N2Africa Project in northern Ghana

Evaluating farmers' decision making on choosing technologies and practices in adaptation trials

Kohji Nakasaka
April 2016
MSc Internship report (PPS-70424)
The N2Africa project in northern Ghana

WAGENINGEN UNIVERSITY
WAGENINGEN UR

IITA
Research to Nourish Africa

N2N

N2Africa Project in northern Ghana

Evaluating farmers' decision making on choosing technologies and practices in adaptation trials

Kohji Nakasaka

April 2016

MSc Internship report (PPS-70424)

The N2Africa project in northern Ghana

Supervisor: Joost van Heerwaarden

Examiner: Katrien Descheemaeker

Acknowledgements

I would like to thank Joost van Heerwaarden for facilitating this internship with the N2 Africa project. He provided guidance in establishing research questions and analysing points. I would also like to express my appreciation to Samuel Adjei-Nsiah, N2Africa country coordinator in Ghana. He was of great help in introducing me to the research fields and local partners. He coached me on agronomic knowledge in the fields. In addition, it was good fun to work together with the other colleagues from N2Africa: Eric, Kojo Ahiakpa, Akakpo Daniel Brain, Abdul-basit Ussif Alabi, and Arnold Amppiah. They supported me a lot by welcoming me at the IITA office, arranging the fieldwork, and having some stimulating discussions. Finally, I want to thank all of the farming households that took part in the interview surveys. They welcomed me with cooperative attitudes.

Summary

The internship was conducted in Ghana from 17th of July to 26th of September as part of the N2Africa project. The work was based at the IITA (International Institution of Tropical Agriculture) office in Tamale. The N2Africa project aims to enhance biological nitrogen fixation of leguminous crops grown by smallholder farmers in Africa, which leads to increased productivity and improved cash income. The leguminous crops focused on here are cowpea, soybean and groundnut. New technologies such as new varieties of seeds, chemical fertiliser, inoculant, and management practices, are introduced to farmers through demonstration plots established in each community. Farmers are then invited to use the demonstrated technologies on their own farmlands, after which data on their practices and experiences are collected. The use of tablets with the Open Data Kit (ODK) software was introduced as a tool for collecting field data. I collected data on forty-four on-farm trials in three regions (Northern, Upper West and Upper East). The farmers that adapted our new technologies were highly motivated to solve their common problems such as low productivities, pest, and climate vulnerabilities. Farmers' selections of new technologies were mainly based on their observations in the demonstration plots and the physical appearance of the seeds. Regarding the choice of practices, ninety-three present of farmers did not choose intercropping system in N2Africa plots to see exact effects of the distributed technologies packages. On the other hand, twenty-three percent of farmers selected intercropping in their own fields due to limited land space, complementary planting, and preference. Ninety percent of farmers selected row planting in N2 Africa plots because of benefits such as maximizing yield and convenient weed management. However, thirty-two percent of farmers did not choose row planting in their own plots. Their main concerns were time and lack of skills. When it comes to plant survival rates, soybean was poorer compared to the other crops. A main reason of the bad survival rates was heavy or no rain after sowing seeds. Hence, it might be helpful to give the meteorological information to farmers in sowing season.

When it comes to the implementation of tablets, most of local partners gave us positive feedback due to an easy data integration between questionnaires, pictures and GPS record. While, they were feeling inconvenient because of the lack of a sufficient number of tablets in each region. The project was found to face a number of challenges such as lack of options in choosing technologies for farmers and untimely delivery of resources for collecting data to field extension officers. These can lead to the decrease in farmers' motivation and data accuracy. Therefore, it is significantly important to develop a regular supply system of project's resources in order to facilitate the project smoothly.

Table of contents

Introduction

Northern Ghana is composed of three parts: Northern, Upper East and Upper West (Fig 1). Although Ghana has undergone considerable development in recent years, thirty-six per cent of people living in the three areas still have difficulties accessing sufficient, safe, and nutritious food that meets their dietary needs (Elliot & WFP, 2012) Crop productivity is low, to a large extent due to the deficiency of nitrogen in the soil and lack of mineral fertiliser use (Dakora & Keyaz, 1997). Farming practices in northern Ghana have changed from shifting cultivation to continuous cropping due to increasing population pressure (De Ridder et al, 2004). Continuous cultivation removes inorganic nutrients in the soil through up-taking by plants, and reduces soil organic matter that can supply nutrients to the soil as well as improve nitrogen use efficiency as a long-term perspective (Braimoh & Vlek, 2004; Giller et al, 2006). As a consequence, growing food insecurity in these areas has caused increased migration to the southern part of Ghana (Elliot & WFP, 2012).

Leguminous crops have the potential to improve soil nitrogen fertility of smallholder farming systems through biological N2-fixation (Ojiem et al, 2007). N fixation by legumes occurs through symbiosis with rhizobium bacteria that live inside nodules on the roots of the legume plant. Generally, the amount of bacteria in the soil is limited. Also, the amount of N fixation by leguminous crops differs between varieties, soil types, and climate conditions (Dakora ’ & Keyaz, 1997). For example, the activities of rhizobia may be suppressed in tropical areas due to high annual temperatures (Zahran, 1999). As a consequence, the contribution of nitrogen supply by leguminous crops may be constrained in northern Ghana. Therefore, it is important to disseminate available technologies that support nitrogen fixation.

The government of Ghana is focusing its development efforts on these northern regions to bring new technologies and investments such as certified seeds, agrochemicals, inoculants, and management practices (MoFA, 2010). According to Bressers (2012), the highest yield of leguminous crops was observed on farm fields applied with TSP (triple superphosphate) and inoculants compared to fields without any technologies and applied TSP or inoculants in northern Ghana. However, many smallholder famers there are not familiar with such modern agricultural technologies (Verloo and Roggeband, C. 1996).

The N2Africa project, led by Wageningen University and funded by the Bill and Melinda Gates foundation, aims to ensure sufficient food and nutrition for smallholder farmers in Africa by improving the productivity of leguminous crops. The aim is to disseminate best practices and inputs such as improved seeds, fertilisers, and inoculants. The project is also creating a sustainable input supply chain of the technologies and marketing for the output produced by smallholder famers, which would enable them to independently secure their own food. The core countries of this project are Ghana, Nigeria, Ethiopia, Uganda, and Tanzania. Wageningen UR and IITA are the main fieldwork coordinators and implementers. The first phase of this project was conducted from 2009 to 2013, with the second phase starting in 2014. In this present phase, the focus is on delivering technologies developed and tested in the first phase to farmers through collaboration with public and private partners in each region. Farmers have the opportunity to see how the plants with technologies were growing in demonstration plots established by field extension officers. Based on their observations, farmers could choose specific technologies to grow on their own farms in so-called adaptation trials. The aim of the adaptation trial is to assess patterns of farmers' decision making when implementing proposed technologies on their own farmlands. The technology package distributed to farmers contained improved legume seeds, fertilisers, and inoculants with recommended planting practices. The packages were supposed to be used in each plot in 10 x 10 m (N2 plots). Farmers were asked to cultivate the same legumes in their own plots with their own seeds, inputs and practices (farmers' plots).

