Africa Research in Sustainable Intensification for the Next Generation

Sustainable intensification of cereal-based farming systems in the Guinea-Sudano-Savanna of West Africa

Technical report: 1 October 2014 to 31 March 2015

Submitted to:
United States Agency for International Development (USAID)

May 2015

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www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IFPRI

IITA Research to Nourish Africa

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Contents

Partners

AMASSA	Association Malienne pour la Securite et la Souverainete Alimentaire - Afrique Verte, Mali-
AMEDD	Association Malienne d'Eveil et de Developpement Durable, Mali
ARI	Animal Research Institute, Ghana
AVRDC	The World Vegetable Center
CBOs	Community-based Organizations, Ghana
CIAT	International Center for Tropical Agriculture
CMDT	Compagnie Malienne de Developpement des Textiles, Mali
CRI	Crops Research Institute, Ghana
FRI	Food Research Institute, Ghana
GLDB	Grains and Legumes Development Board, Ghana
GUIFFA	Guinea Fowl Farmers Association, Ghana
HI	Heifer International
ICRAF	World Agroforestry Center
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IER	Institut d'Economie Rurale, Mali
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INSTI	Institute for Scientific and Technological Information, Ghana
IWMI	International Water Management Institute
KNUST	Kwame Nkrumah University of Science and Technology, Ghana
MOBIOM	Mouvement Biologique du Mali, Mali
MoFA	Ministry of Food and Agriculture, Ghana
MoH	Ministry of Health, Ghana
NORGFA	Northern Region Guinea Fowl Farmers Association, Ghana
SARI	Savanna Agricultural Research Institute, Ghana
SEEDPAG	Seed Producers Association of Ghana
SRI	Soil Research Institute, Ghana
UDS	University for Development Studies, Ghana
UG	University of Ghana, Ghana
WIENCO	Wienco Seed Company, Ghana
WU	Wageningen University, The Netherlands
WIAD	Women in Agriculture Development, Ghana
WRI	Water Resources Institute, Ghana

Summary

Implemented work and achievements for the period 1 October 2014 to 31 March 2015 for the Africa RISING project in Ghana and Mali are reported. Research-for-development platforms were established in all the intervention districts. Data from on-farm testing and adaptation of several sustainable intensification (SI) options to intensify the crop-livestock-vegetable-tree farming systems in the region were analyzed. Both biological and economic performance of the SI options, and gender disaggregated preferences by farmers of some SI options are presented. Results from soil, land and water management studies, household nutrition, and post-harvest management of stored cereal and legume grains are also presented. Group and individual training were conducted to strengthen the capacity of farmers and researchers and development partners. Project outputs were disseminated through farmers' field days and farmer field schools.

The International Institute of Tropical Agriculture (IITA), as the responsible organization for the implementation of the project, commissioned an external review of the project. Field and partner visits by the review team took place during September and October 2014. The team's recommendations are being implemented.

Efforts have been made to create linkages for synergies and mutual learning with other USAID funded initiatives in both countries.

With the recruitment of a gender specialist by IITA a big step has been made towards strengthening social research in Africa RISING. The expert joined the team in March 2015 and will dedicate 50% of her time to Africa RISING West Africa.

Increasing the capacity of young scientists and farmers continued to be a focus of the project. Nineteen graduate students are supervised or co-supervised by Africa RISING scientists. A series of field days have been held to expose farmers to improved technologies and discuss with them their advantages.

Introduction

The Africa RISING program is organized around four research outputs that are logically linked in time and space, namely:

1. Situation Analysis and Program-wide Synthesis
2. Integrated Systems Improvement
3. Scaling and Delivery of Integrated Innovation
4. Monitoring and Evaluation

The West Africa project is being implemented in 25 intervention communities in the three northern regions of Ghana (Fig. 1), and 10 villages in the Bougouni-Yanfolila and Koutiala Districts of the Sikasso Region in southern Mali (Fig. 2). It is intended to result in spillover effects to other similar agro-ecological zones.

