academicJournals

Vol. 9(6), pp. 593-602, 6 February, 2014
DOI:10.5897/AJAR12.1698
ISSN 1991-637X ©2014 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Challenges to maize fertilization in the forest and transition zones of Ghana

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Accepted 12 November, 2013

Maize (*Zea mays*) is Ghana's most important cereal crop grown in all agro-ecological zones by smallholder farmers. The average yield of maize (1.7 tha^{-1}) is far below attainable yield of 5.5 tha^{-1}. This is due to reliance on rain fed farming, local seed varieties and low inputs use. Farmers face many challenges in their attempt to adopt the use of fertilizer to improve their maize production. To unearth these challenges, data on the potential and limitations to maize fertilization in the maize belt of Ghana were collected through a farm level survey in October 2011. A four stage randomized sampling procedure was used to select 168 maize farmers who were interviewed using formal questionnaire. Some of the farmers especially, settlers do not have land of their own and have to rely on tenancy arrangements to access land for farming. Farmers were of the view that their crop lands are gradually declining in fertility. Almost 55% of the farmers practise continuous maize cropping. The lack or low accessibility to credit and high cost of fertilizer are the key constraints to farmers' ability to expand their maize farming. Additionally, the mode and distance needed to transport fertilizer to the farm is a disincentive.

Key words: Maize, fertilizer use, Ghana, farmers, continuous cropping.

INTRODUCTION

Presently, maize (*Zea mays*) is Ghana's most important cereal crop, accounting for 55% grain output (Angelucci, 2012). It is grown by the vast majority of rural households in all parts of the country except the Sudan savannah zone where it is now gaining prominence (Morris et al., 2001). The vast majority of maize is produced by smallholder farmers under rain fed conditions. Available data obtained from the Statistics, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA) showed that maize production volume increased by 38% from 2007 to 2011 (MoFA, 2007-2011) but this was mainly due to 30% increase in area harvested over the same period as the average yield hovered around 1.70 t ha-1 (± 0.2 t ha-1) because of reliance on traditional farming methods. Under traditional production methods using rain fed conditions, yields are well below their attainable levels of up to 5.5 metric tons per hectare under improved seeds, fertilizer, mechanization and irrigation (Armah, 2000). The MoFA estimated the annual domestic deficit from 2007 to 2011 to be between 84,000 and 145,000 metric tons and is projected to reach 267,000 metric tons by 2015. These represent the shortfall in domestic production of between 9 and 15% of total human consumption in the years under review (Armah, 2000). Further, beyond these projected figures for house-hold consumption, there is considerable unfulfilled demand for processed maize uses and for the growing animal feed sector within

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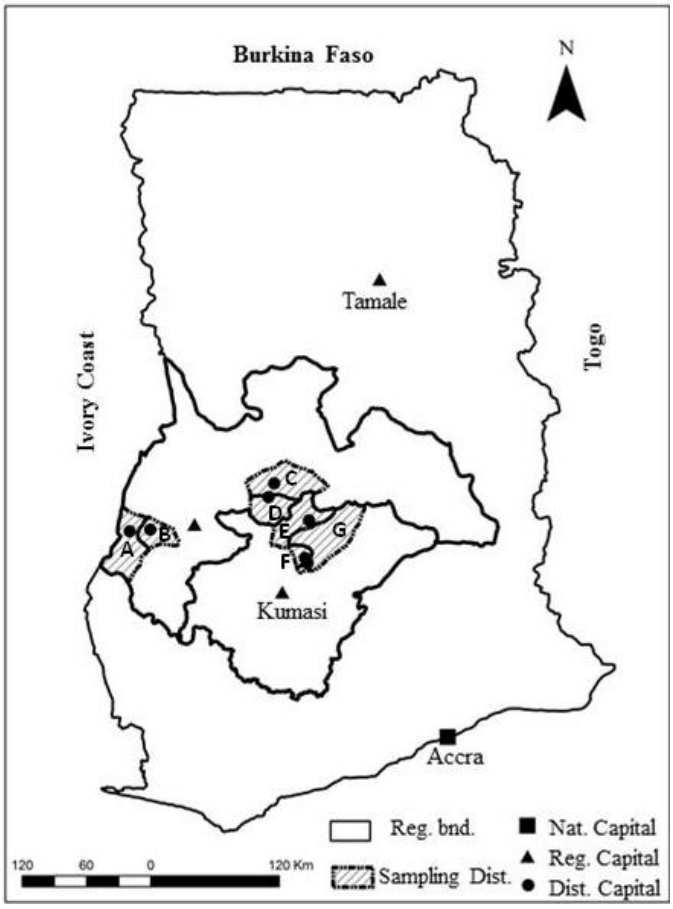

Figure 1. Map of Ghana showing distribution of survey sites (A: Dormaa West; B: Dormaa East; C: Nkoranza North; D: Nkoranza South; E: Ejura Sekyeredumase; F: Mampong Municipal and G: Sekyere Central).