Interviews with farmers were conducted two times during the season: before harvest and after harvest. The project recently started to use tablets (SAMSUNG Galaxy) for implementing surveys using electronic forms (Open Data Kit). Results were aggregated on a central server, with the aim of evaluating technology performance and suitability among trials.

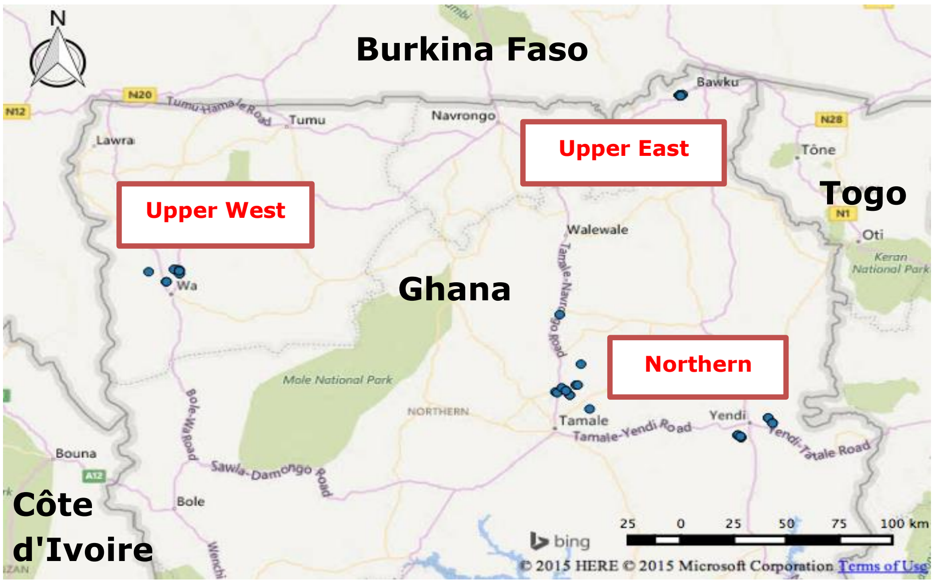
During this internship I conducted interview surveys with adaptation farmers before the harvest season with electronic forms on the tablets as new data collection tool.

The objectives of this report are: 1) to describe farmers' properties and field conditions and characterise crop management in adaptation trials; 2) to assess farmers' decision making on choosing technology packages and practices, comparing N2 plots and farmers' own plots; 3) to identify the challenges and develop recommendations in terms of how to utilise tablets as a new data-collecting method by our project partners.

Methodology

Area description

The target regions are three regions in the northern part of Ghana; Northern, Upper East, and Upper West. The farming style in this area is mainly rain-fed. There are two main seasons: the rainy season between May and October and the dry season between November and April. The average rainfall between 2001 and 2010 in Northern, Upper East, and Upper West were 1204, 937 and 947 mm, respectively.



Sample plots

Figure 1 Map in the northern part of Ghana

The main crops in this area are maize, yam, cassava, rice, sorghum, millet, cowpea, groundnut, soybean, and tomatoes. With regards to the soil in the northern part of Ghana, silty to sandy soils are dominant probably due to the effects of wind deposition in this area. The structure of soil is poor because of low organic matter and clay contents; also, the soil does not have sufficient levels of nitrogen (Braimoh & Vlek, 2004; FAO, 2005). Soil fertility in the Upper East region is relatively better than in the other regions (Table 1).

Table 1. Fertility Status of Top Soils in the Regions

Region	Soil pH	% Organic matter	% Total Nitrogen	Available Phosphorus (mg/kg soil)
Upper East	5.1-6.8	1.1-2.5	0.06-0.14	1.75-14.75
Upper West	6.0-6.8	0.5-1.3	0.01-0.07	2.0-7.4
Northern	4.5-6.7	0.6-2.0	0.02-0.05	2.5-10.0

Source: Soil Research Institute, CSIR-Kumasi

N2 Africa demonstration and adaptation

The three legume crops are distributed from N2Africa project in Ghana: soybean (Glycine max), cowpea (Vigna unguiculata), and groundnut (Arachis hypogaea). Soybean varieties were Jenguma and Sonpongo. Groundnut varieties were Chinese, Sumnut 22, and Sumnut 23. Cowpea varieties were Songotura, Padituya, and Apagbaala. Cowpea is the main legume crop in the dry savannah regions of West Africa (Dugje, Omoigui, Ekeleme, Kamara, & Ajeigbe, 2009). It is an important crop for farmers because of the resistance to drought and the ability to improve soil fertility. The stem and leaves are used or sold as animal feed. Groundnut is also a main food and cash crop in this area. It is also highly valued as fodder for livestock and is often traded in West Africa. Soybean is relatively new compared with other leguminous crops; the Ministry of Food and Agriculture (MoFA) in Ghana has been promoting soybean production not only for the function of nitrogen fixation but also for human diets as a protein source and income source in northern Ghana (Akramov, 2012). The inoculants that were provided to farmers in Ghana were imported from Legume Technology in the UK (http://www.legumetechnology.co.uk/).

Adaptation trials are conducted in phase two of N2 Africa to assess deviations and decision-making patterns when farmers select a technology from several options we provide. Eventually, the adaptation of particular best-bet technologies are evaluated and selected by farmers. In the trials, there are between 200-1000 adaptation farmers per target region. All farmers provided with an N2Africa technology package are registered on the "Input Distribution and Feedback Form." The packages in the local demonstration trial are distributed before they start farming to make sure that the inputs for the adaptation trials are applied in time. Field days to demonstrate the technologies to farmers are set up in each community. After being presented with information about the technologies, all farmers have the opportunity to choose one technology to evaluate on their own farms. They create a small trial plot (10m × 10m) in the same field as their own legume crop following the instruction leaflet, including information for plot establishment, practices, and harvesting methods. In the leaflet, the recommendation given is to sow the beans at 25 cm between plants and 50 cm between rows and to grow them solely. But they are allowed to adopt the practices they think best.

In northern Ghana, three different adaptation trials were conducted: varietal, input and density trials. Each community in the three regions was assigned to one of the trials with one legume crop by the project. In communities of varietal trials demonstration plots were established with several varieties and control (farmers' variety) to compare the effects of the varieties. Farmers in the communities had options to select seeds varieties they like when technologies packages were distributed. The communities of input trials got demonstration plots that plants had grown with different fertilizers with or without inoculants. The technologies packages of input trials contained seeds (specific variety for each legume), TSP fertilizer and inoculant (only for soybean farmers). In the communities that density adaptation trials were conducted, there were demonstration plots with different row and plant densities. Farmers in this communities could choose the preferable densities when they sow the distributed seeds on their own farm.

Focal adaptation farmers were selected to gain detailed information of the on-farm performance of N2Africa packages. They are supposed to be selected randomly, at least 20 among the adaptation farmers who planted the packages per target region. The interview surveys with the focal adaptation farmers were conducted two times: mid-season and in the harvest season. The main survey mid-season was to capture the reasons why farmers selected the technologies and the practices to cultivate the provided leguminous crops. The yield data of surveyed farmers was collected in the harvest season.