The implementation strategy, gender awareness and quality issues, scale of operation, knowledge transfer strategies and research which will contribute to the overall program research and development outputs have been outlined in the report submitted for the period 01 April 2014 - 30 September 2014.

This document presents some results of the implemented work during 01 October 2015 - 31 March 2015.

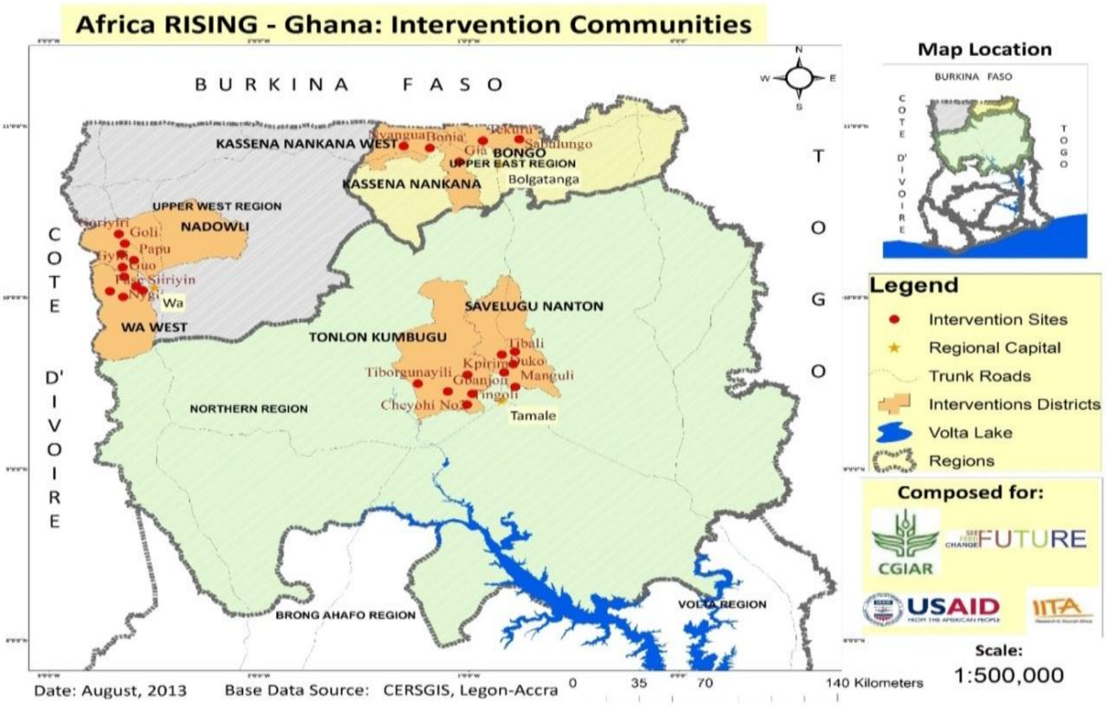


Figure 1: Africa RISING intervention communities in Ghana

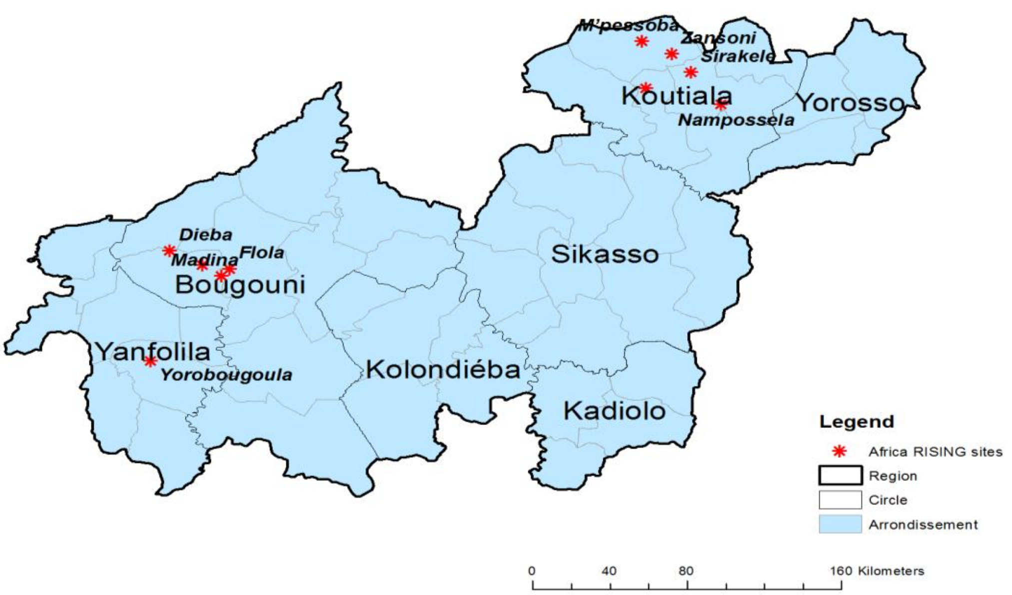


Figure 2: Africa RISING intervention villages in Mali

Implemented work and achievements

1. Situation analysis (Research Output 1)

1.1 Research-for-development platform establishment and facilitation, Ghana

In Northern Region, the Tolon District platform was inaugurated on 20 January whilst the Savelugu District R4D platform was inaugurated on 21 January 2015. Participants at both meetings are shown in Table 1. The institutions present nominated a representative each to constitute the district R4D platform committee (Tab. 2).

Table 1: Participants' profile and their associated work during the district R4D platform inauguration meetings in Tolon and Savelugu Districts, Northern Region, Ghana

Stakeholder	Function in the platform	Tolon	Salvelugu
Farmer Based Organizations (crop and livestock)	Users of research products. Generate research agenda. Engage in R4D process.	10	10
Input dealers	First line of supply of inputs for out scaling.	2	1
Market Actors	Access to markets. First line of produce quality assurance.	1	1
Produce processors	Add value to products. Create demand for produce.	1	1
