384		
	Total	47				
K	Replication	3	1.187	0.396	3.70	
	Cropping cycle	3	0.603	0.201	1.88	0.148
	Error	41	4.387	0.107		
	Total	47				
Ca	Replication	3	159.34	53.113	5.98	
	Cropping cycle	3	72.143	24.048	2.71	0.058
	Error	41	364	8.888		
	Total	47				
Mg	Replication	3	40.154	13.385	2.69	
	Cropping cycle	3	97.376	32.459	6.51	0.001
	Error	41	204.371	4.985		
	Total	47				
Na	Replication	3	0.0003	0.0001	0.27	
	Cropping cycle	3	0.0022	0.0007	1.98	0.131
	Error	41	0.0153	0.0004		
	Total	47				
pH	Replication	3	1.375	0.458	3.89	
	Cropping cycle	3	0.8106	0.270	2.29	0.092
	Error	41	4.827	0.118		
	Total	47				
%Sand	Replication	3	818.68	272.89	5.77	
	Cropping cycle	3	155.93	51.98	1.10	0.361
	Error	41	1939.21	47.30		
	Total	47				
% silt	Replication	3	292.52	97.51	4.11	
	Cropping cycle	3	123.43	41.14	1.74	0.175
	Error	41	971.88	23.70		
	Total	47				
%Clay	Replication	3	356.25	118.75	4.08	
	Cropping cycle	3	366.92	122.31	4.21	0.011
	Error	41	1192.08	29.08		
	Total	47	1			

Appendix 2: ANOVA table of the impact of tobacco cropping cycles on soil micro organisms

Soil property	Sources of variation	DF	SS	MS	F	P-value
Fungi	Replication	3	1.056	0.352	0.12	
	Cropping cycle	3	18.692	6.231	2.05	0.122
	Error	41	124.733	3.042		
	Total	47				
Bacteria	Replication	3	3.855	1.285	0.46	
	Cropping cycle	3	3.975	1.325	0.47	0.701
	Error	41	114.394	2.790		
	Total	47				
Rhizobia	Replication	3	6.806	2.269	3.08	
	Cropping cycle	3	4.120	1.373	1.86	0.151
	Error	41	30.224	0.737		
	Total	47				

Appendix 3: ANOVA table of the impact of maize break fallow crops cycles on soil properties

Soil property	Sources of variation	DF	SS	MS	F	P-value
N	Replication	3	0.004	0.014	3.20	
	Cropping cycle	3	0.023	0.008	1.73	0.186
	Error	25	0.112	0.005		
	Total	31				
P_{av}	Replication	3	132.523	44.174	5.52	
	Cropping cycle	3	31.992	10.664	1.33	0.286
	Error	25	199.901	7.996		
	Total	31				
K	Replication	3	0.7626	0.254	2.27	
	Cropping cycle	3	0.194	0.065	0.58	0.635
	Error	25	2.796	0.112		
	Total	31				
Ca	Replication	3	178.159	59.386	11.24	
	Cropping cycle	3	34.858	11.619	2.20	0.113
	Error	25	132.127	5.285		
	Total	31				
Mg	Replication	3	37.391	12.464	4.34	
	Cropping cycle	3	11.882	3.961	1.38	0.272
	Error	25	71.728	2.869		
	Total	31				
Na	Replication	3	0.002	0.001	1.20	
	Cropping cycle	3	0.004	0.001	2.37	0.095
	Error	25	0.014	0.001		
	Total	31				
pH	Replication	3	2.0184	0.673	3.95	
	Cropping cycle	3	2.6334	0.878	5.15	0.007
	Error	25	4.2578	0.170		
	Total	31				
%Sand	Replication	3	247.6	82.5	0.81	
	Cropping cycle	3	253.6	84.5	0.83	0.490

Error	25	2545.8	101.8		
Total	31				

Appendix 3 Cont'd: ANOVA table of the impact of maize break fallow crops cycles on soil properties

Soil property	Sources of variation	DF	SS	MS	F	P-value
%Clay	Replication	3	188.00	62.67	0.96	
	Cropping cycle	3	567.00	189.00	2.89	0.055
	Error	25	1635.00	65.40		
	Total	31				
%Silt	Replication	3	489.09	163.03	8.43	
	Cropping cycle	3	67.59	22.53	1.17	0.343
	Error	25	483.28	19.33		
	Total	31				

Appendix 4: ANOVA table of the impact of maize break fallow crops on soil micro organisms

Soil property	Sources of variation	DF	SS	MS	F	P-value
Fungi	Replication	3	7.438	2.479	1.11	
	Cropping cycle	3	24.782	8.261	3.71	0.025
	Error	25	55.618	2.225		
	Total	31				
Bacteria	Replication	3	10.252	3.417	1.21	
	Cropping cycle	3	1.754	0.585	0.21	0.890
	Error	25	70.503	2.820		
	Total	31				
Rhizobia	Replication	3	4.853	1.618	2.09	
	Cropping cycle	3	0.849	0.283	0.37	0.779
	Error	25	23.065	0.775		
	Total	31				