Data collection

A total of forty-four interview surveys were conducted in four regions (Savelugu, Upper East, Upper West, and Yendi) during this internship. A subset of so-called focal adaptation farmers was selected by field extension officers from the full list of adaptation farmers. Interviews were conducted in the fields with field extension officers translating the answers given by farmers. The questionnaires contained questions on the reasons for choosing the packages and practices (intercropping or not, row planting or not, recommended spacing or not). They were conducted with open questions. We also asked farmers several questions on: the cultivation experiences of the legumes, varieties and inputs (fertilizers and inoculants) they chose in this trial, whether they used all materials (seeds, fertilisers and inoculant) distributed by the project, the number of seeds in one hole, whether they planted the same legumes in their own plots with their own inputs and practices, and crop succession and the yields (1 year and 2 years ago) in N2 plots. In the fields, we verified the properties such as slope (flat, moderate and steep), fertility (good, moderate and poor), drainage (good, moderate and poor) through both interviews to farmers and our observations. For example, fertility was determined by the soil colour, soil types (clay or sandy) and the observation of an organic matter content. Drainage was also assessed by soil type and farmers' opinions. If the assessment day was after rain we took into account the field conditions whether it had become dry immediately or kept puddle of water. We also measured soil depth (at three points), spacing of the row and plants, and germination rate with four levels (0–25%, 25%-50%, 50-75%, and 75%-100%). We took GPS data standing in the centre of N2 plots. In addition, we took overview photos in N2 and farmer's plots respectively. One interview took about forty minutes, including the field surveys.

The tablets (SAMSUNG Galaxy) are used for collecting data from this survey in the N2Africa project. The electronic-based field book (version 'FB_FocalAdaptation_Part1_2015_V1.5') are registered in Open Data Kit (ODK) on the tablets. ODK is an open-source software to manage mobile data collection. It was developed by researchers at the University of Washington. After finalising them, interview results with GPS data and photos were aggregated on a server, from which they were downloaded from the website (http://odk.n2africa.org:8080/ODKAggregate). This was expected to save time cleaning up the row data collected by field officers. The collected data was analysed in the Microsoft Excel© software.

The reasons for choosing technology packages were grouped into five main categories with high priority answers from farmers interview. The results were summarised for each adaptation trial: varietal, input, and density. When it comes to farmers' reasons for selecting practices, the results were compiled in tables for each practice: intercropping, row planting, and recommended spacing. A Chi square test was conducted to assess statistical significances of difference of choosing patterns between N2 plots and farmers' own plots. Average plant survival rates for each legume was calculated comparing between N2 plots and farmers' own plots. A T-test was conducted to comprehend the statistical significances of the two average rates.

Results of the field survey

The number of interview surveys

In terms of the gender of sampled focal adaptation farmers, twenty-five farmers (57%) out of forty-four were female and nineteen farmers (43%) were male. The number of surveys in cowpea, groundnut, and soybean plots were 14, 11, and 19, respectively. There were 16 varietal adaptation plots, 26 input adaptation plots, and 2 plant density adaptation plots (Table 2). All interviewed farmers planted the N2Africa packages in their farmlands or communal lands. Forty out of forty-four farmers had their own plots where the same leguminous crops as on the N2 plots were planted.

Table 2. The sample number of interview surveys in each region

	Cowpea		Groundnut		Soybean			Total
Region	**Input**	**Varietal**	**Input**	**Varietal**	**Input**	**Density**	**Varietal**	
Savelugu	2		1	2	6 (2)		5 (1)	**15**
UE	2			4		2 (2)		**8**
UW	2	4	2	1	2 (1)			**11**
Yendi	4		2		4 (2)			**10**
Total	**10**	**4**	**5**	**7**	**12**	**2**	**5**	**44**

* UE = Upper East, UW = Upper West

*(): Inoculated

Farmer properties and farmland conditions

Ninety-one percent of the N2 plots were established on farmers' own land and the rest was on communal lands. Eighty-two percent of the farms were flat lands and eighteen percent were in moderate condition. With regards to soil fertility, fifty-four percent of farmers answered that N2 plots has good fertility, thirty percent were moderate, and sixteen percent were poor. The fertility condition of sixty-four percent of N2 plots were better, compared to other farmlands owned by farmers and the another thirty-six percent of N2 plots had more or less the same fertility condition with other farmlands. Only seven percent of farmlands had poor drainage, but over half of the plots had high drainage.

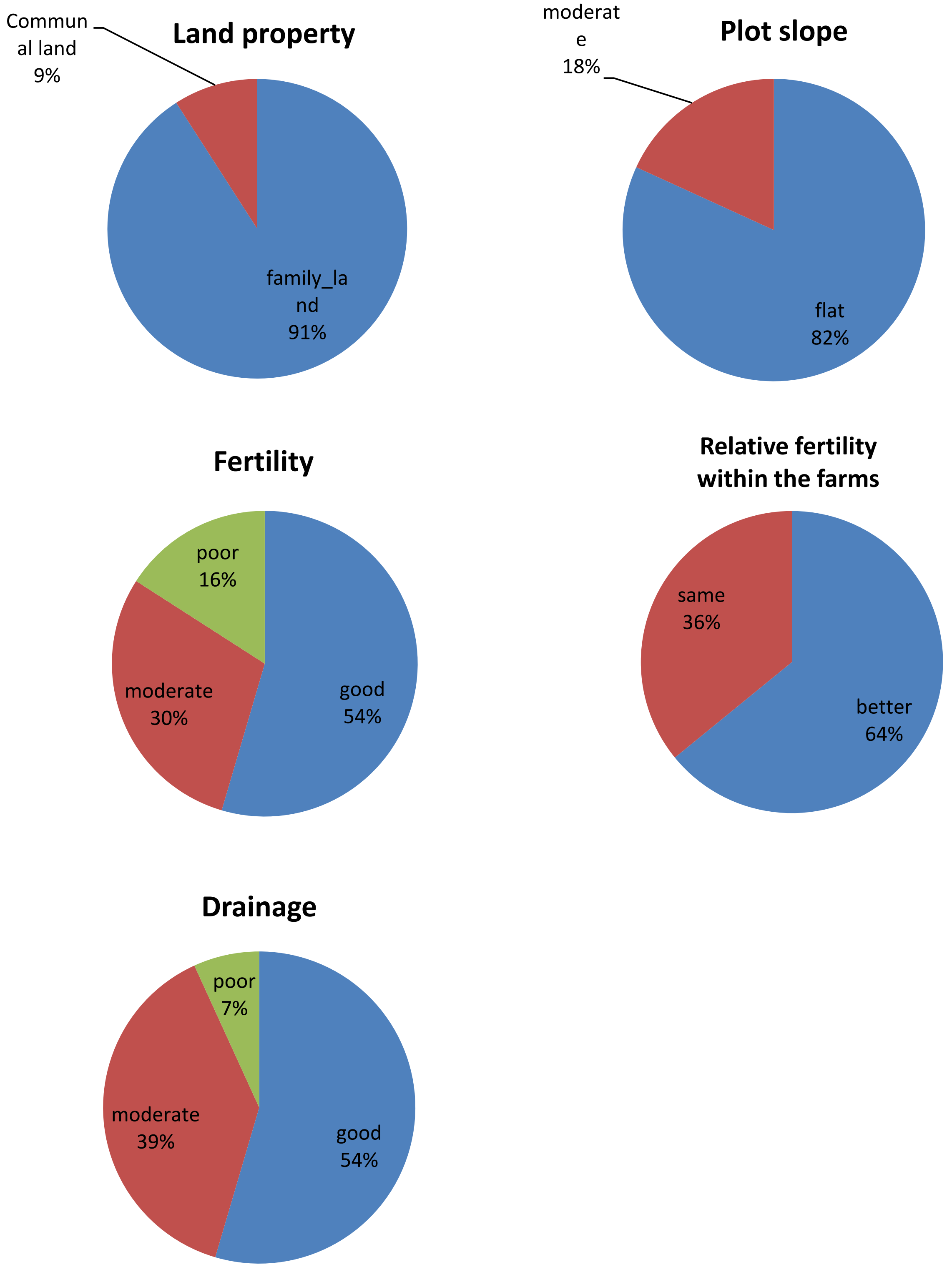


Figure 2 farmers' properties and farmland conditions of N2 plots

Reasons for choosing the package

The reasons for choosing technology packages were divided into five categories (figure 3). All farmers answered that they visited demonstration plots to see how the plants were growing before choosing the packages.