Researchers	Generate new innovations to solve problems. Support extension and adoption.	6	6
Media	Dissemination of innovation information.	3	3
Agriculture Extension Agents	Support adoption process. Support participatory research.	12	12
District Director of Agriculture	Policy guidance for R4D work.	1	1
Local Government	Policy guidance for R4D work.	5	7
Development partners	Up and out scaling of innovation.	2	2

Table 2: Committee and executive members of the Tolon and Savelugu Districts R4D platforms

District	Name	Institution	Position
Tolon	Alhassan Adam	MoFA-Crop AEA	Chairperson
	Amadu Adam	Chief	Vice-chairperson
	Abu Karimu	Ghana Education Service	Secretary
	Mariam Ibrahim	Ghana Health Service	Organizer
	Issah Abukari	MoFA-Veterinary	Treasurer
	Yahaya Damba	Assemblyman	Member
	Abukari Abdul-Nasir	Farmer	Member
	Baba Musah Abdul Nashiru	M&E officer	Member
	Issah Fuseini	Tindana	Member
	Alhassan Adam	MoFA-Crop AEA	Member
	Amedatu Adam	MoFA-WIAD	Member
	Alhassan Azara	Magajiya	Member
Savelugu	Mohammed Salifu Fuseini	Chief	Chairperson
	Mavis Abdul Korah	Ghana Health Service	Vice-chairperson
	Mahammadu Alhassan Sheriff	Ghana Education Service	Secretary
	Alhassan Fuseini	Assemblyman	Organizer
	Fauzia Sadick	MoFA-WIAD	Treasurer
	Mohammed Abdul Rahman	MoFA-Veterinary	Member
	Iddrisu A. Ayuba	MoFA-Crop AEA	Member
	Memunatu Salifu	Magajiya	Member
	Alhassan Abdul Rahman	Tindana	Member
	Issah Mohammed Sani	Farmer	Member
	Abukari Nassam	Market Actor	Member
	Hardi Akibu	Seed producer	Member

In Upper East Region, district-level R4D platforms for the Kassena-Nankana and Bongo Districts were inaugurated on 16 and 18 December 2014 respectively. Participants and their institutions are presented in Tables 3 and 4.