Ghana. One major factor underlying the low crop yields in sub-Saharan Africa (SSA) is soil quality decline resulting from disappearing fallows, continuous cropping without fertilization, agricultural extensification, deforestation, poor crop management practices and soil nutrient mining (Scoones and Toulmin, 1999; Hilhorst and Muchena, 2000).

According ISSER (2009), the relatively high cost of agricultural inputs and lack of easy accessibility to credit in Ghana makes it difficult for the many poor smallholder farmers who dominate the agriculture sector to afford them. As a result, most farmers only apply fertilizer to selected crops such as maize, rice and vegetables. Even when they do apply fertilizer, the recommended application rate is rarely used (UNEP-GEF Volta Project, 2010).

Fertilizer consumption by type and nutrient in Ghana is low. The average fertilizer application rate of 5 kg per hectare of cultivated land is about half the level of SSA and a quarter of the level of Africa as a whole (UNEP-GEF Volta Project, 2010). Consequently, more plant nutrients are being removed and lost than are being applied, with a progressive impoverishment of soils. Traditional soil exhausting cultivation practices are still used extensively (Gerner et al., 1995). Almost all the nutrient balance assessment in Ghana show a nutrient deficit, that is, the difference between the quantities of plant nutrients applied and the quantities removed or lost (FAO, 2004). An understanding of nutrient dynamics under smallholder farming systems would therefore contribute to a better management of nutrients for enhanced and sustained productivity.

The objective of this study is to assess smallholder farmers' access, current use, potential and limitations to fertilizer use. This was done through formal surveys in the maize belt in Brong Ahafo and Ashanti regions of Ghana.

MATERIALS AND METHODS

Study area

The study was carried out in the Brong Ahafo and Ashanti regions of Ghana that forms the maize growing belt of the country (Figure 1). The belt has a tropical climate, with high temperatures averaging 23.9°C and a double maxima rainfall pattern. Rainfall ranges from an average of 1000 mm in the northern parts to 1400 mm in the southern parts. The region has two main vegetation types, the moist Semi-deciduous Forest and the Forest Savannah Transition zones. The level of development and variations in economic activity are largely due to these two vegetation types. For example, the moist semi-deciduous forest zone is conducive for the production of cash crops, such as cocoa whilst livestock, cashew and yam are in the transition zone.

Sampling scheme

To assess maize production and fertilizer use in Brong Ahafo and Ashanti regions of Ghana, data on maize production and fertilizer use in the regions were collected in October 2011. A four stage randomized sampling procedure was adopted. The stages involved selection of (1) Districts, (2) Enumeration area (EA) which is based on MoFA division of districts into operational areas for effective monitoring by individual extension agents, (3) Enumeration community (EC) and (4) maize farmers (Table 1). Six farmers were interviewed in each of the 28 ECs from 14 EAs and seven districts giving a total of 168 maize farmers. The districts are those with high maize production in the regions for the past 10 years. The sampling districts were Dormaa West, Dormaa East, Nkoranza North and Nkoranza South districts in the Brong Ahafo Region; Ejura Sekyeredumase, Mampong Municipal and Sekyere Central districts in the Ashanti Region as lettered A-G in Figure 1.

At the community level, an open forum was held to introduce the purpose of the study, after which six farmers were randomly selected from the audience in the EC. Based on the random sampling approach, it is considered that the selected maize farmers are representative of their community, operational area, district and then the regions of study.

Data collection and analysis

Survey enumerators were trained on the objectives of the study, detailed question-by-question review of survey instrument and

Table 1. Sampling procedure for the maize production and fertilizer use at farm level survey.

Stage	Sampling unit	Selection criterion	Sample size at each unit	Cumulative sample size
1	District	Districts with good maize production figures in the past 10 years	7	7
2	Enumeration area	Randomly selected from operational areas based on MoFA divisions	2	14
4	Enumeration community	Randomly selecting from communities within the selected operational area	2	28
3	Farmer	Randomly selected from among all maize farmers in the operational area	6	168

Table 2. Age, gender and marital status of respondent farmers.

Age class	Farmers interviewed (%)	Gender		Marital status			Main occupation	
		Male (n)	Female (n)	Single (n)	Married (n)	Other[a] (n)	Farming (n)	Other[b] (n)
17-19	1.1	2	0	1	1	0	1	1
20-29	4.8	6	2	3	5	0	8	0
30-39	26.8	33	12	2	40	3	40	5
40-49	25.6	29	14	4	38	1	39	4
50-59	20.8	16	19	1	29	5	34	1
60-69	14.9	19	6	0	22	3	25	0
70 and over	6.0	5	5	0	8	2	10	0
Total	100	110	58	11	143	14	157	11

[a]Includes separated, divorce and widowed; [b]Trading, handiwork, civil/public service and others.

interviewing techniques. The survey instrument was pre-tested at Kotei in the Ejisu Juaben District.