The most common reason, at forty-one percent, was that they wanted to compare the productivity of the new technologies with their own varieties or practices.

Twenty-one percent of farmers chose the package because they had learned about the potential of good germination rates from the demonstration plots established by the N2Africa project. There were also farmers who decided to adopt the packages after hearing about the benefits of them from field extension officers.

Eighteen percent of farmers selected the package because of how the seeds looked. The answers related to the physical appearance of seeds were mostly from varietal adaptation farmers, especially groundnut and cowpea farmers.

Another eighteen percent of farmers didn't have the opportunity to select the technology packages that interested them because the project didn't have enough seeds and inputs to distribute to all adaptation farmers. Therefore, the farmers received specific packages that were available at that time.

Nine percent of farmers had previously cultivated the same crops with the same varieties and were aware that the varieties were highly productive, but they seemed to expect even better results from the improved seeds provided by N2 Africa even though they had grown the same varieties before.

When it comes to crop preferences, farmers preferred cowpea because it can be harvested earlier than other leguminous crops. They thought that it would be helpful to satisfy their children's nutrition demands. Soybeans and groundnut are popular because of the rich variety of recipes with these crops. All of the reasons that mentioned children and cooking were stated by female farmers. Also, there were some unique answers from soybean varietal adaptation farmers. Two of them selected Jenguma as a soybean variety because this variety has more patient about the cracking during harvest season than with other varieties, which means that they do not have to worry about the harvest timing so much.

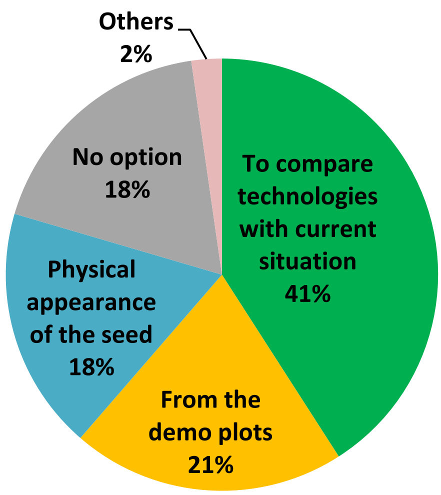


Figure 3 The reason for choosing package

Table 3 shows the reason for choosing the package in each group of varietal, input, and density adaptation, respectively, in detail. Thirteen varietal farmers had previously cultivated the selected crops before, while three farmers had never. The main reason for choosing the packages was due to the physical appearance of the seed, such as size and smoothness of the seed skin.

Table 3. The reason for choosing the package (Varietal adaptation)

Group	Ever cultivated this crop before?	Ever cultivated this variety before?	Reason for choosing package	Number of responses
Varietal (16)	Yes (13)	Yes (1)	Not able to select the preferred package	1
		No (12)	Physical appearance of the seed	6
			To compare new technology with current situation	5
			Learned from the demonstration / field officers	1
	No (3)		Physical appearance of the seed	1
			To compare new technology with current situation	1
			Learned from the demonstration / field officers	1

With regards to input trials without inoculant, sixteen out of twenty-one farmers had previously grown the crop before. It was first time for fourteen farmers to grow with the fertiliser. Six farmers out of the fourteen selected the packages because they wanted to know the benefits of the new technologies. Three farmers did not have the opportunity to choose due to a lack of resources of technologies packages from the project. Another three farmers chose the packages because they had previously learned about the benefits from the demonstration plots or extension officers. While, five farmers had never cultivated the same leguminous crop before. They were also interested in growing crops with new technologies, and they decided to grow them following observation in demonstration plots.

There were five focal adaptation farmers who received inoculants in their packages. Three of them had previously cultivated the crops, but none had previously grown the varieties or used inoculants.

Table 4. The reason for choosing the package (Input adaptation)

Group	Ever cultivated this crop before?	Ever cultivated with the fertiliser before?	Ever cultivated with the inoculant before?	Reason for choosing package	Number of responses
Input without inoculant (21)	Yes (16)	Yes (2)	-	Not able to select the preferred package	2
		No (14)	-	To compare new technology with current situation	6
				Not able to select the preferred package	3
				Physical appearance of the seed	1
				Learned from the demonstration / field officers	3
				Others	1
	No (5)	No	-	To compare new technology with current situation	2
				Learned from the demonstration or field officers	2
				Not able to select the preferred package	1
Input with inoculant (5)	Yes (3)	No	No	To compare new technology with current situation	2
				Learned from the demonstration / field officers	1
	No (2)	No	No	Learned from the demonstration / field officers	1
				Not able to select the preferred package	1

When it comes to density adaptation farmers, they were growing soybeans with recommended plant spacing. The reasons why the farmers chose the packages were that they wanted to know more about the new technologies to improve their productivity.

Table 5. The reason for choosing the package (Density adaptation)

Group	Ever cultivated this crop before?	Ever cultivated with the fertiliser before?	Ever cultivated with the inoculant before?	Reason for choosing package	Number of responses
(2)	Yes (2)	-	-	To compare new technology with current situation	2

Adaptation of demonstrated technologies

According to table 6, forty-one out of forty-four farmers were growing the crops with sole planting in N2 Africa plots. On the other hand, there were 3 farmers out of 44 who were intercropping in N2 plots. When it comes to farmers' plots, nine farmers out of forty were conducting intercropping practice in their farmlands. The Chi square test indicated that there was a significant difference between N2 and farmers' plots in terms of intercropping (P=0.04).

Ninety percent of farmers used row planting with spacing, with ranges between 60 and 75cm in the N2 plots while there were four farmers who did not adopt row planting. With regard to farmers' plots, about sixty-eight percent of farmers selected row planting; however, the rest of farmers didn't choose the practice. According to the Chi square test, the difference had statistical significance (P=0.017).

Among farmers who conducted row planting with spacing, seventy-six percent of farmers did the practice with the recommended plant spacing from the project while twenty-four percent of farmers did not follow that. In farmers' plots, seventy-six percentage of farmers conducted recommended plant spacing and twenty-four percent of farmers did not. The proportion between N2 and farmers' plots did not show a significant difference (P=0.965).

Table 6. The frequency and percentage of adapted practices: intercropping, row planting, and recommended plant space in N2 and farmers' plots across all crops. P-value is the probability value from the Chi-square test for differences between N2 and farmer's plots for each practice.