Table 3: Participants' profile and their associated work during the Kassena-Nankana and Bongo Districts R4D platform inauguration meetings, Upper East Region, Ghana

Stakeholder	Function in the platform	Kassena	Bongo
Farmer Based Organizations (crop and livestock)	Users of research products Generate research agenda Engage in R4D process	13	6
Input dealers	First line of supply of inputs for out scaling	2	1
Market actors	Access to markets First line of produce quality assurance	1	1
Produce processors	Add value to products Create demand for produce	1	1
Researchers	Generate new innovations to solve problems Support extension and adoption	5	7
Media	Dissemination of innovation information	3	1
Agriculture extension agents	Support adoption process Support participatory research	11	12
District Director of Agriculture	Policy guidance for R4D work	2	1
Local Government	Policy guidance for R4D work	4	4
Development partners	Up and out scaling of innovation	3	2
Community leaders	Lead community innovation adoption process	10	5
Total		59	41

Table 4: Committee and executive members of the Kassena-Nankana and Bongo Districts R4D platforms, Upper East Region, Ghana

District	Name	Institution	Position
Kassena Nankana	Edward Chanagia	MoFA	Chairman
	Maxwell Abagye	Assembly Man	Vice Chair
	Abdul Baqil Alhassan	Municipal Assembly	Secretary
	Henrieta Agua	Magagia	Treasurer
	Paul Adiga	Cooperative Officer	Organizer
	Martin Seguri	CBO	Member
	Ayuu Asutia	CBO	Member
	Linda Attibila	Youth Harvest (NGO)	Member
	Akomoveh Ayageapam	MoFA	Member
	Jagula Cletus	Assembly Man	Member
Bongo	Grace Anafu	MoFA	Chairman
	Jacob Akalga	MoFA	Secretary
	Nicholas Atibiga	Bongo Rural Bank	Treasure
	Philip Atongo	Association Of Churchs	Organizer
	Bertrand Nabere	MoFA	Member
	Henry Ayamga	MoFA	Member
	Saddat Hamidu	MoFA	Member
	Cosmos Asaah	FBO	Member
	Alice Amoah	FBO	Member

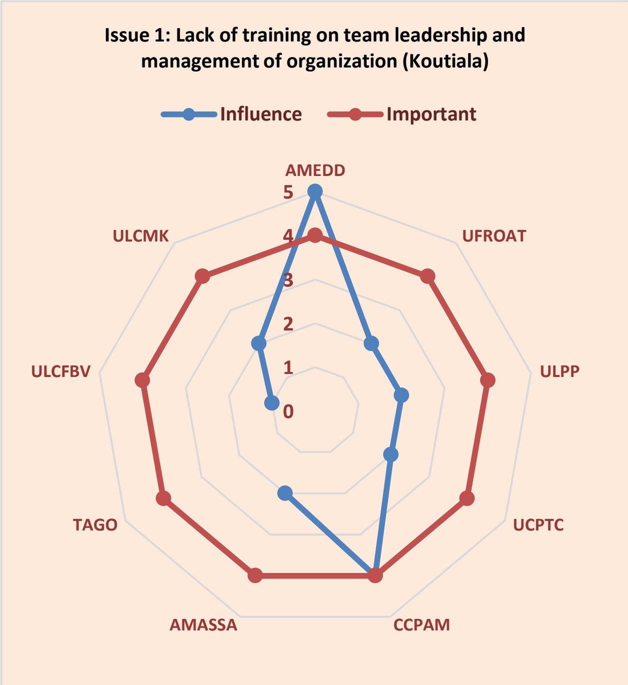
1.2 Characterization of the local stakeholders to promote the uptake of SI options in Mali

A baseline study was carried out to identify and characterize the existing stakeholders involved in agricultural development and assess the level of interaction among different stakeholders. The study covered: 1) stakeholder inventory in Bougouni and Koutiala, 2) identification of critical main agricultural issues faced by the selected stakeholders, 3) analysis of stakeholders' interest and influence on the critical issues, and 4) stakeholder characteristics and interactions. The purpose was to identify gaps needed to be filled to better establish and strengthen institutional linkages and networks among different actors in order to foster awareness and adoption of improved sustainable intensification technologies.