Appendix 5: ANOVA table of the impact of tobacco cropping cycles on weed flora occurrence

Weed sp	Sources of variation	DF	SS	MS	F	P-value
B. pilosa	Replication	3	0.110	0.037	0.39	
	Cropping cycle	3	0.714	0.238	2.53	0.066
	Error	57	5.367	0.094		
	Total	63				
C. benghalensis	Replication	3	0.304	0.101	1.23	
	Cropping cycle	3	0.905	0.302	3.67	0.017
	Error	57	4.682	0.082		
	Total	63				
C. velutina	Replication	3	0.214	0.071	0.75	
	Cropping cycle	3	1.750	0.583	6.11	0.001
	Error	57	5.439	0.095		
	Total	63				
C. floribundus	Replication	3	0.481	0.160	5.28	
	Cropping cycle	3	1.161	0.387	12.74	<.001
	Error	57	3.372	0.030		
	Total	63				
C. hirta	Replication	3	0.102	0.034	1.80	
	Cropping cycle	3	0.406	0.135	7.18	<.001
	Error	57	1.073	0.019		
	Total	63				
D. parviflora	Replication	3	0.826	0.275	4.73	
	Cropping cycle	3	0.774	0.258	4.43	0.007
	Error	57	3.320	0.058		
	Total	63				
E. cylindrica	Replication	3	0.178	0.059	2.55	
	Cropping cycle	3	3.828	1.276	54.84	<.001
	Error	57	1.326	0.023		
	Total	63				
M. mer	Replication	3	0.238	0.079	0.84	
	Cropping cycle	3	1.100	0.366	3.88	0.014
	Error	57	5.372	0.094		
	Total	63				
P. max	Replication	3	0.691	0.230	7.56	
	Cropping cycle	3	1.535	0.511	16.78	<.001
	Error	57	1.738	0.030		
	Total	63				
P. pur	Replication	3	0.317	0.106	6.33	
	Cropping cycle	3	1.944	0.648	38.81	<.001
	Error	57	0.951	0.017		
	Total	63				
S. rhombifolia	Replication	3	0.086	0.029	0.64	
	Cropping cycle	3	0.446	0.149	3.36	0.025
	Error	57	2.526	0.044		
	Total	63				
Tagia	Replication	3	0.085	0.028	6.60	
	Cropping cycle	3	0.275	0.092	21.49	<.001
	Error	57	0.243	0.004		
	Total	63				

Appendix 5 Cont'd: ANOVA table of the impact of tobacco cropping cycles on weed flora occurrence

Weed *sp*	Sources of variation	DF	SS	MS	F	P-value
G.scabra	Replication	3	0.650	0.217	4.17	
	Cropping cycle	3	0.583	0.194	3.74	0.016
	Error	57	2.960	0.052		
	Total	63				
O.latifolia	Replication	3	1.200	0.400	11.83	
	Cropping cycle	3	0.097	0.032	0.95	0.421
	Error	57	2.927	0.034		
	Total	63				
P.conv	Replication	3	0.001	0.000	0.06	
	Cropping cycle	3	0.014	0.005	1.17	0.328
	Error	57	0.232	0.004		
	Total	63				
P.ovalifolius	Replication	3	0.195	0.065	1.00	
	Cropping cycle	3	0.377	0.126	1.93	0.135
	Error	57	3.703	0.065		
	Total	63				
S.nigrum	Replication	3	0.040	0.013	7.44	
	Cropping cycle	3	0.010	0.003	1.86	0.147
	Error	57	0.101	0.002		
	Total	63				
B.diffusia	Replication	3	0.019	0.006	0.22	
	Cropping cycle	3	0.168	0.056	1.96	0.130
	Error	57	1.630	0.029		
	Total	63				
C.rot	Replication	3	0.049	0.016	0.40	
	Cropping cycle	3	0.606	0.202	4.95	0.004
	Error	57	2.327	0.041		
	Total	63				
C.trigyna	Replication	3	0.594	0.198	3.10	
	Cropping cycle	3	0.363	0.121	1.89	0.141
	Error	57	3.639	0.064		
	Total	63				
Crot. Spp	Replication	3	0.024	0.008	5.32	
	Cropping cycle	3	0.007	0.002	1.55	0.212
	Error	57	0.084	0.001		
	Total	63				
E.heter	Replication	3	0.286	0.095	3.83	
	Cropping cycle	3	0.087	0.029	1.17	0.331
	Error	57	1.419	0.025		
	Total	63				
Triumfeta	Replication	3	0.016	0.005	0.14	
cardifolia	Cropping cycle	3	0.724	0.241	6.02	0.001
	Error	57	2.284	0.040		
	Total	63				