	Plot	Yes (number)	(%)	No (number)	(%)	Total number	P-value
Intercropping	N2	3	6.8%	41	93.2%	44	0.040
	Farmers	9	22.5%	31	77.5%	40	
Row planting	N2	37	90.2%	4	9.8%	41	0.017
	Farmers	21	67.7%	10	32.3%	31	
Recommended plant space	N2	28	75.7%	9	24.3%	37	0.965
	Farmers	16	76.2%	5	23.8%	21	

Table 7 indicates the reasons why farmers selected the practice in N2 plots. When it comes to intercropping, the reasons were due to land limitation, bad germination of the seeds from N2Africa and to know more about the benefits of the intercropping system. A farmer complementally sowed seeds of Bambara bean due to the bad germination of the leguminous crops, which utilised the space efficiently. Another farmer was experimenting with the intercropping system to learn more about its benefits. His plot had two parts; half was intercropping with maize, and another was sole cropping of soybean. He said that if the yield were better in the intercropping plot, he would adopt it as a main practice in his farmland next year. On the other hand, the main reasons why farmers did not adopt intercropping was because they wanted to know beforehand the exact productivity of the new technologies, followed by negative assumptions about intercropping, such as that it would decrease the yield because of competition with other crops.

The main reason for choosing row planting was due to the efficiency of weeding and applying fertiliser because of sufficient spacing between plants to work. Twelve farmers considered that row planting could maximise the yield of leguminous crops. Four farmers preferred to conduct row planting because the practice made the field look good. On the other hand, four farmers could not afford to conduct row planting due to lack of time. A female farmer learned about the benefits of row planting from a demonstration plot, but the husband, who was responsible for sowing the seeds on their farmlands, did not follow her suggestion, despite having explained that it would save him time.

Five farmers who conducted row planting did not follow the recommended plant spacing because they believe that their traditional spacing would maximise yields. One farmer's row spacing was 90cm for cowpea. He believed that the recommended space led to overcrowded density, which could decrease yields. Two cowpea adaptation farmers planted with 27 cm and 30 cm row spacing, respectively. One believed that this practice was optimal for maximising yields, while the other had some miscommunication issues between the wife who attended the training and the husband who actually sowed the seeds in the field.

Regarding farmers' own plots, the reasons for choosing practices were more or less similar with the reasons in the N2 plots. Nine plots were intercropped with other crops such as yam, sorghum, pigeon pea, millet, and maize. Five of them adopted the intercropping system due to land limitations, while the other three farmers experimented with intercropping on their farmlands to understand better the benefits of this practice. Thirty-one farmers did not use intercropping. The main reasons were that they believed that intercropping would decrease yields, followed by wanting to know the exact yield of the leguminous crops they planted before adopting the practice. Regarding the reasons that farmers did not select row planting, nine farmers preferred to use their traditional practices in their own plots.

Table 7. The reason for choosing the practices in N2 and farmers' plots

Intercropping	Reasons	Number (N2)	Number (farmers)
Yes	Land limitations	1	5
	Complementary planting due to bad germination	1	1
	To know the benefits of intercropping better	1	3
Total number		**3**	**9**
No	To know the exact yield for leguminous crops beforehand	19	12
	Intercropping decreases the crop yield	17	16
	Soil fertility is not enough	2	1
	No space	1	1
	No extra seeds	1	1
	Saving time	1	0
Total number		**41**	**31**

Row planting	Reasons	Number (N2)	Number (farmers)
Yes	To make the weeding practice easier	17	10
	To maximise the yield	12	9
	To make the field look nice	4	1
	ND	4	1
Total number		**37**	**21**
No	No time/skill to adopt a row planting	4	5
	Prefer traditional practice	0	3
	Miscommunication with family members	0	2
Total number		**4**	**10**

Recommended spacing	Reasons	Number (N2)	Number (farmers)
Yes	Learned from the demonstration plot	11	5
	Efficiency for weeding and applying fertiliser	11	9
	Fixed space by the ploughing machine	6	2
Total number		**28**	**16**
No	Prefer traditional practice	5	4
	Lack of necessary tools for row planting	3	0
	Miscommunication with family members	1	1
Total number		**9**	**5**

Sole planting with row & recommended spacing

Sole planting without row planting (scattered)

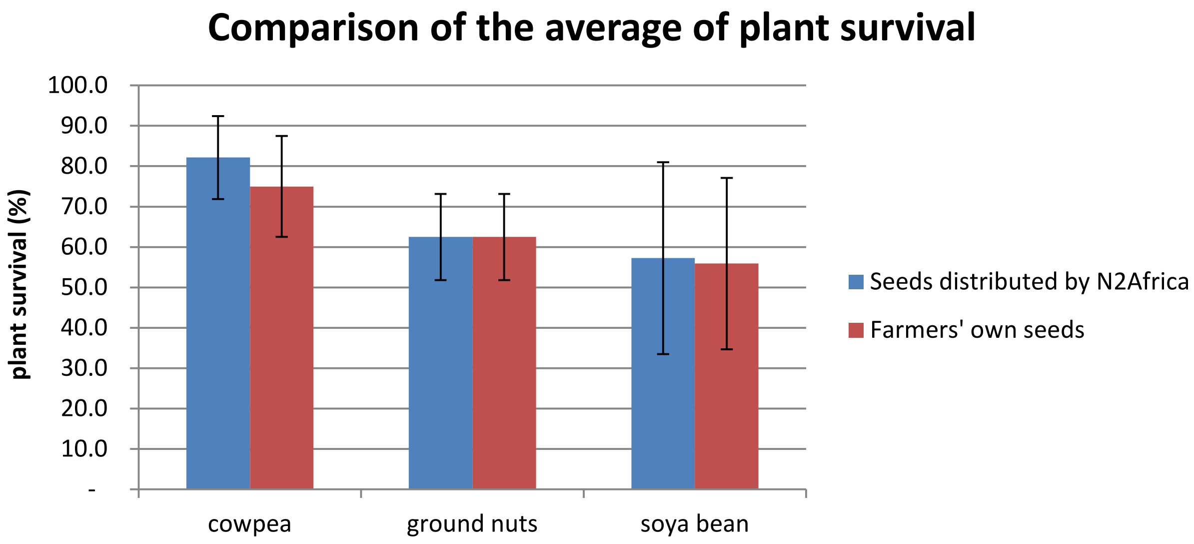
Sole planting with row planting but without recommended spacing

Intercropping

Figure 4. Photos of each type of practice

Plant survival

The average plant survival rates of cowpea, groundnut, and soybean in the N2 plots were 82.1% (±10.3), 62.5% (±10.7), and 60.4% (±23.8), respectively, across all practices. The percentage in farmers' own plots were 75% (±12.5), 62.5% (±10.7), and 55.9% (±21.2). In general, cowpea has good germination rates compared to others. On the other hand, 3 out of 18 soybean adaptation farmers had very poor germination rates, around 10-20%. The farmers told us that this was due to heavy rainfall, a long dry spell, and invasion of black ants after seed sowing. The survival rate of groundnut was the same in the two plots. Although the average survival percentages of cowpea and soybean on the N2 plots were higher than on farmers' own plots, there were no significant differences in both of them (P=0.12, 0.86).



	cowpea	ground nuts	soya bean
F test	0.49	1	0.64
T test	0.12	1	0.86

Figure 5. Comparison of average plant survival rates

75-100 %

50-75%

25-50 %

0-25 %

Figure 6. Soybean plant survival

Previously cultivated crop in N2Africa plots

The information about the crop that was cultivated in N2 plots one year and two years ago was collected in this interview survey. The results showed that maize was the most cultivated crop in the N2 Africa plots both years, followed by groundnut, cowpea, millet, and soybean (Appendix-I). The average yield of maize was 1,829 kg/ha (one year ago) and 1,161 kg/ha (two years ago), but the calculated data varied. There was no correlation between the average yield of privious crops and fertility in each plot.