Four main issues were defined to be critical for a better development of stakeholder activities, namely: 1) lack of training in team leadership and management of organizations; 2) ineffective access to appropriate inputs and credit; 3) inefficient marketing of agricultural products, and; 4) lack of coordination/interactions among support services.

In Koutiala, the lack of training in leadership and organization management can be addressed through capacity building on group dynamics and team leadership with focus on management facilitated by AMEDD and Centre Commercial des Produits Agricoles du Mali (CCPAM) who seem to have a stronger influential power on the issue (Fig.3). In Bougouni, Cooperative des Riziculteurs et Maraichers (CORIMA), Bureau d'Appui Conseil aux Initiatives Rurales (BACIR) and Cooperative Semenciere Nationale Dalabani (CSN-Dalabani) were the most influential stakeholders that can facilitate the process of addressing the issue.

To address the accessibility and affordability of appropriate inputs and credit, the identified stakeholders should be linked with input dealers and microfinance institutions. The R4D platforms can be better avenues to make this effective both in Koutiala and Bougouni. AMASSA, CCPAM and a local farmers' organization (TAGO) appeared to be the more influential organizations that can significantly impact the issue, while CSN-Dalabani can play the same role in Bougouni (Fig. 4).



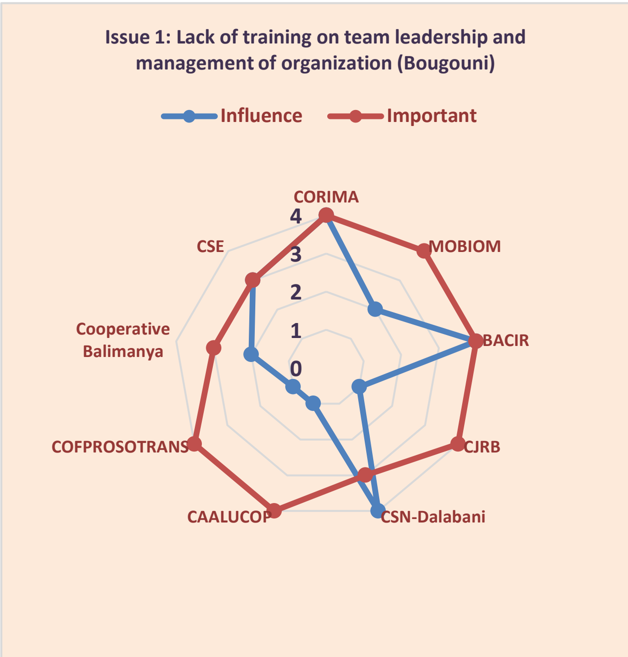
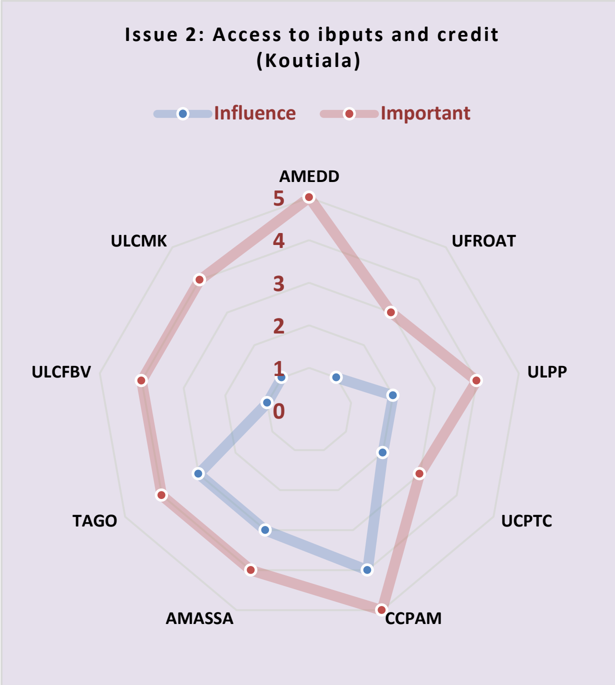


