Enhancing Soil Fertility for Cereal Crop Production Through Biological Practices and the Integration of Organic and In-Organic Fertilizers in Northern Savanna Zone of Ghana

James M. Kombiok, Samuel Saaka J. Buah and
Jean M. Sogbedji

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1. Introduction

In Ghana, it has been estimated that 60 % of the population makes their living from subsistence farming with an average of 27% living in extreme poverty (MoFA, 2002). This is because the most dominant economic activity of the area is agriculture and once agriculture is not well developed, one of the effects is poverty. As observed by many, one of the characteristics of underdeveloped agriculture is the dominance of subsistence farming in these regions (MoFA, 2002, RELC 2004). The slow economic growth and high poverty level prevailing in Northern Ghana (Upper East, Upper West and the Brong-Ahafo regions) is therefore directly linked to the underdeveloped agricultural sector of the area.

The most affected area in the country is Northern Ghana as it is estimated that up to 80% of the population in this part of the country is poor (Ekekpi and Kombiok, 2008). The many agricultural interventions to transform the small scale farming system and reduce poverty in northern Ghana have largely failed due to several problems such erratic rainfall and poor soils. Further analysis of the northern Ghana agricultural sector problems indicates that poor soils result in low crop yields which are negatively affecting the development of Agriculture (RELC, 2005).

It is therefore not surprising that low soil fertility has always been mentioned by farmers as one of the constraints affecting cereal production in Northern Ghana (RELC, 2005). This is confirmed by the fact that low grain yields of cereals attributed to poor soils for the past decade has been ranked first among the constraints collated from all the districts of northern Ghana at the various regional planning sessions.

The low soil fertility in this part of the country is therefore blamed on the bush fires which usually occur annually during the dry season commencing from October to April the following year (SARI, 1995). This situation renders the soil bare exposing it to both wind and water erosion in the dry and rainy seasons respectively thereby depleting the macro-nutrients such as Nitrogen, Phosphorus and Potassium (NPK) and organic matter from the soil.

Initially, farmers used to replenish the soil with its nutrients by practicing shifting cultivation or land rotation. However, with the increase in population which has put pressure on land use, this practice is not being sustained and this therefore calls for other measures to maintain soil fertility for sustainable crop production in the savanna zone of Ghana.

The purpose of this chapter is therefore to expose to Agricultural science teachers/trainers, scientists and farmers:

- to the available soil fertility enhancing practices applicable in the Savanna zone of Northern Ghana.
- To discuss and recommend for adoption the most proven practices involving organic and in-organic materials either by applying each individually or the combination of both in the management of soil fertility for crop production in the Savanna zone of Ghana.

2. Materials and methods

Materials used were the various works done in the area of soil fertility management in the Savanna regions within the sub-Saharan Africa. These are published books, journal papers, annual reports and technical reports. It also included works done by the author, students dissertation supervised by the author and personal experiences gathered. Success stories from other interventions by the Government and Non-governmental Organizations implemented in the form of projects to raise soil fertility status in the zone were also considered. All were reviewed, discussed and conclusions drawn from the results of these various practices.

The various interventions being practiced within the Sub-region to enhance or maintain the soil fertility status include the manipulating of the crops planted (cropping systems) in the area. Others are land rotation, conservation agriculture and the application of different types of soil fertility enhancing materials and the integration of some or all of these as a single treatment. The difficulties associated with adoption of these practices will also be outlined. Some of these are:

3. Land rotation or shifting cultivation

It is a crop production system based on rotation of cultivated period on a given piece of land. The cultivated period is always shorter than the fallow period because the system is characterized by the use of very little or no external soil fertility improving inputs. The soil fertility is therefore recovered by a natural process which is often very slow. The length of fallow period is determined by land availability but can last between 10 and 20 years after which the vegetation is cut back to allow another cycle of farming activities(EPA, 2011). This is no longer practiced because of the scarcity of arable land as a result of high growth in population of the country.

4. Cover cropping and improved short-season fallow with leguminous cover crop

The practice of planting certain crops to cover the cultivated area of fallow land thereby providing protection for the purpose of reducing erosion by rain drop splash and surface runoff and weed growth is referred to as cover cropping. Where necessary, cover crops are cut down or killed by weedicides so that the seasonal crops can be planted in the mulch.

Improved short fallow is the planting of leguminous cover crops consciously with the objective of protecting the soil surface and fixing nitrogen as part of the crop fallow. The system is practiced where land is limited and farmers rely on little or no external soil enhancing materials to improve the soil fertility status. Examples of cover crops*: Mucuna pruriens, Dolicus lablab Canavalia ensiformis.* Sometimes edible cover crops such as the creeping types of cowpea are used.

Improved fallow systems using e.g. *Mucuna puriens* are promoted by different projects in Ghana. So far, the system seems to be adopted only by some farmers in certain areas (Quansah et al., 1998). Benefits observed by the farmers may vary and include increased soil moisture, weed suppression and residual yield effects on maize. Leguminous fallows have been used in northern Ghana to accumulate N from biological N fixation (BNF), smother weeds, and improve soil physical properties (Fosu et al., 2004). Leguminous cover crop systems apparently were more extensively tested than tree fallow systems in the country. Demand for arable land in many parts of the country has increased in recent years in response to increasing human population. This situation is gradually moving the emphasis from resting fallow to continuous and intensive cropping. However, some farmers in southern Ghana can still fallow their lands up to two years or two seasons. Leguminous cover crops such as *Callopogonium, Dolichos, Mucuna* and *Cannavalia* species are the main cover crops used during this short fallow. In the north, farm lands to undergo short term fallow of about two years were planted to either *Mucuna* or *Callopogonium* and left for these number of years. In the third year the residue was either ploughed in or if it was dry, the crop was planted directly into the mulch. This system was found to increase maize yields in both on-station and on-farm trials (Kombiok et al, 1995) as seen in Table 1. The highest mean yield of maize was obtained when residue was left but maize planted in it and this could be due to the micro-climate created by the residue on the surface and the decay of some of the residue to make N available to the crop.

Treatment	0 N kg/ha	40 N kg/ha	Mean
1-Residue not removed /No till	4110	4630	4370
2-Residue removed/No till	3043	3825	3434
3-Residue worked in by hoeing	3542	5176	4359
4-Residue removed/hoeing	3249	4249	3749
Mean	3486	4470	3978

Source: Kombiok et al 1995

Table 1. Maize Yield (kg/ha) under 4 different Management Practices after 2 years of *Callopogonium* fallow and three rates of nitrogen fertilizer at Nyankpala

In the wetter southern parts of the country, *Cannavalia or Mucuna* is planted as a minor-season fallow, from August to March. In the next major season beginning in April, farmers plant their crops (maize, yam, cassava or any other crop) through the mulch without burning. Weed control in the crops is by the hoe in northern Ghana and cutlass in southern Ghana when necessary. Where rainfall during the major season is not reliable, farmers plant the cover crop in April, and plant the food crop in the minor season (August–September). A synthesis of results of trials of a *Mucuna* fallow system by Carsky et al. (2001) suggested that in simultaneous intercropping systems, the yield of maize associated with *Mucuna* is decreased dramatically as the Mucuna smothers the maize. However, maize yield reduction from relay intercropping of Mucuna at 40 to 50 days after maize planting is only about 5%.