Discussion of the field survey

Farmers' selection

The main reason for farmers to choose particular technologies was that they wanted to see the (potential) benefits of the new varieties or inputs. They hoped to alleviate the current problems that they faced, such as low productivity, pests, and climate vulnerability. Twenty-one percent of farmers decided to take the most suitable technology to their own field after observation in demonstration plots or learning from field extension officers. They seemed to convince themselves to choose technologies. On the other hand, it seems that varietal adaptation farmers who never cultivated the crop before tended to select the new varieties from their physical appearance of seeds. The look of seeds can be an important factor for farmers in choosing new technologies. These two factors appeared to be important ways to encourage farmers to decide to cultivate crops themselves. Conversely, eighteen percent of farmers could not select the technologies they wanted because of lack of resources for packages distribution from the project. Farmers may have felt too demotivated to consider growing the crops anymore.

The reasons why farmers preferred the crops were very diversified. Farmers wanted to cultivate cowpea because of the short growing period. Cowpea can grow even in dry areas where the rainfall range is between 500 and 1,200 mm/year. There is also an improved variety that can survive even in the Sahel where the rainfall is less than 500 mm/year and is also well adapted to sandy soils (Dugje et al., 2009). Farmers facing issues related to climate vulnerability and soil fertility tended to select cowpea due to the high resilience potential. In terms of groundnut, farmers' own seeds varieties were Chinese in the target regions. Farmers who were on groundnut adaptation trial selected two varieties, Sumnut 22 and Sumnut 23. The appearance of the seeds was given as the reasons for choosing packages for both varieties. No groundnut adaptation farmers answered that they chose the packages following observation in demonstration plots. This might indicate that farmers did not see a big difference in terms of growing conditions in both varieties. Soybean is relatively new for farmers in these regions (Akramov, 2012), but two farmers answered that they like to cook using soybean, which means that some farmers are already familiar with how to utilise soybeans in their daily meals. The distribution of cooking recipes for soybeans might encourage more farmers to grow the crop.

Farmers' practices

According to the results on farmers' practices, most farmers selected sole planting in the N2 plots to see the benefits of the technology. It seems that they were expecting positive differences with the developed methods from their traditional practices. On the other hand, there were some negative perceptions of row planting. Some farmers were concerned that the practice consumed a lot of time and labour, especially when they cultivate on a large scale. Although the intercropping system is not common among the farmers, limiting factors such as land space constraints and bad germination of sowed seeds encouraged them to choose intercropping in order to complement the limitation.

In terms of the use of organic fertiliser, there were only two out of forty-four farmers who used it on their farmlands last year. Livestock rearing is an important component of the farming system in this area and is used as insurance in case of crop failure and a source of cash, and results in good utilisation of crop residues. Manure generated by livestock also has an important role as an input of organic carbon and nitrogen into the soil. The use of manure in crop production systems is becoming more diffused due to awareness by farmers of the need to improve soil fertility for sustainable crop production (Karbo & Agyare, 2002). However, one of the constraints is the difficulty in collecting manure due to the system of keeping livestock on a free, open range (Karbo & Agyare, 2002). Secondly, the amount of feed for livestock during the dry season is insufficient, resulting in low-quality manure. An optimal manure allocation strategy that can spread SOM in the fields homogenously, which thereby leads to enhanced nitrogen fixation by leguminous crops, is needed.

Plant survival and past yield

The germination rate of cowpea was good while the rate of soybeans was relatively low and the variability was large. The reason for the low, variable rates for soybean was mainly because of heavy rainfall or a long dry spell after seed sowing, and also invasion by black ants. Soybeans grow well in soils with high organic material content. In general, soybeans prefer a pH of between 5.8 and 7.8, and do not perform well under extreme alkaline or acid conditions (Nieuwenhuis & Nieuwenlink, 2005). Some farmers might still not be used to the management of this crop. According to Bressers (2012), it became clear that the influence of planting time played an important role in the productivity of leguminous crops in the Ghanaian trials. The average grain weight in kg per ha of soybeans and groundnut decreased over planting time between July to August. The month with the highest average yield of cowpea was July, followed by August. This might be because of reduced pest pressure during flowering and podding during the end of the season. Information from the project on the appropriate time for sowing would be helpful, especially for improving the low germination rate of soybeans.

When it comes to yields in the N2 plots one year ago, the reported maize yield (1829 kg/ha) and cowpea yield (1596 kg/ha) had high standard deviations at 754 and 1089, respectively. The reported average was calculated from only six (maize) and four (cowpea) farmers. Removing the highest reported yields (3212 kg/ha of maize and 3212kg/ha of cowpea) bring the average to 1522 kg/ha (SD±473) for maize and 1058 kg/ha (SD±650) for soybeans, respectively.

For soybeans, the average yield last year (494 kg/ha) and two years ago (993 kg/ha) are far below the national average of 1910 kg/ha (Wood, 2013). Although the majority of the crop grown in the N2 plots last year and two years ago was maize, leguminous crops such as cowpea, groundnut, and soybeans were also cultivated. It would be interesting to compare results of actual yields between the plots cultivated with maize and leguminous crops using the collected data of yields in the N2 plots this harvest season.

General conclusion of field survey

Most of the focal adaptation farmers were highly motivated to adapt new technologies to their farmlands. Their decision making for the technologies were mainly based on the appearance of the seeds and their observation of legume crops grown in demonstration plots. Some farmers did not have the opportunity to select the packages that they wanted due to lack of resources for distribution. This situation should be avoided as much as possible to keep farmers motivated to grow the crops. In terms of the practices, intercropping was not common for farmers, but some of them chose the practice because of limited land space and bad germination rates of the current season. In general, farmers tended to avoid taking time for planting in row with specific spacing to reduce their workload, although some of them reported seeing some benefit of this practice. The yield measurements from these trials should confirm if these benefits were indeed achieved. If so, it may be worthwhile investing their labour in the practices recommended by the project

In terms of plant survival rate, soybean had a lower germination rate than cowpea and groundnut. According to the farmers' answers about poor germinations, the main reason was due to the heavy or no rain after sowing seeds. Hence, proper agricultural management for soybeans, such as specific guidelines on sowing dates and taking into account weather forecasts, might be needed to improve the situation. The most planted crop in the N2 plots one year and two years ago was maize, followed by leguminous crops such as groundnut, soy beans, and cowpea. Although the reported yields had high variations, showing farmers the comparisons between the yield of leguminous crops cultivated in previous years with their own practices and the yield grown this year with technologies after data collection for this harvest season may contribute to adoption and adaptation of these technologies in the future.