Appendix 6: ANOVA of the impact of maize fallow break crop on weed flora occurrence

Weed *sp*	Sources of variation	DF	SS	MS	F	p-value
B.pilosa	Replication	3	0.392	0.131	1.89	
	Cropping cycle	3	1.053	0.351	5.08	0.007
	Error	25	1.728	0.069		
	Total	31				
C.benghalensis	Replication	3	0.305	0.102	1.11	
	Cropping cycle	3	0.283	0.094	1.03	0.397
	Error	25	2.291	0.092		
	Total	31				
I.cylindrica	Replication	3	0.435	0.145	8.14	
	Cropping cycle	3	1.493	0.498	27.93	<.001
	Error	25	0.445	0.018		
	Total	31				
D.velutina	Replication	3	0.416	0.139	1.52	
	Cropping cycle	3	0.284	0.095	1.04	0.393
	Error	25	2.279	0.091		
	Total	31				
E.flor.	Replication	3	0.894	0.298	3.54	
	Cropping cycle	3	0.230	0.077	0.91	0.450
	Error	25	2.106	0.084		
	Total	31				
E.hirta	Replication	3	0.282	0.094	0.98	
	Cropping cycle	3	0.417	0.139	1.45	0.252
	Error	25	2.391	0.096		
	Total	31				
G.parviflo.	Replication	3	0.427	0.142	1.51	
	Cropping cycle	3	0.300	0.100	1.05	0.386
	Error	25	2.364	0.095		
	Total	31				
M.merc.	Replication	3	0.294	0.098	1.97	
	Cropping cycle	3	0.372	0.124	2.50	0.083
	Error	25	1.241	0.050		
	Total	31				
P.max	Replication	3	0.224	0.075	3.54	
	Cropping cycle	3	0.728	0.243	11.51	<.001
	Error	25	0.527	0.021		
	Total	31				
P.pur	Replication	3	0.159	0.053	2.78	
	Cropping cycle	3	0.972	0.324	17.02	<.001
	Error	25	0.476	0.019		
	Total	31				
Sida spp	Replication	3	0.317	0.106	2.66	
	Cropping cycle	3	0.503	0.168	4.23	0.015
	Error	25	0.992	0.040		
	Total	31				
A..zygia	Location	3	0.035	0.012	2.78	
	Cropping cycle	3	0.149	0.050	11.94	<.001
	Error	25	0.104	0.004		
	Total	31				

Cont'd Appendix 6: ANOVA of the impact of maize fallow break crops on weed flora occurrence

Weed flora	Sources of variation	DF	SS	MS	F	p-value
B.diffus	Replication	3	0.052	0.017	0.46	
	Cropping cycle- -	3	0.104	0.035	0.91	0.448
	Error	25	0.951	0.038		
	Total	31				
C.rot	Replication	3	0.047	0.016	0.92	
	Cropping cycle	3	0.034	0.011	0.67	0.581
	Error	25	0.427	0.017		
	Total	31				
C.trigyna	Replication	3	0.190	0.063	1.56	
	Cropping cycle	3	0.374	0.125	3.06	0.046
	Error	25	1.016	0.041		
	Total	31				
P.Ovalifolius	Replication	3	0.530	0.177	2.58	
	Cropping cycle	3	0.423	0.141	2.06	0.132
	Error	25	1.715	0.069		
	Total	31				
S.nigrum	Replication	3	0.006	0.002	1.57	
	Cropping cycle	3	0.004	0.001	0.87	0.468
	Error	25	0.035	0.001		
	Total	31				
C.trigyna	Replication	3	0.426	0.142	2.16	
	Cropping cycle	3	0.316	0.105	1.60	0.214
	Error	25	1.643	0.066		
	Total	31				
Crot.Spp	Replication	3	0.006	0.002	1.26	
	Cropping cycle	3	0.001	0.000	0.25	0.859
	Error	25	0.041	0.001		
	Total	31				
E.heter	Replication	3	0.034	0.011	0.15	
	Cropping cycle	3	0.446	0.149	1.91	0.154
	Error	25	1.945	0.078		
	Total	31				

Cont'd Appendix 6: ANOVA of the impact of maize fallow breaks on weed flora occurrence

Weed spp	Source of variation	DF	SS	MS	F	P-value
G. scabra	Replication	3	0.363	0.121	2.24	
	Cropping cycle	3	0.470	0.157	2.90	0.055
	Error	25	1.349	0.054		
	Total	31				
S.nigrum	Replication	3	0.003	0.001	0.57	
	Cropping cycle	3	0.000	0.000	0.16	0.925
	Error	25	0.050	0.002		
	Total	31				
O.latifolia	Replication	3	0.097	0.032	1.54	
	Cropping cycle	3	0.047	0.016	0.75	0.533
	Error	25	0.524	0.021		
	Total	31				
P.convo	Replication	3	0.003	0.000	0.45	
	Cropping cycle	3	0.005	0.001	0.86	0.474
	Error	25	0.051	0.002		
	Total	31				
Triumfta	Replication	3	0.074	0.025	0.71	
	Cropping cycle	3	0.417	0.139	4.01	0.019
	Error	25	0.867	0.035		
	Total	31				

Appendix 7: QUESTIONAIRE FORM

Respondent.....Date of interview.....