Similarly, in a 2-yr study on a typical plinthic Planleustalf in the savanna zone of Ghana, Kombiok and Clottey (2003) found that maize grain yields obtained after two years of interplanting *Mucuna* was highest at 6 weeks after planting followed by 8 weeks after planting and the least was obtained from 10 weeks after planting (Table 2). It was also found that N was highest in the plot with *Mucuna* planted 6 and 8 weeks after maize compared to 10 weeks and the bush fallow treatments due to the amount of biomass produced by the cover crop. They concluded that the highest yields of maize from relay cropping of *Mucuna* at 6 weeks after maize was due to the beneficial effects of the decay of the higher *Mucuna* biomass produced in that treatment in the previous years. It is clear that if *Mucuna* does not accumulate substantial biomass, then it will not accumulate sufficient N as well as suppress weeds. They however recommended the pruning of Mucuna as a management strategy to ensure it does not smother the maize crop in association with the cover crop.

Treatments	Maize grain yield (kg ha^{-1})[1]		
	1996	1997	1998
Control	1800 a	1180 b	1050 d
6 WAP	1500 b	1620 a	1850 a
8 WAP	1130 c	1110 b	1650 b
10 WAP	1100 c	1530 a	1250 c

[1]For a factor. means followed by a similar letter in a column are not significant at 5% level of significance

[2]WAP. Weeks after planting

Source: Kombiok and Clottey 2003

Table 2. Maize grain yield as affected by time of interplanting mucuna in maize and after two years of continuous mucuna

In some cases where weed infestation is high, farmers still have to do one weeding. After establishment, the *Mucuna* survives the short dry period during July–August and later forms a thick biomass that peaks in mid-November. This biomass canopy then covers the soil until it starts to decompose in the dry season in December– January. *Mucuna* seeds are then harvested and stored for later use. Unlike the late-maturing *Mucuna* variety, planting the medium- to early-maturing mottled variety is done at the onset of the minor season (Loos et al. 2001). Clearing and at least one initial weeding may be necessary for successful establishment. Once established, the biomass covers the soil surface and dies back naturally with the onset of the dry season. This means that no other food crop can be planted on the land that has an improved *Mucuna* fallow. After the improved fallow, farmers plant any other crop such as maize, yam, cassava or plantain. Incorporating *Mucuna* into the local cropping systems by intercropping *Mucuna* with plantain during the first season can be very economical. Such a system reduces the overall demand for labour, as it requires only spot weeding of *Mucuna* vines at certain intervals.

In places where rice cultivation is significant, farmers have developed and adapted *Mucuna*–rice rotations. Here, farmers cultivate rice in the major season and follow it with *Mucuna* in the minor season to suppress weeds and improve the fertility of the soil. *Canavalia ensiformis* did not attract the same attention as *Mucuna* because it was less vigorous in growth and did not suppress weeds as well as *Mucuna*. The less aggressive nature of *Canavalia* made it an ideal cover crop to use in mixed-cropping systems.

5. Cropping systems

A cropping system may be defined as a community of plants which is managed by a farm unit to achieve various human goals (FAO, 1995). In this particular case the cropping system is to achieve an enhanced soil fertility status for increased crop production.

5.1. Multiple cropping

It is the growing of different arable crops and /or other crops on a given piece of land at the same time. The aim is to increase the productivity from the land while providing protection of the soil from erosion. Growing more than one crop at the same time also cushions the farmer against total crop failure as adverse growing conditions might not affect the different crops equally-*sequential cropping* (growing two or more crops on the same piece of land within the same year or season but planting one after harvesting the other) or *intercropping* which is the growing of two or more crops on the same piece of land at the same time (Abalu, 1977). The existence of multiple cropping especially intercropping system involving mostly cereals and legumes among the small scale farmers of West Africa has long since been identified (Norman, 1975) and studied by many workers including Andrews and Kassam (1976), Fisher (1979) and Willey (1979).

Some of the reasons advanced for the persistence of this system of cropping have been precautions against uncertainty and instability of income and unstable soil fertility maintenance (Abalu, 1977). In most of the intercropping trials implemented in the sub-region the results of the crop yields showed that there have been agronomic advantages in the practice since the Land Equivalent ration (LER) is always more than one (1). In addition to the agronomic advantage in terms of yield associated with intercropping systems, a substantial amount of N is also fixed by the leguminous component of the system (Table 3).

Cropping System	Maize grain		Cowpea grain		%N fixed	
	2000	2001	2000	2001	2000	2001
Sole	2734	2400	1401	1153	40.47	62.42
Inter	1069	1731	954	544	30.20	34.74
Intra	-	1938	-	473	-	28.72
SE	124	111	52	28	6.08	10.89
LSD (0.05)	398	355	166	91	NS	NS

Source: Kombiok et al 2005

Table 3. Grain yields (kg ha^{-1}) of maize and cowpea and percent N fixed as affected cropping Systems 2000 and 2001

It was found that more than 50% N was fixed by the component cowpea in maize cowpea mixture. This is very beneficial to the farmers since the cereal crop component of the system will benefit from this N fixed if the legume matures earlier than the cereal. Secondly, there will also be a residual N left in the soil for use by any subsequent crop grown on the same piece of land in the next cropping season.

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5.2. Crop rotation and intercropping

Cereal production in Ghana, especially northern Ghana is limited by low levels of nitrogen in the soil. Strategies such as intercropping/mixed cropping and crop rotations involving cereals and legumes have been adopted to raise crop yields as they fix substantial amounts of atmospheric N, can provide large amounts of N-rich biomass. Legumes grown as a food crop or live mulch (cover crop) can be successfully rotated with a crop which produces high biomass or intercropped with tree species (e.g. alley cropping) in order to provide N, enhance organic matter content and agroforestry. The amount of N returned from legume rotations depends on whether the legume is harvested for seed, used for forage, or incorporated as a green manure.

Crop rotation entails the growing of different crops in a well defined sequence on the same piece of land- Changing the type of crops grown in the field each season or year. Eg; a field could be planted to maize in the major season as in the south of Ghana and after harvesting, the same field is planted to cowpea in the minor season of the year. In the savanna region this will be done yearly since there is only one rainy season/cropping season in a year.

Crop rotation forms a central pillar of CA, and many approaches highlight the use of cereal–legume rotations. Rotations allow crops with different rooting patterns to use the soil sequentially, reduce pests and diseases harmful to crops and sustain the productivity of the cropping system. The most widely grown legumes in the farming systems of Ghana are the grain legumes; groundnut, cowpea and soybean. These crops have the advantage over other legumes in that they provide a direct economic yield for food or for sale. Yet unless there is a ready market for the grain, farmers tend to grow grain legumes on only a small proportion of their land, and certainly not sufficient to provide a rotation across the farm. Analyses in northern Ghana, where farmers indicated their normal rotation is cereal/legume, showed that the actual area sown to the legume was often less than 30% of the farm area. Further investigation indicated that crop rotations tended to be practiced more on the fertile 'home-fields' than on the poorer outfields.

The yield response of cereal crop following a legume can be substantial. In Ghana, the grain yield of sorghum crop following groundnut averaged 30-40% higher than the yield of continuous sorghum (Schmidt and Frey, 1992; Buah, 2004). Horst and Härdter (1994) showed large maize yields in northern Ghana following cowpea. In all the cases, crop residue was not removed from the field after harvest. Nonetheless, crop residues are often removed from the field at harvest so they do not provide the mulch cover wanted for CA. Various field experiments have shown that crop rotation of maize with various legumes was beneficial for maize production and that maize following groundnut often had the greatest yields when compared with maize following other legumes (Härdter, 1989; Horst and Härdter, 1994; Schmidt and Frey, 1992). Cotton-maize rotation is the most common rotation system in the northern part of Ghana. Cotton, even though not a legume, its production is accompanied by the application of inputs such as fertilizers and chemicals. Maize is therefore planted after cotton to take advantage of the residual fertilizers applied in the previous year. Farmers have reported increases in maize yields in the north by several tons per hectare as a result of cultivating maize after cotton in a rotation system. In southern Ghana where there are two cropping seasons, maize is planted in the major season (April-June) and an edible legume such as cowpea or a cover crop (*Mucuna*) is planted in the minor season.