Results of the implementation

Tablet implementation

At the beginning of the internship, the training for using tablets was conducted for local partners. We visited three regions, Upper West, Upper East, and Northern region, where our demonstration plots are based. The participants on the training were from the Ministry of Food and Agriculture (MoFA), Evangelical Presbyterian Development and Relief Agency (EPDRA), Busaka Agribusiness Company Ltd., and IITA. We explained how to use the tablets and demonstrated it on the field by taking GPS data, measuring germination rates, and taking pictures. Participants were generally eager and willing to learn to use the devices for data collection.

Picture 7. Training for field officers on using tablets

As it was the first time in this project that tablets were used for data collection, I received feedback from field officers who used them in the fields. One of the positive aspects was the ease of integration of data collection. Field officers previously had to collect data with hard copy field books, obtain GPS data and take photos with different machines at the same time. Also, some of them said that the tablet could be a good backup source for collected data.

On the other hand, a lot of field officers complained about the lack of a sufficient number of tablets. We distributed three in UW, three in UE, and three in Northern region. However, it was inconvenient having to share the distributed tablets with other district field officers even in the same region because of the very large area covered by project. We suggested that officers who owned a smartphone install the ODK software on it to mitigate that issue. The use of tablets is helpful as a backup for collect data, but some officers were concerned that it would be double the work because they had to edit the data after the interview surveys and fill in the data in hard copy as well. In addition, it took a lot of time for the older field officers to get used to them. Some of them did not try to use the tablets at all.

The challenges of this project

The N2Africa project in Ghana is well implemented by IITA and local field officers. Almost all demonstration plots I visited during my internship were in good condition and the crops were growing well. Also, the field officers implementing in the field are very motivated about this project. However, some challenges still remain. The established project area is so large that IITA officers cannot cover the distances to see all of the plots. It takes a lot of time and cost to travel to check these plots.

Untimely distribution of resources for collecting data, such as money and field books from the IITA office, was an issue as well. I saw a demonstration plot that was abandoned by a lead farmer because the farmer did not receive the inputs from the field officer at the appropriate time. The field officer explained that he was unable to deliver them on time because of lack of money for fuel for his bike.

The input distribution forms were supposed to be filled in completely by field extension officers; however, the forms were not filled in when I started to do the surveys. The reason why is that the forms were provided via e-mail from the IITA office, but some local partners could not afford to print out the documents by themselves for financial and technical reasons. When it comes to random sampling of focal adaptation farmers, this did not work very well. I thought that I could get the input distribution sheets to draw up a list of adaptation farmers in the communities and decide the focal adaptation farmers randomly before going for interviews, but in fact most focal adaptation surveys were conducted with the leader farmers or farmers who were available on that day.

Furthermore, the extension officers were so busy during the rainy season, as they had other projects besides the N2Africa project. They seemed to want to avoid additional work or changes in project operations. There were some instances in which extension officers tried to skip over some questions they had to ask the farmers in order to save time. The questions were, for example, the name of variety, the name of fertiliser, the farmer's own inputs/practices, and so on. But, actually some of the answers I confirmed with farmers were inconsistent with the answers from field extension officers.

Most focal adaptation farmers were very keen to try the new technologies to find out more about their benefits. They were very cooperative during our interviews. Their preferences for our packages were mainly based on their observations of the technology on the demonstration plots and the appearance of the seeds. However, the project's resources such as improved seeds, fertilisers, and inoculants were not enough to distribute to all farmers and to give them all the opportunity to choose their preferred package.

Recommendations for ongoing implementation and conclusion

- Most field officers felt confident handling the tablets for the field survey from the adaptation trial. Although it might take some time to get the hang of using the tablets in the field, I got the impression that the officers would adapt to them soon. I hope that adoption of the tablets can mitigate some of the burden faced by the extension officers, which leads to expand the target area of this project.

- To avoid any misunderstandings with extension officers when they ask questions and translate farmers' answers during the field survey, I strongly recommend that the purpose of the field survey be clearly understood by all before visiting the fields. For example, for farmers' responses to the question "why did you choose this package?" the translated answers that I often got from the field officers were "to get good yields", but what we wanted to know through this question was the specific reasons why farmers chose the particular packages instead of the other options. It is very important for people who conduct interviews to comprehend the exact meaning of the questions and what we are asking according to the survey's aims, and to not only see the "sentence" in the field book. Besides, it is important to establish clear questionnaires that cannot be misunderstood.

- Farmer information such as ID and input distributions should be shared by all who are involved in this project in a timely manner. The use of cloud storage on the Internet such as Google drive can be helpful for sharing with each other and also as a backup, although Internet access is required.
- As for the field book on the tablet, it would be nice if there were free comment spaces in each page to write down the notes. This is because, during interviews using a tablet, I got a lot of valuable answers from farmers that were not directly related to the questions, but it was so hard to take notes in my own notebook and then check or reconcile them with collected data in the tablet.
- Some farmers didn't have any options when the technologies were distributed to them because of lack of resources, such as sufficient seeds, fertilisers, and inoculants. It is important for farmers to have the opportunity to make decisions by themselves, which would make them feel that they have more ownership over growing their crops.
- According to Dogbe et al. (2013), the production of soybeans is still not profitable, and can even create negative net incomes for farmers in the northern part of Ghana. Furthermore, the profits of female farmers are less than male farmers since men have more access to rent land from their friends at a cheaper price and female farmers tend to have higher costs for inputs such as seeds and post-harvest chemicals to reduce labour time and intensity. Farmers who started soybean production need support in setting up links with input and output soybean markets (Sarpong & Mensah-bonsu, 2006).
- With regards to inoculants, two farmers could not choose the packages with inoculants because they couldn't store them in cool places. Cold storage chambers that farmers can use to preserve inoculants should be provided to encourage them to use inoculants.
- Leguminous crops are well known as contributors for improving soil fertility, but the effects depend on residue management and original soil fertility conditions. When it comes to the utilisation of grain legume residues in this area, farmers in the Upper East region preserve about 70%-80% of residues for feeding livestock, while farmers in the Upper West region allow animals to graze on residues in the field instead of storing the crop residues (Akakpo, 2015). The positive

contribution of nitrogen budgets are shown to be more positive when all residues were left on or returned to the field (Marinus, 2014). Therefore, it is important to comprehend farmers' practical residue management practices in depth to maximise the contribution of nitrogen fixation. A practical residue management protocol should also be included in this package leaflet.

References

Al-Hassan, R. M., Sarpong, D. B., & Mensah-Bonsu, A. (2006). Linking smallholders to markets. International Food Policy Research Institute, Ghana Strategy Support Program.

Akakpo, D. B. (2015). Grain legume residues as a livestock feed resource for smallholders in northern Ghana, N2Africa News, Retrieved from http://www.n2africa.org/content/grain-legume-residues-livestock-feed-resource-smallholders-northern-ghana.

Akramov, K., & Malek, M. (2012). Analyzing profitability of maize, rice, and soybean production in Ghana: Results of PAM and DEA analysis. Ghana Strategy Support Program (GSSP) Working, *International Food Policy Research Institute*, 0028.

Braimoh, A. K., & Vlek, P. L. G. (2004). The impact of land‐cover change on soil properties in northern Ghana. *Land Degradation & Development*, 15(1), 65-74.