Interviews were conducted with formal questionnaire. Each respondent was interviewed separately from the others with supervisory monitoring. Data was analyzed using descriptive statistics (frequency, percentage response, mean, mode and median) using the Statistical Package for Social Scientist (SPSS, 1999).

SURVEY RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

Most of the respondents were in the age group of 30-39, 40-49 and 50-59 (Table 2). This affirms the notion that the youths are not interested in farming. About 66% of the respondents were males, indicating an appreciable number of women farmers. In some communities, the male: female farmers were 1:1. Most of the respondent farmers (85%) are married or were married in the past (8.4%). This indicates that most respondents have added responsibility of catering for a spouse and or children and would have to take their farming activities serious. Most (94%) of the respondents consider farming as their main occupation and may carry out trading, service work, handiwork and others to support their income.

Only 20% of the farmers had education up to the Secondary level or higher and 21% had no formal education. Seventy-six percent of the respondents are Christians and 18.5% Muslims.

The average household size is 7.6 with a median and mode of 7 and 6 respectively. Most of the respondents (56.5%) have a household size in the class of 6-10 (Table 3). This is comparatively large compared to the mean Ghanaian family size of 4 (GSS, 2008). Majority of the respondents (72%) are heads of their household with most of the remaining (that is, 25%) being spouses of the head. The average number of children per respondent family is 5.3 with a median of 5 and mode of 4. However 71.4% of the respondents have large family size with 6 or more children.

Land use characteristics

Land ownership

About 27% of the farmers have no land of their own and therefore have to rely on renting land or going into shared cropping arrangement. This has implications for soil fertility maintenance since such farmers will not necessarily invest in the land for fear of not enjoying from their investment for long. Additionally, 16.7% of the land owning farmers own 2 ha or less which poses some challenges in feeding the usually large family size sustainably. Forty-one out of the total respondent farmers are settler farmers with 63% of them having no land of their own and have to resort to tenure arrangement to acquire land for farming.

Most of the farmers are of the view that their farm land

Table 3. Household size and membership.

Household size	Farmers interviewed (%)	Household membership (n)		
		Head	Spouse	Other[a]
1-2	4.8	7	0	1
3-5	23.8	30	10	0
6-10	56.5	61	31	3
>10	14.9	23	2	0
Total	100	121	43	4

[a]Includes child, grandchild and relative.

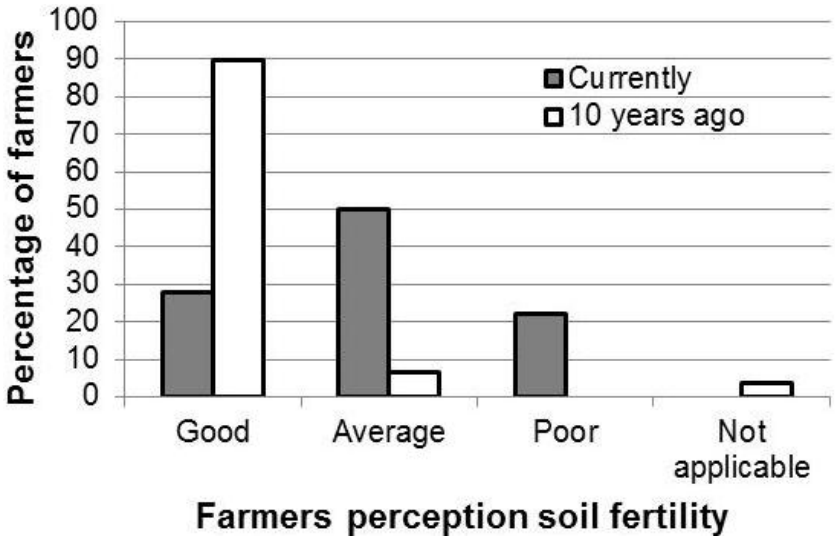

Figure 2. Farmers' perception of soil fertility.

have declined in fertility from good to average or poor over the past 10 years (Figure 2). This is because most of the farmers (90%) admit their land for maize cultivation was fertile 10 years ago, but currently only 28% perceive their land is still fertile for maize production. This situation calls for improvement in management practices to sustain soil productivity. One of the main contributing factors to declining soil fertility is continuous cropping as evident in Figure 3.

It was found that most farmers practice continuous cropping. Almost 55% had maize on the same field in 2009 before the reference year of 2010. However, 28% rotated the maize with legume, root/tuber or vegetables which was a better practice in the absence of abundant land to practice shifting cultivation. Also 10 and 1% of the farmers practice short and long fallow periods respectively to help improve the nutrient base of their soils.

Most of the farmers (61.3%) plant their maize as a sole crop with about 31.6% practicing intercropping (Table 4). The sole cropping allows the use of farm machinery and easy application of agrochemicals and therefore gives room for both intensification and expansion of farm size.

Table 4. Cropping system used for maize.