A legume as a candidate crop in intercrop systems is again being encouraged because of the same reason as above. In the northern part of Ghana where the soils are low in both organic matter and essential nutrients, farmers intercrop cereals with legumes. The most common intercropping systems in this area are maize/cowpea, millet/cowpea, and maize/soybean. In some cases, both in the north and south of Ghana cover crops such as *Mucuna or Callopogonium* is planted in maize at the latter part of its growth cycle (6 weeks after planting maize). In southern Ghana, maize is harvested earlier and the cover crop (*Mucuna*) is left to grow into the minor season (August to March) until the next major season (April to August). In the northern savanna zone however, the cover crop dries when the rains end in October and the residue forms mulch protecting the soil. The incorporation of the residue in the soil after two years of cropping increased both the soil nitrogen and maize grain yield significantly (Kombiok Clottey, 2003).

One approach that has proved to be inherently attractive to farmers and is standard practice in most parts of northern Ghana is intercropping maize or sorghum with the grain legume cowpea or groundnut. If cowpea is sown between maize rows, the plant population and yield of maize can be maintained, whilst reaping the advantage of yield from the cowpea harvest. There is high labour requirement in the practice of intercropping because more than one crop is being planted at a time. So, labour is required for planting the component crops and for the careful control of weeds in the system. Insecticides are needed for the control of insect pests on the legume component either being rotated or intercropped.

Pigeon pea is an ideal legume for intercropping with cereals. Its slow initial growth affords little competition with the cereal for light or water, and it continues growing into the dry season after the maize crop has been harvested. The leaves that fall from pigeon pea before harvest provide a mulch and can add as much as 90 kg N/ha to the soil that then mineralizes relatively slowly during the subsequent season, releasing N for the next maize crop (Adu-Gyamfi et al., 2007). Thus a substantial rotational benefit, although not a perfect soil cover, can be achieved for the next season.

6. Conservation agriculture technologies for soil fertility management in Ghana

Conservation Agriculture (CA) is described as a set of practices or procedures carried out that ensure higher agricultural productivity and profitability whilst improving soil health and environment. It is known to be hinged on three basic principles which are (i) Little or no disturbances of the soil, (ii) The soil should have a cover all year round and (iii) the crops should be in rotation from season to the other or in intercropping situations.

Conservation Agriculture was introduced into Ghana in the early 1970s, mostly through donor funded Agricultural projects. Even though results in terms of crop yields from the various on-farm experiments have been found to be higher than the yields from the traditional slash and burn method of farming, it has not been easy to convince farmers to adopt the practice holistically. Generally the adoption of CA by farmers in Ghana is therefore low and those who are said to have adopted CA may either be practicing one or two of the principles of CA such as no-till, no-till with intercropping but not all the three principles of the practice. Comparatively, climatic and weather conditions in the southern part of the country favour the adoption of some of these principles. For example, the rainfall system in the south is bi-modal with only a dry period of less than three months. This allows the growth and development of vegetation all year round and therefore not prone to bush fires. The decay of these vegetative matter when killed by weedicide, will go a long way to enrich the soil with its nutrients.

On the other hand, the northern part of Ghana has only one rainy season which commences in late May and ends in early November with a dry period of about five months which is characterized by the Hamattan winds. During the dry season, the vegetative matter is dried up and therefore prone to bush fires. The occurrence of bush fires either accidentally or intentionally, clears up all the dry vegetative cover exposing the soil to the Harmattan winds in the dry season and the running water during the rainy season which robs the soil of its nutrients. It is therefore not surprising to know that farmers in the northern part of the country consider any technology that conserves soil and water such as soil bunding as a CA technology. Table 4 shows the results of a survey that was carried out to identify technologies related to CA practiced by farmers in the northern part of Ghana. Comparatively, among the districts covered, East Mamprusi recorded a higher percentage of farmers practicing some of these technologies than Lawra or Bawku which according to Ekekpi and Kombiok (2008) could be indicative of better extension services in that district.

Technology	East Mamprusi (%)	Lawra (%)	Bawku (%)
Contour bunding	19	47	19
Crop rotation/intercropping	60	3	4
Agro-forestry	3	16	3
Manure/refuse application	22	16	19
Minimum tillage	3	0	0
Crop residue management	31	3	2
Composting/application	50	63	50
Organic farming	0	0	0
Animal traction	4	22	20
Rotation kraaling	3	0	0
Bush fallow	3	0	0

Number of respondents = 32

Source: Ekekpi and Kombiok, 2008

Table 4. Percentage of farmer respondents on CA technologies in the savanna zone

6.1. Direct seeding

Direct seeding of crops is carried out without tilling the land in most parts of Ghana. In the southern part of the country (forest zone) where vegetation exists all year round, the vegetation is slashed using a cutlass and the residue instead of burning, is left as mulch on the farm. However, in the north, the crops (maize, sorghum and millet) are planted directly on the bare soil since all vegetative matter would have been burnt during the dry season. In both cases, the crops are planted using a dibbling stick or cutlass to create holes either on the bare soil (North) or inside the mulch as in the case of the South. This is advantageous in the South since the farmer will benefit from the mulch as it will conserve soil water and eventually decay with time to add nutrients to the soil within the season. Under such a situation, the physical and biological properties of the soil are also expected to improve after the mulch decomposes. In the north however, weeding should be carried out within three weeks after planting after which fertilizer or manure would be applied to the farm since the soil is devoid of vegetative cover at planting. This is to be sure that the crops are supplied with enough nutrients and to avoid heavy weed infestation on the farm which can reduce crop yields.

6.2. Minimum or reduced tillage

Minimum tillage is the reduction in the number of times the soil is being tilled as in conventional tillage method (ploughing/harrow/ridge) before and after the crop is planted. In Ghana, most farmers have adopted the use of weedicide to reduce tillage for land preparation for crop production because of its additional benefits of reducing labour cost. Other benefits of minimum tillage include the reduction in energy costs and it enhances the organic matter content of the soil while conserving the soil.

The vegetation is either slashed or sprayed with weedicides followed by either burning the dead vegetation as done in the forest and transitional zones of Ghana before crops are planted. This implies the land is not tilled before planting. However, weeds in this system are controlled by the use of cutlasses in the south while in northern Ghana, this done by hand hoe or the use of bullocks thus reducing the number of times the soil is tilled. The use of hoe as practiced in the north in weed control helps to bury the young weeds that have just emerged after planting which easily decay and return nutrients in to the soil for crop use. The burning of the vegetation before planting the crop by farmers in the south has been discouraged since the full benefits of mulch which include improved moisture infiltration to reduce soil erosion will not be realized in such a situation (Wagger and Denton, 1992).

It is common to see farmers in northern Ghana planting annual crops such as maize, millet and sorghum on the old ridges constructed in the previous year. In the southern part of Ghana, it is the use of *glyphosate* (a total weed killer) at the recommended rate of 3l/ha which can be increased if noxious weeds such as spear grass (*Imperata cylindrical)* is present. It is advisable for farmers to delay planting of their crops for at least one week after the application of *glyphosate* to allow the breakdown of the chemical and to identify the portions not well treated. The dead weeds are either buried or left on the surface of the soil as done in the south. In both cases however, the number of times the land is physically tilled is reduced since tillage activity before planting the crop is avoided and this helps to maintain the structure of the fragile soil of the area.