Bressers, E. (2012). The influence of farm practices and field characteristics on legume grain yields in Ghana, BSc thesis, Plant production System, Wageningen University.

Dakora, F. D., & Keya, S. O. (1997). Contribution of legume nitrogen fixation to sustainable agriculture in Sub-Saharan Africa. *Soil Biology and Biochemistry*, 29(5), 809-817.

De Ridder N, Breman H, van Keulen H and Stomph T J 2004 Revisiting a 'cure against land hunger': soil fertility management and farming systems dynamics in the West African Sahel. *Agricultural systems 80*, 109-131.

Dogbe, W., Etwire, P. M., Martey, E., Etwire, J. C., Baba, I. I., & Siise, A. (2013). Economics of Soybean Production: Evidence from Saboba and Chereponi Districts of Northern Region of Ghana. *Journal of Agricultural Science*, 5(12), 38.

Dugje, I. Y., Omoigui, L. O., Ekeleme, F., Kamara, A. Y., & Ajeigbe, H. (2009). Farmers' guide to cowpea production in West Africa. IITA, Ibadan, Nigeria, 20.

Elliot, K., & WFP. (2012). Ghana Comprehensive Food Security & Vulnerability Analysis 2010: Focus on Northern Ghana, Ministry of Food and Agriculture Ghana Statistical Service, (May), 1–61. Retrieved from http://documents.wfp.org/stellent/groups/public/documents/ena/wfp257009.pdf

FAO. (2005). Fertiliser use by crop in Ghana. *Tropical Agriculture*. First version.

Giller, K. E., Rowe, E. C., de Ridder, N., & van Keulen, H. (2006). Resource use dynamics and interactions in the tropics: scaling up in space and time. *Agricultural Systems*, 88(1), 8-27.

Karbo, N., & Agyare, W. A. (2002). Crop livestock systems in Northern Ghana. Workshop on Crop-Livestock Systems in Dry Savannas of West and Central Africa. Ibadan, Nigeria: IITA.

Marinus, W. (2014). Cowpea-maize relay cropping. MSc thesis, Plant production System, Wageningen University.

MoFA. (2010). GOVERNMENT OF GHANA MEDIUM TERM AGRICULTURE SECTOR INVESTMENT PLAN (METASIP) 2011 – 2015.

Nieuwenhuis, R., Nieuwelink, J., & van Otterloo-Butler, S. (2005). *Cultivation of soya and other legumes*. Agromisa.

Ojiem, J. O., Vanlauwe, B., de Ridder, N., & Giller, K. E. (2007). Niche-based assessment of contributions of legumes to the nitrogen economy of Western Kenya smallholder farms. *Plant and soil*, 292(1-2), 119-135.

USAID. (2013). Gender impact assessment report: Agricultural Development and Value Chain Enhancement (ADVANCE) Program.

Wood, T. N. (2013). Agricultural development in the northern savannah of Ghana. D.P.H. Doctoral Document, University of Nebraska, Lincoln.

Zahran, H. H. (1999). Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. Microbiology and molecular biology reviews, 63(4), 968-989.

Appendix I -

Table. crops cultivated in the N2 plots one year ago

crop	number	%	sub number	yield unit	Ave. yield (per ha)	Standard deviation
maize	11	25.0%	6	kg	1,828.6	754.9
			5	bags	38.0	53.0
groundnut	6	13.6%	3	kg	617.8	349.5
			3	bags	20.3	2.7
cowpea	4	9.1%	4	kg	1,596.9	1,089.6
millet	4	9.1%	4	bags	14.5	8.0
soybean	4	9.1%	1	kg	494.2	-
			3	bags	9.3	5.6
other	4	9.1%	4	-	-	-
yam	2	4.5%	2	-	-	-
none	9	20.5%	9	-	-	-

Table. crops cultivated in the N2 plots two years ago

crop	number	%	sub number	yield unit	Ave. yield (per ha)	Standard deviation
maize	12	27.3%	8	kg	1,160.9	598.6
			3	bags	30.8	31.0
groundnut	6	13.6%	3	kg	1,070.8	555.6
			2	bags	22.7	4.5
soybean	6	13.6%	4	kg	993.4	548.6
			2	bags	13.6	6.2
millet	4	9.1%	1	kg	2,965.3	-
			3	bags	15.2	8.2
cowpea	2	4.5%	2	kg	327.4	228.6
other	1	2.3%	1	-	-	-
none	13	29.5%	13	-	-	-

Appendix II – GPS records at all sample plots

Region	Community	Group	Crop	GPS North/South	GPS East/West	GPS Altitude
Yandi	Binagmendo	Input	cowpea	9.3738	-0.0483	185.42
			soybean	9.3776	-0.0482	195.25
			soybean	9.3806	-0.0510	196.42
			cowpea	9.3818	-0.0524	212.85
	Montondo	Input	groundnut	9.3860	-0.0633	222.22
			groundnut	9.3877	-0.0620	217.44
	Nyanbolini	Input	soybean	9.4442	0.0874	186.14
			soybean	9.4465	0.0872	193.37
	Yingsala	Input	cowpea	9.4701	0.0681	165.36
			cowpea	9.4703	0.0691	168.88
Savelugu	Gbungnaayili	Input	soybean	9.5132	-0.7006	183.69
	Savelugu	Input	cowpea	9.5801	-0.7862	194.91
			cowpea	9.5805	-0.7861	194.00
	Libga	Varietal	soybean	9.5916	-0.8401	193.46
			soybean	9.5959	-0.8479	189.23
	Savelugu	Input	soybean	9.6018	-0.8026	196.80
			soybean	9.6024	-0.8022	198.94
		Varietal	soybean	9.6024	-0.8023	190.08
			soybean	9.6054	-0.8156	202.57
	Afakatufong	Input	soybean	9.6160	-0.8207	196.96
	Nyariyili	Varietal	groundnut	9.6288	-0.7595	188.81
			groundnut	9.6289	-0.7557	188.12
			soybean	9.6294	-0.7519	191.03
	Chahi Yapalsi	Input	soybean	9.7301	-0.7378	166.49
	Pigu	Input	soybean	9.9703	-0.8292	173.25
Nadowli	Loho	Varietal	cowpea	10.1288	-2.5244	344.19
			cowpea	10.1289	-2.5229	337.34
	Samatige	Varietal	groundnut	10.1769	-2.5999	299.97
	Tibani	Varietal	cowpea	10.1846	-2.4833	385.70
			cowpea	10.1877	-2.4786	384.62
		Input	cowpea	10.1667	-2.4664	369.02
			cowpea	10.1708	-2.4665	376.23
			soybean	10.1814	-2.4683	362.85
			groundnut	10.1835	-2.4656	382.03
			soybean	10.1861	-2.4682	374.06
			groundnut	10.1889	-2.4907	360.49
Binduri	Tempelim	Density	soybean	11.0264	-0.3081	240.63
			soybean	11.0264	-0.3085	240.59
		Varietal	groundnut	11.0285	-0.3145	235.58

			groundnut	11.0286	-0.3146	235.43
			groundnut	11.0287	-0.3144	239.18
			groundnut	11.0305	-0.3123	239.25
		Input	cowpea	11.0334	-0.2999	260.95
			cowpea	11.0287	-0.3145	234.79