Method of cropping	Percent
Sole crop	61.3
Intercrop	31.6
Sole/intercrop*	7.1
Total	100

*Using sole crop on part of the farm and intercrop on the other.

Crop productivity

About 67% of the farmers consider maize production as their main agricultural income source and 24% consider it as the second most important source of income. The majority (75%) of the farmers identified lack of credit for their farming activities as a key constraint inhibiting their ability to produce maize. Other constraints include high

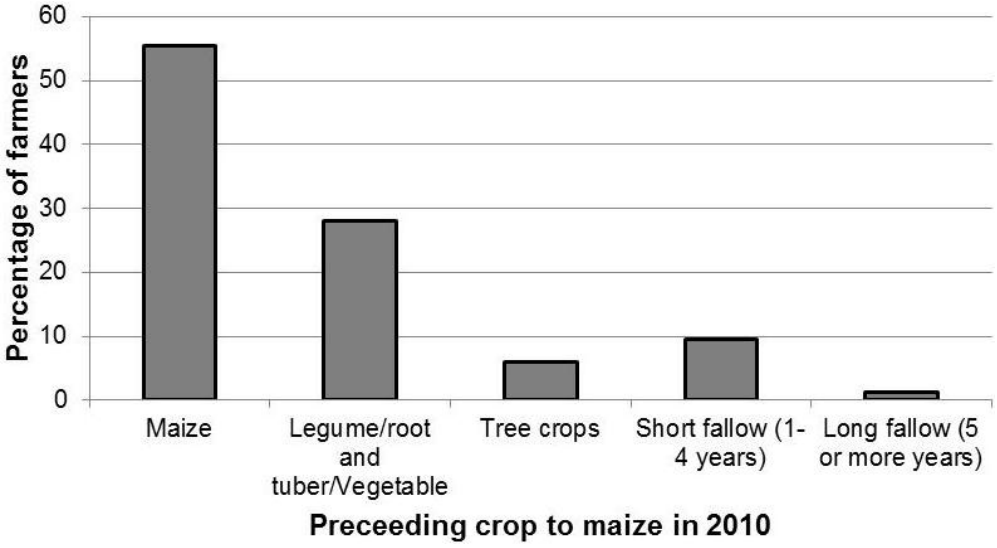

Figure 3. Crop or vegetation preceding maize cultivation in 2010.

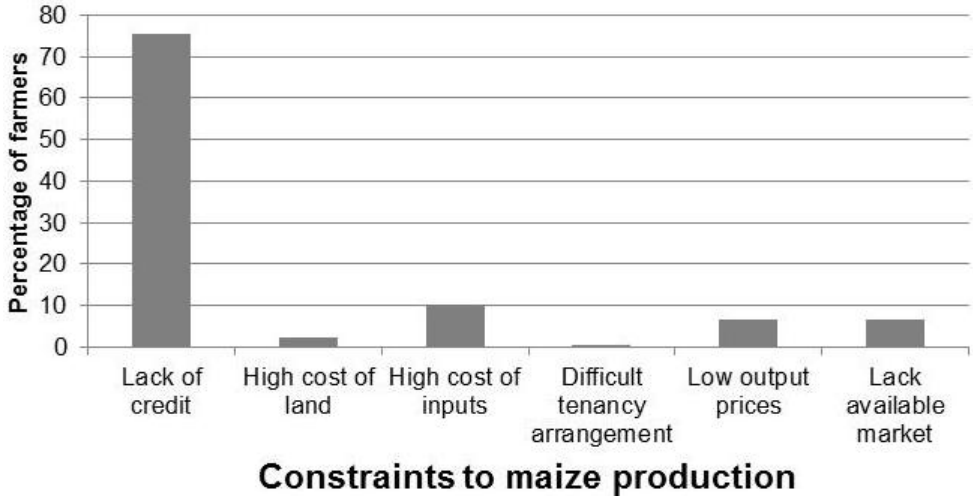

Figure 4. Constraints limiting maize production.

input cost, low prices for their produce and lack of readily available market.

Crops cultivated and fertilizer demand

In 2010, all but one of the respondent farmers cultivated maize as compared to 107 for cassava; 90 for yam; 82 for plantain and 1-58 for 15 other crops including cocoyam, pepper, tomato, groundnut and cocoa. This highlights the importance of maize to the respondents. The most important crop in terms of fertilizer demand is maize, with 105 farmers indicating it as the crop with the highest need for fertilizer. However, 112 of the farmers use chemical fertilizer for maize production. Other crops with high demand for fertilizer are vegetables as indicated by respondents.

The cost of fertilizer varies from one sales point to the other (Figure 5). Sale of fertilizer from the Ministry of Food and Agriculture (MoFA) is subsidized and it is cheaper and therefore the preferred choice for farmers if available. The cost of NPK and urea being by far more expensive than Sulphate of Ammonia.