In some cases, the application of pre-emergent weedicides such as Atrazine for maize production can also help to delay or avoid the use of hand hoe to remove weeds after planting of the crop. Comparing the north and south, not much fertilizer is applied in the south probably because the fertility of the soil is always improved after the mulch decomposes in the subsequent seasons. For high yields of crops in the north, application of higher rates of fertilizers is required.

6.3. Alley cropping with cover crops

Alley cropping is not widely practiced in Ghana but this is found in few places in the southern part of Ghana. It is similar to agro-forestry systems where fast growing shrubs or trees such as pigeon pea is planted in alleys while cover crops such as *Mucuna* or *Calapogonium* spp are planted to protect the soil from erosion and for weed control. Afetr harvesting the pigeon pea in the alleys, the biomass is harvested and used as mulch on the cover crops where maize is planted directly in the mulch. In this system, nitrogen is fixed in the soil from atmosphere by both the pigeon pea and the cover crops. Also, the decay of the biomass from the pigeon pea goes to enhance the N status of the soil which goes to improve the yield of the maize. Soil water is conserved and weeds are controlled effectively under this system.

6.4. Strip cropping

The planting of alternating strips of several crops aligned on the contour in the field is known as strip cropping. It is an effective conservation measure on slope between 5 and 10%. In this case, erosion is largely limited to the row crop strip and soil removed from these is trapped in the next strip down slope which is generally planted to close growing crops.

Strip cropping involving pigeon pea has many additional advantages especially in a mixed farming situation. In northern Ghana, almost every farm family raises livestock (goats, sheep and cattle) as well as poultry in addition to crop production (SARI, 1995). It is therefore common to find strips of pigeon pea on most fields where the grain is harvested and cooked on the farm as lunch for the family. Studies have shown that the biomass of pigeon pea can be pruned over three times within a year and shade-dried to feed livestock during the dry season. Among the three pruning heights of pigeon pea at 30, 60 and 90 cm in the trial, it was found that pruning at 90 cm height for livestock, the pigeon pea would still be able to produce seed at the end of the year which would not be significantly ($p<0.05$) different from the plant that was not pruned (Table 5). With the exception of the pigeon pea pruned at 30 cm, which produced significant highest amount of litter, the quantity of litter produced by those pruned at 60 cm and 90 cm were similar.

Pruning height of Pigeon pea (Fallow)	Dry Matter (litter) tons/ha		Grain yield of maize Tons/ha		Seed yield of pigeon pea (tons/ha)
	1997	1998	1998	1999	1998
Pigeon pea (no pruning)	2.13	4.27	3.32	1.16	1.11
Pigeon pea (30 cm)	0.37	0.73	3.42	0.69	0.06
Pigeon pea (60 cm)	0.87	1.77	2.80	0.93	0.36
Pigeon pea (90 cm)	1.67	1.97	2.53	0.93	0.62
Source: Agyare et al, 2002					

Table 5. Effect of pruning on leaf litter production, grain yield of pigeon pea and maize yield after two years of fallow in the northern Savanna zone of Ghana.

It was found that maize yield after two years of pigeon pea fallow was highest in 1998 at 30 cm pruning height which was followed by the pigeon pea not pruned at all in the trial. But maize yields from plots with pigeon pea pruned at 60 and 90 cm heights were similar in value but significantly lower than the yield obtained from the plots with pigeon pea pruned at 30 cm. The high maize yields at no pruning and the pruning at 30 cm height were attributed to the higher quantity of litter fall from the pigeon pea.

It was then concluded that biomass obtained from the pruning of pigeon pea up to 60 cm will be able to provide sufficient fodder that may be used to supplement livestock feeding in the dry season (Agyare et. al., 2002). This situation would not be sacrificing much in terms of soil fertility status, pigeon pea grain yield and yield of subsequent maize crop. This option makes pigeon pea a valuable leguminous shrub for short season fallow for the mixed farmer.

6.5. Agroforestry

Agroforestry involves the integration of trees/shrubs and sometimes animal husbandry in the farming system. It combines annual crops with herbaceous perennials or trees on the same units.

Both exotic and local tree species were screened for Agro-forestry purposes in SARI as from 1985 (Table 6). The results showed that *Gliricidia* and *Leucaena* which are both exotic tree species are better trees for soil fertility restoration than the local tree species like *Parkia.* Both the *Leucaena* and *Gliricidia* produced enough biomass much earlier for incorporation than the rest of the tree species, It was also found that the incorporation of pruned biomass from the tree species was responsible for the increase in soil nitrogen. This therefore suggest that the faster the growth and development of the tree species to produce biomass for incorporation, the better the tree for agro-forestry system.

N fert. rate (kg/ha)	Acacia	Leucaena	Parkia	Gliricidia	Vilellaria	Check/ control	Mean
0	1397	1397	1533	2240	1227	1987	1625
40	2250	1960	1937	2623	1887	2860	2253
80	2203	2643	2333	2630	1833	3180	2471
Mean	**1950**	**1990**	**1935**	**2498**	**1649**	**2676**	**2116**
Source: SARI, 1985							

Table 6. Maize grain yield (kg/ha) under agroforestry system at SARI.

7. Application of fertilizers

The most common of the materials used as soil fertility enhancing substances however, are the organic and in- organic fertilizers. The recommended rates of in-organic fertilizers for the production of cereals especially maize in Ghana are the basal application of compound fertilizer made up of 15 % each of Nitrogen, Phosphorus and Potassium (NPK) at planting or two weeks after planting of 2 fifty kilograms (50 kg) bags per acre. This is followed by the application of either sulphate of Ammonia or urea at 1 fifty kilogram bag (50kg bag) or twenty-five kilogram bag (25 kg bag) per acre respectively just before the tasseling of maize. However, the acquisition of these materials whether the organic or in-organic fertilizers by farmers have also been faced with a lot of challenges.

In the first place, most of the small scale farmers are poor and cannot afford the recommended rates of the in-organic fertilizers to increase their crop yields. Most often, they just purchase the quantities that they can afford which are far below the recommended rates for the crops and therefore those quantities are unable to increase their yields. As a result, their crop yields still remain low and that explains why they remain poor.

Secondly, even though almost every farm family in northern Ghana possesses few livestock such as cattle, sheep, goats and or poultry, the dung (manure) they produce is highly inadequate to fertilize an area of one acre. Most of these categories of livestock are also on free range thereby making the gathering of their dung very difficult. In addition, some of the farms are very far from their homes so carting these bulky materials to their farmlands posses another challenge.

The above situation where farmers cannot afford recommended rates of in-organic fertilizers because they are poor and they also do not have enough animal dung to fertilize their crops call for the combination of both.

Maize grain yields (tons/ha)			
Treatments	**Bunkpurugu**	**Walewale**	**Karaga**
Tillage			
Bullock	0.98	1.21	0.41
Manual	1.06	0.85	0.08
LSD $_{(0.05)}$	**0.29**	**0.58**	**0.38**
Fertilizers			
NPK	1.12	1.46	0.30
Manure (6t/ha)	0.70	0.99	0.16
1/2 rates (manure &NPK)	1.00	1.09	0.37
FP (No NPK/No manure)	0.54	0.60	0.24
LSD $_{(0.05)}$	**0.27**	**0.31**	**0.33**

Source: CSIR-SARI 2007 Annual report

Table 7. Effect of tillage and fertilizer on maize grain yields at Bunkpurugu, walewale and Karaga

Studies have been conducted on the effect of tillage and fertilizers on the yield of maize for three consecutive years in three communities of the northern part of Ghana by the Savanna Agricultural Research Institute (SARI). Results confirmed that the application of the combination of half the rates of the organic and recommended in-organic fertilizers was as good as the application of the recommended in-organic fertilizers (Table 7) This suggests that, farmers with limited number of livestock or poultry can always supplement the manure they generate from these animals with half the rates of the recommended in-organic fertilizers to obtain high crop yields. The results however showed that there was no significant difference in yield of maize between the bullock and manual tillage systems indicating that any of the tillage systems will give similar maize yields.