Figure 3: Factors affecting stakeholder activities in Koutiala and Bougouni, Mali – Leadership



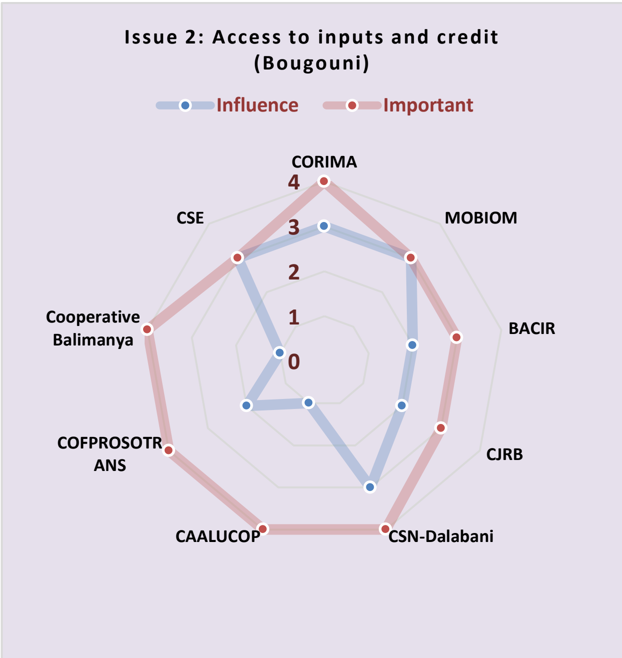
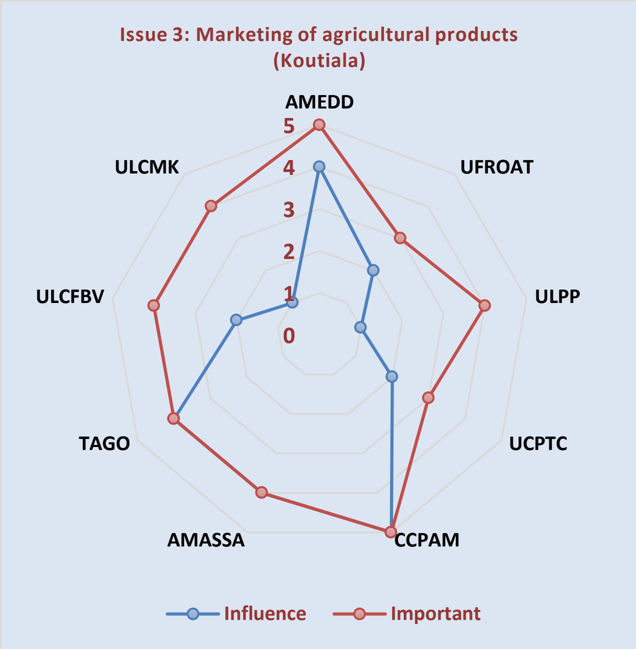


Figure 4: Factors affecting stakeholder activities in Koutiala and Bougouni, Mali – Inputs and credit

Figure 5 shows that AMEDD in Koutiala and MOBIOM in Bougouni are network members with the most influential power to deal with the issue of lack of coordination/interactions among support services. Consequently, their involvement in the different platforms must be critical. The social network analysis showed five clusters in Koutiala (Fig. 6) and four in Bougouni (Fig. 7).