Among factors such as knowledge on proper use, high cost, product availability, distance to sales point, distance to farm and labour requirement for application of fertilizer, 65.5% of the farmers consider high cost of fertilizer as the most limiting factor (Figure 6). Farmers therefore emphasized the need for credit support to purchase fertilizer as well as timely fertilizer availability.

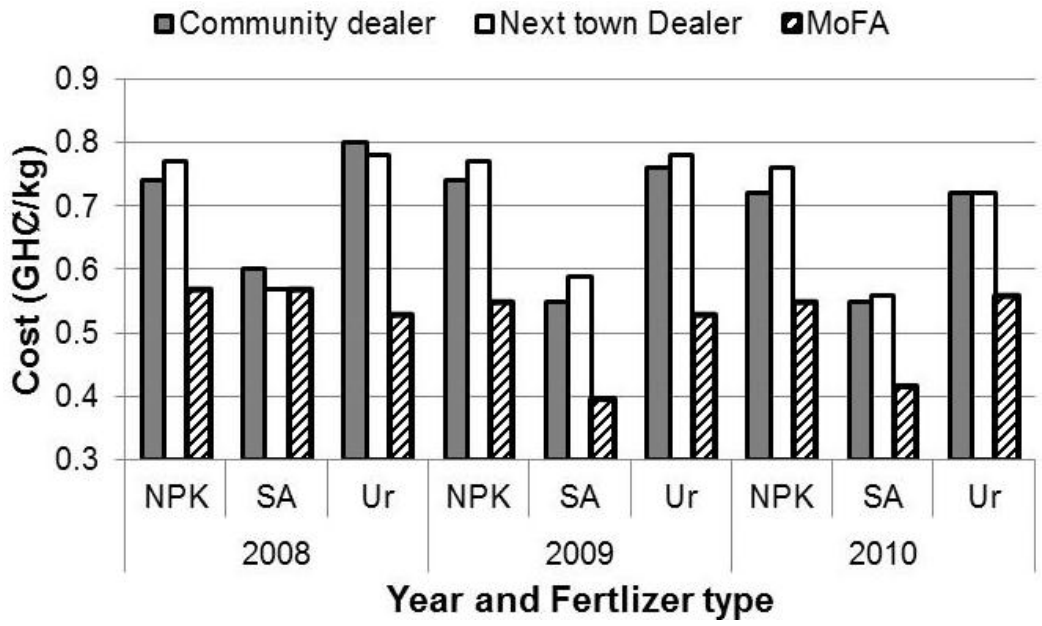

Figure 5. NPK, Sulphate of Ammonia (SA) and Urea (Ur) cost from different sales point (2008 to 2010).

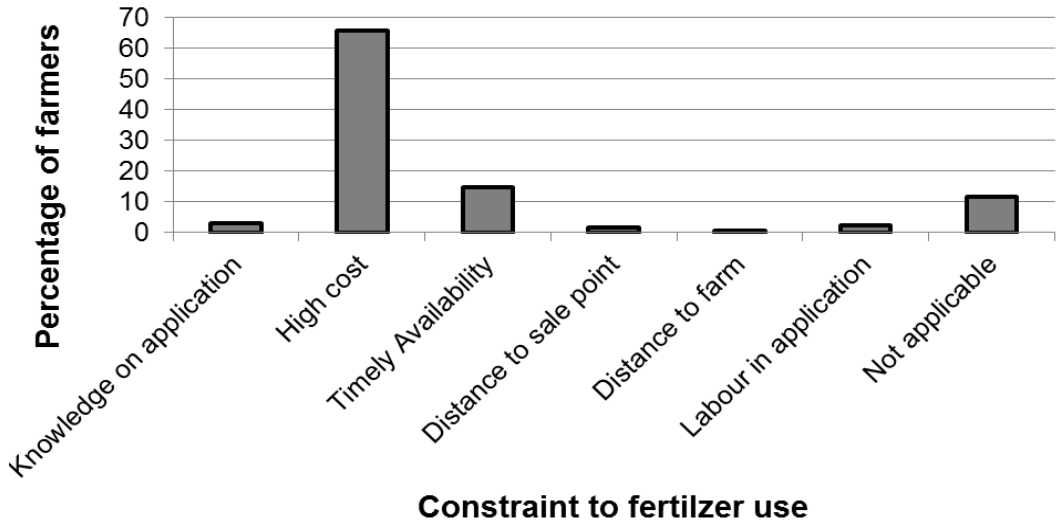

Figure 6. Constraints associated with fertilizer usage by farmers.

It is generally agreed among the farmers (that is, 98.2%) that fertilization can improve their maize yield. Therefore the high cost or unavailability of the product at the appropriate time is the major hindrance to maize production.