Similarly, it has been found that the household waste generated and deposited outside the houses for several years are as rich in nutrients as the animal manure. Kombiok et al 1995 compared the yields of maize fertilized by animal dung and household waste in four communities of the East Mamprusi District of the Northern Region (Table.8).

Community	**Yield ton/ha**		
	R D(refused dump)	**A M (Animal dung)**	**No fertilizers**
Yaroyili	3.2	3.4	0.60
Bowku	2.7	2.8	1.33
Boayini	2.4	3.2	1.06
Tangbini	2.3	1.3	1.00
Average	2.65	2.68	0.99

Source: Kombiok et al 1995

Table 8. Effect of refuse and animal dung on the yield of maize at 4 sites in West Mamprusi District

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The results showed that in some of the communities, the yields of maize under the animal manure and the household refuse were similar suggesting that both materials could contain similar quantity of nutrients. The use of these as soil fertility enhancing materials will not only increase crop yields but will also help to improve the sanitation status of these communities since all these heaps would be carted to the farms.

8. Effect of some soil fertility enhancing interventions on soil nutrients (NPK)

Table 9 shows the nutrient (NPK) values before and after some soil fertility enhancing interventions initiated by scientists within the Savanna zone of Ghana. The initial values of N in particular show that the highest was 0.049% and the lowest was 0.022% within this zone. These values are percent total nitrogen and not available N which means that not all these will even be available to the plant. The low N content of these soils therefore explains why yields of cereal crops are very low and in some cases no yield is obtained if no soil fertility enhancing material is applied to the soil. Results from omission trials carried out in Nyankpala for three consecutive years (2002-2005) showed that among the three major plant nutrients, nitrogen was the most limiting element for maize production (SARI, 2005)

		N%		**P (ppm)**		**K (ppm)**
Type/period of intervention	Initial soil N	**N After intervention**	Initial Soil P	**P After intervention**	Initial Soil K	**K After intervention**
Intercropping *Mucuna* in maize (6WAP)	0.024	0.043	15.59	11.96	49.90	45.65
Effect of pigeon pea pruned at 30cm	0.028	0.095	14.89	19.25	46.36	52.85
2 years of *callpogonium*. fallow	0.049	0.062	13.60	23.90	39.58	42.62
The application of house hold refuse	0.022	0.085	14.83	20.08	45.60	48.45
The application of manure (cow dung)	0.028	0.092	16.58	22.65	40.01	44.82
Improved fallow *Mucuna* (1 year)	0.026	0.088	18.65	20.80	42.60	46.25

Table 9. Effect of different soil fertility enhancing interventions on soil NPK values within the Savanna zone of Ghana

With a minimum of two years of the various interventions however, there were increases in the nutrient (NPK) values which is indicative of the positive influence of these interventions on these elements in the soil. In most of the studies, the N values after the interventions were significantly ($p< 0.05$) higher than the initial N values but for P and K, there were no significant differences between the initial and after two years of intervention. The significant increases of percent N in the soil as a result of the various interventions also show how limited nitrogen is in the savanna soils.

9. Average farmer yields of some selected cereal crops Ghana

The average cereal yields of farmers in Ghana are very low. There may be many causes to the low crop yields obtained by farmers in Ghana. These include the use of local crop varieties which are low yielding; poor management of the crop on the field (late weed removal, inadequate plant population, late harvesting) but paramount among these is low soil fertility. This is because the same variety used by farmers without adequate supply of plant nutrients have been found to yield lower than the same variety properly managed by research scientists including the provision of adequate quantities of nutrients especially nitrogen.

Table 10 shows some of the average yields of cereal crops by farmers in Ghana as against the yields obtained from properly managed fields with adequate supply of nutrients which leaves a very large yield gap of more than 40 %. Among the crops, sorghum has the largest yield gap of about 60 % with millet recording the lowest of about 30 %. Farmers in northern Ghana are of the view that sorghum does not require fertilizer for high yields and therefore do not apply fertilizer to the sorghum crop. On the other hand, the millet available are mostly local varieties and do not respond to fertilizer. With the application of fertilizers and adequate management of the millet crop, the increase in yield was just 0. 5 tons/ha compared to the rest of the crops which had increases in yield of more than 1 ton/ha.

Crop	Average yields of farmers	Achievable yields	Yield gap	Yield gap (%)
Maize	1.5	2.5	1.0	40
Rice - rainfed	1.8	3.5	1.7	49
Sorghum	1.2	3.0	1.8	60
Millet	1.0	1.5	0.5	33

Source: Ministry of Food and Agriculture (MoFA)

Table 10. National average yields (tons/ha) of some selected cereal crops in Ghana

10. Challenges to adoption of soil fertility enhacement practices

Conservation agriculture and some of the practices that enhance the fertility of soil for crop production have been tested on-station by research in Ghana and most of them have been found to be proven. These practices are now at the on-farm testing stages by research and

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the Ministry of Food Agriculture in different parts of the country. Some of these practices are either new to the farmers such as conservation Agriculture, Agro-forestry and Alley cropping or they are the improved versions of farmers' practices such as crop rotation (alternating cereal and legumes), intercropping cereal and legumes, root crops with cereals and legumes, cover cropping. Despite the benefits demonstrated to farmers from the use of these technologies, adoption rate is very low. Some of the challenges militating against the adoption of these practices by farmers include:

10.1. Ownership of land

Most of the farmers in Ghana do not own the land they farm on and they are therefore described as settler or migrant farmers if they come from other parts of the country and settle at that particular place. The amount of money to invest on such rented lands by these farmers will therefore depend on the length of time the land is rented for farming. A farmer with one year rent period will not be willing to invest so much on that land for farming compared to a farmer who is renting the land for over ten years. Secondly, the land owners may not even allow farmers to introduce long term investments on such short term rented lands. It will therefore be difficult for such farmers to adopt soil fertility enhancing techniques such as Agro-forestry system or even the cultivation of tree crops since this will take a long time to yield benefits to the farmer. However, It was found that the system of land tenure in the forest or the transitional zones where the farmers are allowed to use a plot for several years for farming may not have difficulties in adopting no-till as part of soil fertility management practices. This, according to Ekboir et al. (2002) if these farmers are allowed to use such lands for several years it will enable them to recoup the profits of their investments. Also, data collected on the farmers adopting any particular tillage system showed that farmers using their own lands adopted CA practices more easily than farmers on rented lands (Adjei et al. 2003).

Farmers in the forest and transition zones where share cropping arrangements exist between the settler or migrant farmer and land owners, they are encouraged to practice CA and other related practices because increase in the productivity of their crops will lead to an increase in their share of the harvest. Unlike in the north, lands are almost given out free to settler farmers and can also be seized back at anytime by land owners without any notice as there is no agreement signed between the farmers and their land owners. There are certain times land owners even seize back their lands when they find increases in crop yields of the settler farmers. In such situations, farmers in the northern Savanna zone will definitely be discouraged from adopting any of these soil fertility improving practices since the land owners do not benefit from such increases and there is also no agreement signed between them to protect the farmers from their lands being seized back.