Status of respondent: Participant..... 1 Non-participant.....2

Sub-county.....Village.....

SECTION 1: SOCIAL DEMOGRAPHIC INFORMATION

1.0 Sex: Male.....1, Female.....2

1.1 Age in years.....

1.2 Marital status; Single: 1, Married.....2, Widowed.....3

1.3 Education level/profession: Number of years in school.....

1.4 Occupation; off activities.....1

Full on land.....2

1.5 No. of years spent farming.....

1.6 Type of farmer

Small subsistence scale.....1
Medium semi commercial.....2
Large scale commercial scale.....3

SECTION 2: LAND ACREAGE

2.0 Total amount of land owned in acres.....

2.1Land form: consolidated.....1. Fragmented.....2

2.2 How did you acquire this land?

Inherited.....1
Rented.....2
Borrowed.....3
Given.....4
Bought.....5
Other.....6

SECTION 3: FARMING ACTIVITIES

3.0 Crop husbandry (Traditional cash crops, e.g coffee, cotton)

Presence.....1
Absent (None).....2

3.1 Annual crops.....

3.2 Change in productivity:

Increased.....1
Decreased.....2
No change.....3

3.3 Reason for change in productivity.

Weather fluctuation=1
Soil exhaustion=2
Pests and diseases=3
Poor extension=4
Use of agrochemicals = 5
Other = 6

3.4 Animal husbandry

Animal species kept

Animal products

Rating for milk yields

Very low=1
High=2
Low=3
Very high=4

3.5 Where animals are grazed

On fixed paddocks----------1

Fallowed land----------2
Communal grazing land----------3

SECTION 4: CULTURAL PRACTICES

4.1 Knowledge of the importance of manure

Yes----------1 No.....2

If yes, have you used them on your land?
Yes.....1
No.....2
Only on tobacco.... 3

4.2 Do you use organic manure
Yes.....1
No.....2

If yes, specify (Compost = 1, Green manure = 2, Farm yard manure = 3)

4.3 Do you use inorganic manure?
Yes.....1
No.....2

If yes, specify the types that are used (NPK = 1, CAN = 2, both = 3, other)

4.4 How many bags of NPK do you apply on your garden?
(1 bag =1, 2 bags = 2, 3bags =3, none =4)

4.5 How many bags of CAN do you apply on your garden?
(1 bag =1, 2bags=2, 3bags = 3, none = 4)

4.6 Do you practice mulching?

Yes.....1
No.....2

If yes, what type of mulch do you use?
(Crop residues = 1, cover crop = 2, other = 3)

4.7 Do you rotate your crop?
Yes.....1
No.....2

If yes, which crops do you grow in the rotation? .....

4.8 Do you practice intercropping?
Yes.....1
No.....2

If yes, which crop do you grow together?

4.9 Do you leave your land to rest (fallow)?

Yes.....1

No.....2

If yes, what is the average rest-period?.

4.10 Tillage method mostly practiced (zero tillage = 1, minimum = 2, conventional tillage = 3)

4.11 Tillage implements used (Hand hoe, Animal traction= 2, Tractor plough = 3, any combination among the three = 4) What tillage implements have you been using?

4.12 Do you see any forms of soil organisms during ploughing, harrowing or planting?

Yes.....1

No.....2

4.13 Do you use pesticides?

Yes.....1

No.....2

If yes, which types.....

How much pesticide do you mix in 15-litre tank? .....

4.14 Do you burn grass and crop residues on your land?

Yes.....1

No.....2

4.15 Do you maintain ground cover on your land?

Yes.....1

No.....2

SECTION 5: LAND USE HISTORY IN RELATION TO TOBACCO GROWING

5.1 Original natural cover of the area (Forest = 1, Grass land = 2, Other =3)

5.2 Number of years spent growing tobacco on this land.....

5.3 Have you been using chemical pesticides and mineral fertilizers on your tobacco for all this time?

Yes.....1 No.....2

5.4 What was the previous land-use prior to tobacco growing this season (Food crop fallow = 1,Grass fallow =2, tobacco crop = 3, other = 4)