The distance to agro-input dealer sales point can influence the desire to use fertilizer. The mean distance from the house to fertilizer sales point and farm is about 4.3 and 4.1 km, respectively according to farmers who use fertilizer for maize production. Some of the farmers have to travel more than 5 km to purchase fertilizer (Table 5). Also, most of the farmers have to travel or transport their fertilizer over 1-5 km or more to their farms. About 69% of the farmers have to carry the fertilizer to the farm as head-load or on bicycle (Table 6) over an average distance of 4.1 km. Covering these long distances on foot or bicycle with loads of fertilizer does not encourage large scale use and adequate fertilizer application. In some cases the farmers will not use fertilizer at all and find other reasons to justify it.

Among the farmers who do not apply fertilizer to maize, their main concern is lack of the financial resources for

Table 5. Distance (km) from house to fertilizer sales point or farm.

Distance (km)	Farmers (%)	
	House to fertilizer sales point	House to farm
0 – 0.9	41.9	20.2
1.0 – 5	19.9	54.2
6 – 10	18.3	19.0
11 – 20	16.0	5.4
20 >	3.9	1.2

Table 6. Method of transporting fertilizer from sales point to the house and later to the farm by farmers (%).

Transportation method	Sales point to house	House to farm
Vehicle	55.1	16.3
Tractor	0.8	2.3
Motorcycle	6.2	12.4
Bicycle	12.4	28.6
Head-load	25.5	40.4

Table 7. Perception of farmers (%) on the impact of fertilizer use on maize yield and quality.

Grade	Fertilizer use improves maize				
	Grain yield	Fodder yield	Grain taste	Cob size	Stalk size
No idea	10.7	10.7	10.7	10.7	10.7
Best	73.8	33.9	10.7	51.8	31.0
Good	14.3	36.3	24.4	33.9	42.3
Average	1.2	4.8	36.9	3.6	7.1
Poor	0	14.3	17.3	0	8.9

46% of them and 40% indicating that their land is fertile enough and therefore does not need the application of fertilizer. The second view implies farmers will continue to mine the soil until the land resource is depleted before considering the application of fertilizer to improve it. Maintenance of the fertility of inherently fertile soils through proper nutrient management can help sustain it for generations to come. Most of the farmers (74%) agree that applying fertilizer to maize results in the best possible grain yield due to bigger cob sizes with good stalk size and biomass yield but with an average to poor taste as presented in Table 7.

Crop characteristics

A significant number of farmers still rely on old maize varieties for cultivation. Fifty-nine percent of respondent farmers cultivated local maize variety. This is irrespective of the training and education by research and extension over the years. This is based on the fact that they believe that the local varieties are more reliable under limited resources such as water and nutrients but with the background knowledge that it is less responsive to fertilizer application. However, it is noteworthy that in the past (that is, before 2010) 140 of the farmers cultivated local varieties. Also, some farmers may cultivate both local and improved varieties. This indicates that about 41 farmers (24%) have changed to improved varieties. However, the single most adopted improved maize variety is the 'Obatanpa' which is cultivated by 92 of the 167 maize farmers in 2010 (Figure 7).

Crop management

About 68% of the farmers still rely on fallowing for nutrient build-up in their soils and may not immediately apply fertilizer in the first year after fallowing. Almost half of the respondent farmers practice continuous maize

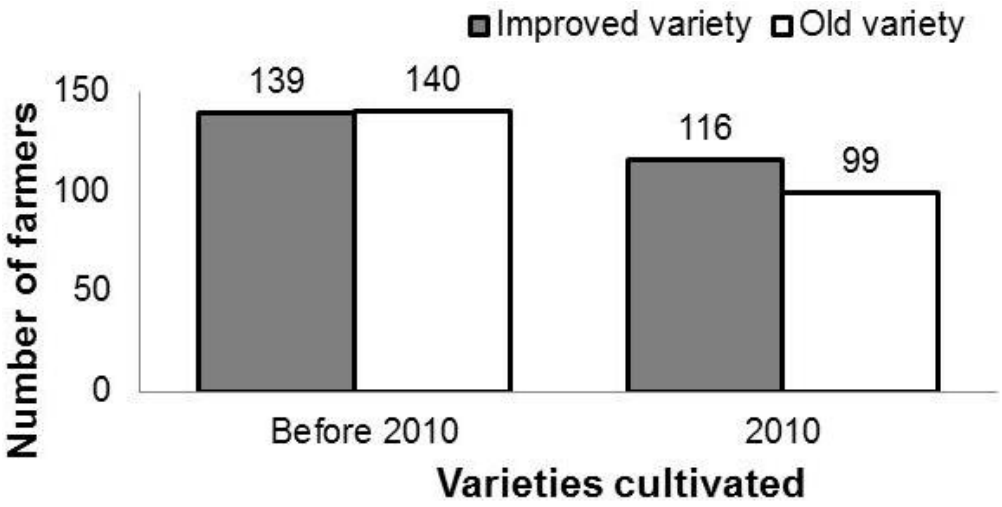

Figure 7. Typology of maize varieties cultivated by farmers in the past and at present.

Table 8. Cropping systems and planting pattern used for maize.