10.2. Difficulties in maintaining soil cover

One of the three pillars CA is hinged on is the provision of adequate soil cover and it is one of the several ways of enhancing soil nitrogen. Unfortunately, it is very difficult to provide soil cover in the northern Savanna zone of Ghana because of rampant bush fires during the dry season. The northern part of the country also houses most of the country's livestock (goats, sheep and cattle). These animals either feed on the available crop residue left as a cover to the soil or the residues are removed and fed to them at home by the farmers. The removal of crop residue from the soil for livestock or the destruction by bush fires renders the soil bare. This exposes the soil to sunshine which is followed by erosion by the harmattan winds during the dry season and by running water at the beginning of the rainy season.

Most of the cover crops being promoted as materials for soil fertility improvement are not edible and so farmers are not very enthusiastic in adopting them for use. Most farmers therefore choose grain legumes among the range of soil fertility management practices due to the immediate provision of food (Chikowo et al., 2004; Adjei-Nsiah et al., 2007; Kerr et al., 2007; Ojiem et al., 2007). It has however been found that practices such as green manures and agro-forestry legumes even though do not provide immediate benefits, they are more efficient in providing nitrogen and mulch for subsequent crops (Giller and Cadisch, 1995). Experience has shown that farmers in the northern part of Ghana do not regard cover crops as part of their traditional crops and therefore cover crops have no significance in monetary terms to them. This explains why farmers are not adopting cover crops such as *Callopogonium* and *Mucuna* for soil fertility improvement even though results have shown that these cover crops give adequate cover to the soil and increase soil nutrients for high crop yields. It is difficult for farmers to replace crops they are used to with new crops especially when the new crops cannot give immediate economic returns to them.

Farmers in northern Ghana practice mixed-cropping which mostly involves cereals/legumes and cereal/cereal and this situation does not favour the inclusion of *Mucuna* and *Callopogonium* because of the climbing nature of these cover crops. Intercropping these cover crops with cereals can easily smoother the main crops and these cannot also be easily used as short season fallows since each of them needs more than six months to develop and cover the soil for optimum benefits. Work done by Loos et al. (2001) showed that *Mucuna* planted too early would result in competition for nutrients with the associated crop but planting it late also reduces its chance to properly establish. Knowing when to plant *Mucuna* is therefore very important if weed suppression and high quantity of N (150 N kg/ha) are to be achieved from the cover crop. Yield loss estimated at 30 % has also been recorded from fields of *Mucuna* intercropped with maize due to competition for nutrients, light and space.

Reports from farmers in the forest and transition zones also indicate that planting crops in no-till system is time consuming and laborious since it is by using a dibbler or a cutlass to create holes for placing the seeds. Farmers further complained that germination of seeds was negatively affected when these were planted in high amounts of soil cover. In such situations, the reduction of the soil surface mulch by partial burning becomes necessary to enhance germination which gives the farmer additional work. Other difficulties involved in planting crops under thick mulch include hidden tree stumps which could wound farmers in the process or dangerous reptiles like snakes hiding in the mulch to bite farmers during planting or weed control by hand. The introduction of jab planters reduced the time used in planting crops in the mulch but it was also dependent on the experience of the farmers.

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10.3. Other uses of crop residues by farmers

Farmers in northern Ghana traditionally use crop residues as livestock feed, for housing, craft materials and as household energy source. Using crop residues as soil cover and organic matter replacement is therefore foreign and conflicts with the uses that they are already familiar with for several years. The use of crop residues such as millet or sorghum stover as livestock feed in the Upper East region of Ghana where farmers produce crops alongside rearing of animals is very common. In the Upper East region in particular, due to high population density in that part of the country, there is pressure on land use resulting into small farm lands. Despite the fact that common lands for livestock grazing is limited due to lack of land, farmers still rear livestock because of the high culture and economic value the natives place on livestock. Farm families keep livestock as investment and insurance against the risk of crop failure, for traction, for manure production and for milk and meat. These according to the farmers, make use of crop residue to feed livestock to take precedence over other uses. Animals are therefore allowed to feed on crop residues directly on the farm or the residues are carted home and fed to them. Some of the farmers are able to transport the manure from these crop residues consumed by the animals back to the fields others do not thereby depriving the soils of organic matter.

Of late, there have been increases in livestock numbers in the drier part of northern Ghana especially in the Upper East Region. The increase in the livestock industry in this region has also led to an increase for the demand for their feed and since they depend on crop residues for dry season feeding, residue for mulching the soil will be on the decrease. As a result of this intensification of livestock production, there is a fast developing market for crop residues in these areas which further encourage the removal of these residues for sale to raise income for the family at the expense of maintaining the fertility of the soil. In the northern Savanna zone of Ghana where most farmers practice mixed farming, it is therefore left for the individual either to use the crop residue for mulch or use the residues as livestock feed. So far, experience has shown that most of the farmers go in for the earlier option where they use the residues to feed their livestock. Farmers however, still have several options of improving the fertility of their soils for high yields. These include selling some of the livestock to buy in-organic fertilizers, returning the residue in the form of manure to the farm or in some cases when the plot sizes are small, compost is produced and applied to the crops.

Experience has also shown that in areas where livestock numbers are low such as in the forest and transition zones, the crop residues are not left as mulch but burnt as practiced in the traditional slash and burn system of farming. Apart from burning to control weeds in that system, it has also been found that burning helps to control pests and to reduce the population of rodents which tend to increase when crop residues are left on the field. Even though retention of crop residues is always advocated in CA, under situation of very high mulch content, retention is not feasible and burning to reduce it seems to be a good option.

10.4. Weed management

At first sight, spraying to kill the existing vegetation in the northern Savanna zone to plant a crop as in CA system appears like no other weed will ever germinate again. However, two weeks after planting the crop, one finds a huge mass and diversity of weeds vigorously springing up thereby making the first weeding after planting very difficult and laborious since this is done by hand. At times the high infestation of weeds in such a system is due to bad selection of weedicide, low doses of the chemical and poor spraying techniques.

Rio (1992) estimated over 45 % as the annual yield loss of crops due to weed infestation in heavily infested fields. Other effects include waste of human energy in controlling weeds. It has been found that reducing tillage intensity alone as described in CA without adequately covering the soil as practiced by most farmers is one way of promoting weed infestation on their fields. In the situation whereby crops are planted haphazardly leaving some gaps, weeds quickly infest and occupy these areas making their control very difficult as this requires weeding several times by hand hoe.

10.5. Unavailability of cover crop seeds

Even though some farmers now know the benefits of growing cover crops as an intercrop with their cereals or in a short fallow system, seeds of these cover crops are not easily available. Few of the cover crops which have been tested and found useful for soil fertility enhancing materials are *Mucuna, Pueraria, Canavalia* and *Callopogonium species* but their seeds are scarce and difficult to find in Ghana. This makes it difficult for many farmers to adopt and use these materials to enhance the fertility of their soils. It has been observed that seeds of these cover crops are easily found when there is a project promoting them. For example when there was intensive promotion of *Mucuna* for weed suppression and soil fertility in the transition zone of Ghana, it was easy to get *Mucuna* seeds to buy because some farmers produced the seeds for sale. Initially, the project motivated the farmers to produce the seeds by buying the seeds off from them during the project but when the project ended and seeds were not bought again, the farmers also stopped producing the seeds. This situation calls for the introduction of edible cover crops because if *Mucuna* were edible, farmers would have continued to produce the crop for food while maintaining the fertility of their soils.

Cover crops which are not edible as mentioned earlier are less attractive to farmers because they do not give immediate benefit to the farmer. The option of growing cover crops as short season fallows is more feasible in the transition zones where population is less dense with large farms but not in areas where there is pressure on land use and there is no fallow period permitted. Practicing no-till on bare soil with less than 10 % surface mulch as in the Savanna zone with rampant bush burning may result in reduced crop yields.

10.6. Difficulties in getting appropriate equipment and tools

The practice of some of the soil fertility enhancing technologies such as in Agro-forestry and CA require the use of some equipments, inputs and tools. It has been observed that the required inputs such as glyphosate as used in CA land preparation are mostly not available at the appropriate time needed by farmers. At times where they are available the cost may be so high that the average farmer may not be able to afford. Agro-inputs distribution is therefore described as being poor because the right inputs are always not available at the right time needed. Chemical fertilizers which are needed to generate biomass at the beginning of CA practice in the Savanna zone have their depots located in the regional capitals of the country making it almost impossible for most of the farmers who are in rural areas. One of the difficulties involved in the implementation CA and other technologies designed to enhance crop yields may be lack of accessibility to inputs such as weedicides.

The Food Crops Development Project (financed by the African Development Bank) implemented mostly in the forest and transition zones saw the supply of inputs to project clients by some major agro-input companies. According to Boahen et al., (2007) farmers use the project as collateral to gain access to the inputs for crop production. In that system the Project sent a request to the shop to provide a certain quantity of inputs, for which the farmer pays later into a bank account created for this purpose. The Inputs and tools supplied to the farmers in this system ranged from pesticides and fertilizer to equipment and tools like knapsack sprayers, cutlasses and hoes. The above indicates that the implementation of any soil fertility enhancing technologies in Ghana by donors through projects is always successful but the systems breaks down immediately the project ends.

This calls for sustainability to be built into every project implemented to make sure that the farmers own and operate the system even after the project. Some of the suggestions given to introduce sustainability into such projects include:

Urging the farmers to form co-operatives where they can be registered and linked to financial institutions such that even after the project, the farmers can get financial assistance from such Institutions

Secondly, training of farmers on both the process and the content of the project will be very important for the visibility of the project after it has been concluded.

The donors or project implementers should always look for their local partners and work with them. This will enable the activities of the project to continue through the efforts of the local partners after the duration of the project.

Farmers in the north of Ghana have expressed their gratitude for the introduction of CA and other related technologies as labour is scarce and some of these practices are ways of reducing labour costs for crop production. Technologies such as no-till and direct seeding are practices demonstrated to the farmers of the north which are devoid of tilling the land either by hand hoe or tractors. Even though the introduction of these technologies are appropriate, the equipments and tools to go with these practices are not yet available for sale in Ghana except those used for the demonstrations. The planting of the crops in the mulch without these tools remains a challenge to the adoption of these technologies as farmers spend more time to get the seeds planted using dibblers and cutlasses. Implements like knife-rollers, rippers and no-till seeders are needed to facilitate planting in CA which are yet to be made available in the country. According to the farmers, planting is easier with dibblers or cutlasses when the soil is bare but becomes more difficult if there is a high surface mulch as in CA and the crop is to be planted in rows.

Currently in Ghana, the most common practice available for medium- and large-scale farmers is the tractor-mounted disc plough and harrow which are imported and sold to either individuals or group of farmers. However, due to the fragile nature of the Savanna soils, these equipments have been observed to be responsible for the destruction of the soil structure and increase soil erosion by running water during the rainy season. So far, the components of CA being demonstrated are targeting the small-scale farmers but if it is to be adopted by the medium and large-scale farmers, the availability of machines and equipment becomes very necessary. In order to expose the technologies to these category of farmers, there is the need to develop appropriate machinery, tools and other implements or at best adapt the existing ones, fabricate them and make them accessible to such farmers. This can be done by effectively training the local artisans and craft men/women to produce such equipments for the farmers. Even though most of these equipments are operated by tractors, if those to be produced are designed to be operated by bullocks and donkeys, it would attract many more farmers to adopt the practice.

10.7. Farmers lacks access to credit and markets

Farmers in northern Ghana have been known to be poor probably because of the poor harvest they obtain from their crops which is traced mostly to low soil fertility and erratic rainfall. Most of them therefore lack collateral security to obtain financial assistance from these financial Institutions. Meanwhile the adoption of any soil restoration practices such as CA requires the purchase of inputs such as weedicides and fertilizers and other equipments for direct planting and spraying of the weedicides. The inability to purchase these inputs therefore means that such farmers would not be able to adopt such soil fertility enhancing practices.

The system where farmers sell their crop produce through the middlemen is one of the reasons why most of them remain poor. Prices offered to the farmers by these middlemen for their produce are so low that they are never able to pay for the cost of production. Farmers whose activities for crop production are pre-financed by these middle men suffer most as they take the produce in lieu of cash at harvesting time when prices are generally low. In addition such farmers might not easily adopt some soil fertility techniques such as CA which does not give immediate returns to the farmer.

10.8. Pests and disease problems

Experience has shown that providing thick soil mulch creates a micro-climate for reptiles such as snakes that can bite farmers operating on the land without protective clothing. Most farmers also complained of the increase in scorpions and other insects which can cause significant losses to the crops planted in the mulch. Some farmers who were introduced to direct seeding in the mulch complained of poor plant stand due to damage by crickets and grass hoppers. According to the farmers, that is why they have cultivated the habit of burning the crop residues before planting. It is now well known by farmers who have ever produced cover crops such as *Mucuna* that the cover crop is a suitable abode for snakes both in the live stage and when it is dry and left on the soil as mulch which makes farm operations by farmers very dangerous. Some farmers have come out with a calendar of spraying programme to control the pests in these cover crops to save the crops from insect damage and to make farm operations safe. This is because the chemicals (insecticides) used in spraying to control the insects also drive the snakes and the scorpions out of the mulch. However, the farmers are of the view that the adoption of such technologies also increases cost of production since they have to purchase insecticides to control these insects.

10.9. Difficulties in promoting soil fertility enhancing technologies

In the first place, in Ghana the number of extension agents of the Ministry of Food and Agriculture (MoFA) responsible for agricultural extension services is very low. This makes it impossible for them to have a large coverage of farmers within a specific time to effectively extend whatever new technology developed by Research. Also, the knowledge of these extension agents in the various soil fertility restorations may be low compared to other subject areas. It has been realized from experience that the knowledge and lessons learnt from the past soil fertility enhancement project have not been made use of by the agents indicating that they have not been trained in that line.

Until recently, MoFA was structured into departments such as crop and extension services departments and for soil fertility restoration technologies to be extended effectively for adoption, there is need to establish a unit to champion the activities of this subject which is neither crops nor extension services.

So far, areas with conservation Agriculture and its related practices have been traced to the existence of donor projects. The donors of all these projects have been in collaboration with MoFA with the activities carried out since the extension agents have been responsible for site and farmer selection. However, Boahen et al. (2007) reported that the number of farmers using these technologies reduced by an estimated 30% when the related projects ended. It was also found that the visits by extension agents to these project communities reduced from twice a week to once every two weeks since the project was no longer giving them fuel allowances and the associated cost of travel.

10.10. Lack of adequate institutional support

For farmers to adopt the soil fertility regeneration and maintenance practices, its extension needs to be well co-ordinated and collaborated among major stakeholders in soil health. In that way, the numerous benefits of CA can be realized and appreciated by farmers, researchers and extension staff of MoFA. So far, even though the activities of these projects have been carried out in collaboration with MoFA, data on the practice and adoption of these including CA are scanty. It has been observed that even where data exists, they may not be coherent or accurate. There are few success stories on some of the practices that can regenerate and maintain soil fertility for crop production but these are not properly packaged for extension and for policy makers. Both donors and the implementers of CA in Ghana have therefore not been able to convince policy makers the benefits of these practices for support. This may explain why the Government still imports tractors with both disc ploughs and harrows without considering the importation of equipment and tools used in CA. The adoption of CA and its related practices by farmers does not really depend on the availability of these tools and inputs; it also depends on the attitudes of all stakeholders in the supply chain such as the input dealers and manufacturers.