Cropping system	Planting pattern (n)			
	Row on flat	Row on ridge	Random	Total
Does not know	2	0	0	2
Maize/legume rotation	17	2	0	19
Maize/legume intercrop	3	0	1	4
Maize/maize continuous cropping	66	14	5	85
Maize in mixed cropping	35	2	21	58
Total	123	18	27	168

Table 9. Percentage of farmers who had received advice and/or training on fertilizer use.

Advice/training source	Advice	Training
No advice/training	2.7	21.7
NGO	2.7	4.4
MoFA/Extension	78.4	73.0
Researchers	0.0	0.9
Agro-input dealer	9.0	0.0
Other farmers	7.2	0.0
Total	100.0	100.0

Table 10. Method of fertilizer application to maize.

Method	Percent
Broadcast	2.7
Band/ring	13.5
Strip	4.5
Dibble	25.3
Surface placement	54.0
Total	100.0

cultivation, that is, plant maize after maize on the same piece of land (Table 8) with little fertilizer application. Other cropping systems used by the farmers include mixed cropping, maize/legume rotation and maize-legume intercrop. Most farmers plant in rows on the flat or ridges with about 16% of the farmers still planting maize randomly. Most of the farmers who plant randomly practise mixed cropping. The high adoption of row planting means it will be easy to mechanize activities on the farm and apply fertilizer to enhance production. Therefore it is important for farmers to adopt proper management practices if they are to sustain maize production. One key way is to use crop rotation where enough land is available to rotate maize with others and also apply the right quantity of fertilizer.

In all, 112 of the farmers applied mineral fertilizer in 2010 or before to their maize (Table 9). Only one farmer indicated ever applying compost to maize. Organic fertilization of maize is not a common practice. Over 70% of farmers who use fertilizer have had some advice or training from extension staff from the MoFA. This is an indication of the good relationship between MoFA and farmers and therefore the need to involve MoFA in any activity aimed at boosting agricultural production in the

Table 11. Percentage of farmers that apply fertilizer at a given period.

Fertilizer application time	First application	Second application
2 WAP*	25.9	0.0
3 WAP	57.1	0.0
4 WAP	5.4	12.6
5 WAP	0.0	27.2
6 WAP	0.0	26.3
7 WAP	0.0	20.4
8 WAP	0.0	10.6
Others	11.6	2.9
Total	100.0	100.0

* WAP: Weeks after planting.

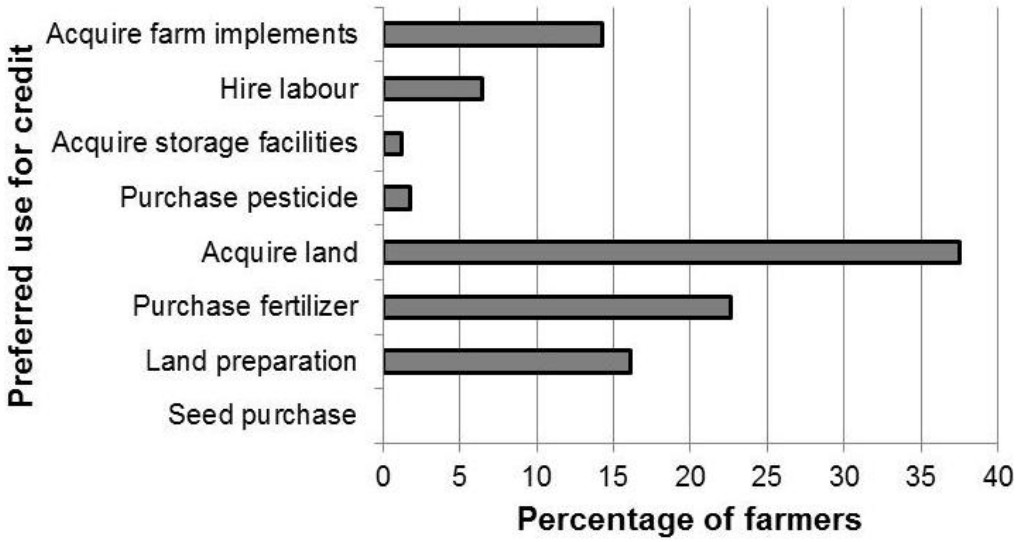

Figure 8. Preferred use of credit if available.

country.

Farmers adopt different methods in their application of fertilizer to maize. These methods include: broadcast, ring, strip, dibble and point surface placement for fertilizer application. The dominant application method is the point surface placement method adopted by 54% of the farmers that applies fertilizer to their maize (Table 10). This method is easy and less labour demanding but not efficient in terms of nutrient availability to the plant as the fertilizer can easily be lost.

Timely fertilizer application is very critical to sustain good crop yield. The earlier the first application of fertilizer the better it is for good plant growth. However, most farmers do their first application in the third week after planting and the second application in 5-6th week after planting (Table 11). The delayed first application of fertilizer is because most farmers want to be sure of a good crop stand before applying fertilizer. This is to cut cost in case there is poor crop establishment and re-planting has to be done.

It is evident that most farmers aspire to own land; as those without land prefer using any resource available to them to acquire land. In general, majority of the farmers will prefer using credit if available to them to acquire land than to purchase fertilizer (Figure 8). The last item on farmers shopping list is the purchase of seed, followed by storage facilities and then farm implements. However, if farmers are to make improvement in their farming venture then these factors will also have to be considered sooner than later.

These above findings corroborate some of Braimoh and Vlek (2006) who combined a soil quality index on a continuous scale with a social data set to model maize yield in Northern Ghana using linear multiple regression and came out with five significant variables of soil quality index, fertilizer use, household size, distance from main market, and the interaction between fallow length and soil quality index.

Conclusion

Maize is the main or primary agricultural income source among 19 other crops cultivated by the farmers, an indication of the importance of maize to most farmers in the maize belt of the country. Most of the farmers have had interaction with extension staff from MoFA and obtained information or training from them.

Some of the farmers especially, settlers do not have land of their own and have to rely on short-term tenancy arrangements to access land for farming. Such a practice does not promote proper management of land as farmers are always on the look for fertile land to rent and crop rather than sustain productivity on the same piece of land. Farmers are of the view that their crop land are gradually declining in fertility, thus there is the need to adopt improve management practices to sustain productivity. Almost 55% of the farmers practise continuous maize cropping. Most of the farmers (61.3%) plant their maize as a sole crop which means they can conveniently adopt good management practices that includes fertilizer application.

Farmers acknowledge the importance of fertilizer in improving maize yield as compared to other crops. Sixty-six percent of the farmers use fertilizer in maize production. They are constrained in the use of fertilizer by its high cost; timely availability; cropping system such as mixed cropping that makes mechanization difficult; method and distance needed to transport it to the house and or the farm. Also a significant number of farmers still rely on old maize varieties which they find to be more reliable under limited resources such as water and nutrients. Farmers adopt different methods in their application of fertilizer to maize. More than 50% of the farmers practice point surface placement of fertilizer and do their first application late, that is, in the third week after planting which affect crop yield.

The lack or low access to credit coupled with high input cost for farming activities are the key constraints inhibiting farmer's ability to expand and improve their maize farming. As an issue of priority, landless farmers will want to use credit if available to acquire land whiles others will use it to purchase fertilizer.

There is the need to provide credit facilities to farmers to enable them purchase fertilizer to boost maize production. Farmers must be trained on effective methods and timely application of fertilizer by MoFA extension staff.

ACKNOWLEDGEMENTS

The authors are most grateful to the International Fund for Agricultural Development (IFAD) for making fund available through International Fertilizer Development Center (IFDC), North and West Africa Division for the study. The Ministry of Food and Agriculture (MoFA) District Directors of Agriculture and their staff in the enumeration districts who were very supportive of the survey and provided information that aided in the selection of enumeration communities. We are also grateful to the enumeration team and the numerous farmers, and opinion leaders of communities where the survey was carried out for their time and information.

REFERENCES

Angelucci F (2012). Analysis of incentives and disincentives for maize in Ghana. Technical notes series, MAFAP, FAO, Rome.

Armah M (2000). Maize, Soya and Rice Production and Processing. Millennium Development Authority. Invest. Opport. Ghana pp. 3-4.

Braimoh AK, Vlek PLG (2006). Soil quality and other factors influencing maize yield in northern Ghana. Soil Use Manage. 2(22):165-171.

FAO (2004). Gateway to land and water information : Ghana national report. FAO Land and Water Development Division, on-line resource (last updated 2004), URL http://www.fao.org/ag/agl/swlwpnr/swlwpnr.htm.

Gerner H, Asante GH, Owusu-Bennoa EO, Marfo K (1995). Ghana privatization scheme, IFDC-Africa, Lomé.

Ghana Statistical Service (GSS) (2008). Ghana Living Standard Survey Report of the Fifth Round (GLSS 5), P. 4.

Hilhorst T, Muchena FM (Eds) (2000). Nutrients on the move – Soil fertility dynamics in African farming systems. International Institute for Environment and Development, London.

ISSER (2009). The state of Ghanaian economy in 2008, Accra.

MoFA (2007-2011). Agriculture in Ghana: facts and figures. Produced by the Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture. Accra.

Morris ML, Tripp R, Dankyi AA (2001). Adoption and Impacts of Improved Maize Production Technology: A Case Study of Ghana Grains Development Project. Economics Program Paper 99-01, pp. 2-4.

Scoones I, Toulmin C (1999). Policies for Soil Fertility Management in Africa: A report prepared for the Department for International Development. IDS and IIED. Russell Press, Nottingham.

UNEP-GEF Volta Project (2010). Volta Basin Transboundary Diagnostic Analysis: National report on Ghana.

SPSS Inc. (1999) SPSS base 10.0 for Windows User's Guide. SPSS Inc., Chicago IL.