The Government of Ghana's modernization of agriculture programme through the Ministry of Food and Agriculture seeks to modernize and mechanize agriculture in Ghana. This programme has begun with the importation of modern tractors equipped with new disc ploughs and harrows probably targeting the medium and large scale farmers with the neglect of the small scale farmers of less than one hectare. This situation also makes it difficult for even the donors to fund such soil fertility regeneration practices like the CA because it would be like working directly against the government's programme. A compromise could have reached by the importation of tractors and no-till seeders and other equipments for the small scale farmer who can not afford the services of the tractor ploughing services.

10.11. Use of farmers' indigenous knowledge with the technology

The activities of research and development in producing any agricultural technology for the farmer should be seen to be improving or incorporating farmers' indigenous knowledge and not producing modern technology that seem not to have any input from them. The adoption of any technology developed in a participatory manner among the farmer the researcher and the extension agent seem to be faster than when indigenous knowledge from the farmers are ignored. This situation calls for in-depth studies on traditional practices and the strategies farmers employ to cope with the declining soil fertility status of the savanna region. This will assist in the development of a technology that will not be difficult to extend to the farmers for adoption if the technology is built on the existing indigenous knowledge of the farmers. The introduction of the use of herbicides to kill the weeds for the planting the crop was met with happiness in some parts of the northern region of Ghana where farmers plant on the bare soil immediately after the onset of rains without tilling the soil. In another development, earth and stone bunding to control both soil and water has not been difficult to extend the technology for adoption by farmers with their farms located on steep slopes and rocky areas because they were already doing something similar before. Most of the farmers are not adopting the cultivation of cover crops such as *Mucuna* because the crop is not edible. It is envisaged that if the edible cover crops such as the local creeping cowpea is introduced to replace *Mucuna*, a lot more farmers will adopt the practice as both the leaves and grain of the cowpea are edible.

11. Conclusion and recommendations

From experience, conservation agriculture and other related practices geared towards regenerating soil fertility for crop production had many important impacts on the lives of adopters. Practices such as Agro-forestry, use of cover crops and many more have helped in increasing grain yields of crops several folds. Also reducing the number of times the soil is tilled as in CA has helped to reduce energy and labour costs and the decay of the vegetative

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mater has improved soil fertility status which in several places has translated into high crop yields.

From the numerous works done in the areas of soil fertility management and other related field activities carried out in the past, showed that conservation technologies in general, is site-specific and depends on the local bio-physical and socio-economic settings. Also from the interaction with farmers, there are many important changes that CA brought to farming activities, they mentioned reduced investment in cash and labour, higher yields, easier weed and pest control, and saved time for farmers.

From the knowledge gained in the past from several desk tops research and other methods of research conducted to assess the extent which CA and other soil fertility enhancing practices have been adopted by farmers in Ghana, the following observations and conclusions have been drawn:

Farmers adopting CA in the savanna region of Ghana are faced with challenges of generating enough biomass to begin with and the control of weeds in the transitional phase of the system. Related to weed control in CA is the knowledge of the type of herbicide to use and mode of application for effective control of the emerged weeds.

In order to effectively extend CA and other practices related to soil fertility regeneration for adoption, enough information especially on cover crops and their profitability are needed. Also knowledge on how they fit into the various ecologies of Ghana, the best crop associations possible and their effects on soil fertility status, are essential for the dissemination of the cover crop technology among farmers.

It is essential to have relevant knowledge in the selection of herbicides and mode of application. The selection and timely incorporation of cover crops in the various cropping systems are also important in the practice of CA. Some of the skills required by farmers practicing CA are the ways and means of controlling rodents and other pests in order to obtain high yields.

In the Savanna zone of Ghana, it is difficult to maintain soil cover with crop residue or cover crops because of the rampant bush fires during the long dry season and the grazing of several different livestock on free range.

Tools and inputs such as seeds of appropriate types of cover crops, the required herbicides to be used in CA practices are essential requirements for the practice of CA which may not be easily available to farmers at the right time.

Some of the requirement for the practice of soil fertility regeneration technologies such as agro-forestry and growing of cover crops in improved fallows system help to raise the total cost of production. This is because these require initial land clearing in the case of the cover crop fallow, additional labour for spreading the mulch and planting through the residue, which is laborious and time wasting.

Even though direct planting without tillage in CA is said to be cheaper than conventional land preparation, due to the scarcity of herbicides at planting time, the price of the commodity is high enough to cause significant impact on cash demand of farmers during the farming season.

Manual planting by hand, using stick or cutlass on fields with mulch is more difficult and time wasting than using the same tools to plant on bare or conventionally ploughed fields.

It is important to impact basic knowledge in handling of equipment like spray machines for herbicides or application of other chemicals to farmers. Farmers' yields can be enhanced if they are assisted in decision making on appropriate crops to be grown, rotations, record keeping and costing of each operations.

Following the observations and findings from our experiences on soil fertility management for crop production, the following recommendations are made for further observation and consideration:

Depending on the availability of ready market, emphasis on cereal-legume rotations/intercropping for CA should involve multipurpose grain and fodder legumes. The production of fodder in the system will take care of the livestock component since on the average every farm family rears animals alongside crop production in the Savanna zone of Ghana.

Training farmers on aspects of CA and introducing to them simple and appropriate CA equipment and implements will significantly enhance labour productivity and encourage many more farmers to adopt CA and other related soil fertility improvement practices.

In order for the Donor-led projects to build a good number of success stories on the various soil fertility management practices including CA, the knowledge and experience acquired over the past years should be harnessed, repackaged and used. In this way, they will be able to convince the government on the benefits, of CA and its potential to resolve food security problems and promote a sustainable source of livelihood for rural small-scale farmers.

The promotion of most of these practices of CA should go beyond the small scale farmer since there are emerging medium scale farmers who can help broaden the scope of the programme. This can be done through adaptive research targeting different groups of farmers in the different environments and socio-economic settings.

The first step in promoting CA effectively is to consider National institutions and farmers' groups to be the driving forces of CA in the country. These groups can re-package and properly lobby the policy regularly for support.

Messages developed for extension services should be specific for the occasion and not blanket for all issues as it is now. This will assist the farmers to be able to assess their constraints and be able to opt for suitable practices that can maintain and improve soil fertility for sustainable crop production.

Both farmers and extension officers need to understand the processes through which the soil fertility can be maintained for extension to enable farmers to adopt if the practices are imported from other regions and not for adaptation alone. This is important because if the environmental factors of the place the practice is imported from are the same with the local environment, but the socio-economic setting may be different.

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Intensification of the integration of cover crops and crop rotation in CA systems should be pursued and monitored since there are several cover crops and other crop varieties. This situation can lead to the reduction of pests and diseases in the CA systems.

Farmers should be encouraged to form co-operatives. This is because if the groups are well co-ordinated, agricultural policies including the regeneration of soil fertility for crop production can be well implemented

Author details

James M. Kombiok[1], Samuel Saaka J. Buah[2] and Jean M. Sogbedji[3]

*Address all correspondence to: kombiokjm@yahoo.com

1 Savanna Agricultural Research Institute, Tamale, Ghana

2 Savanna Agricultural Research Institute, Wa Station, Wa, Ghana

3 IFDC, Rue Soloyo, Lome, Togo

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