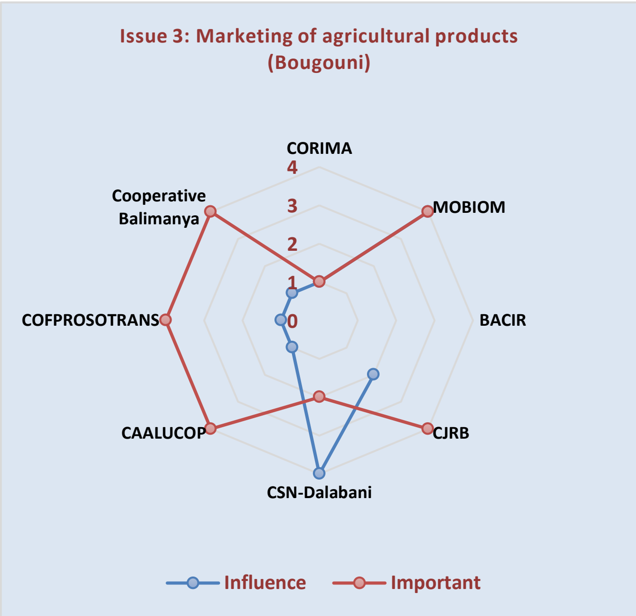


Figure 5: Factors affecting stakeholder activities in Koutiala and Bougouni, Mali – Marketing

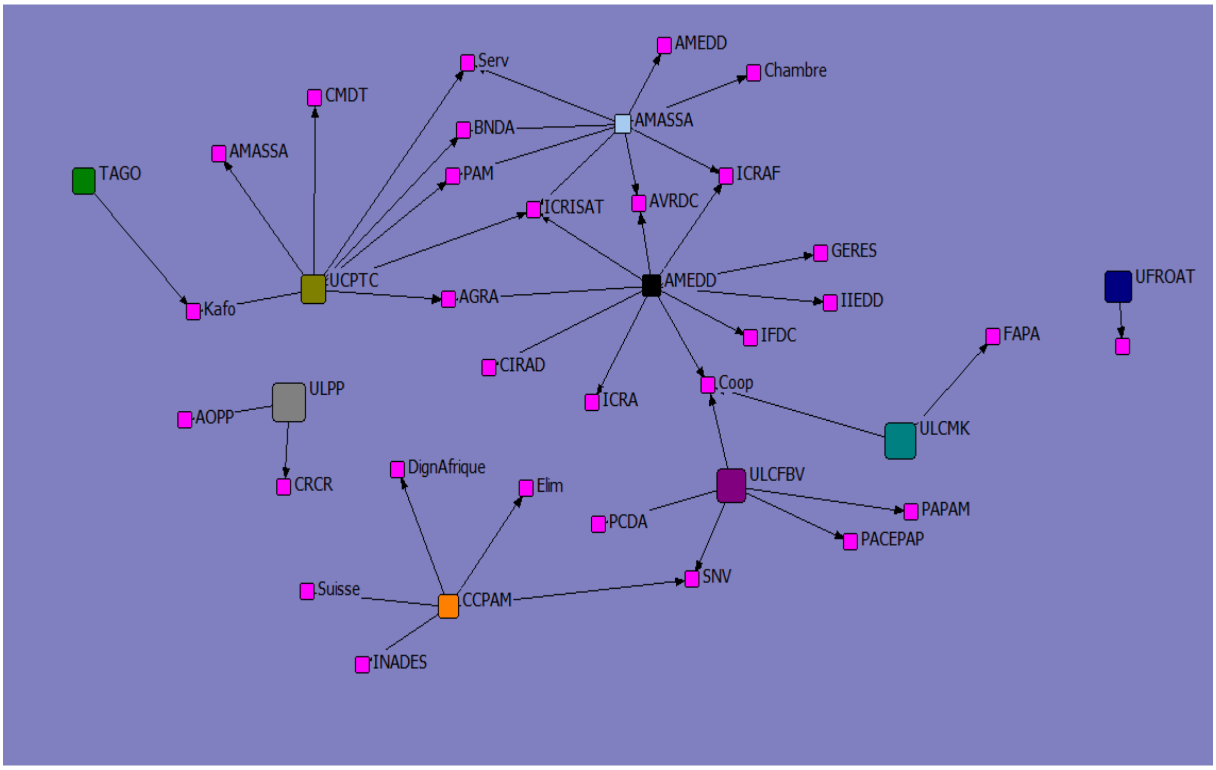


Figure 6: Collaboration network in Koutiala

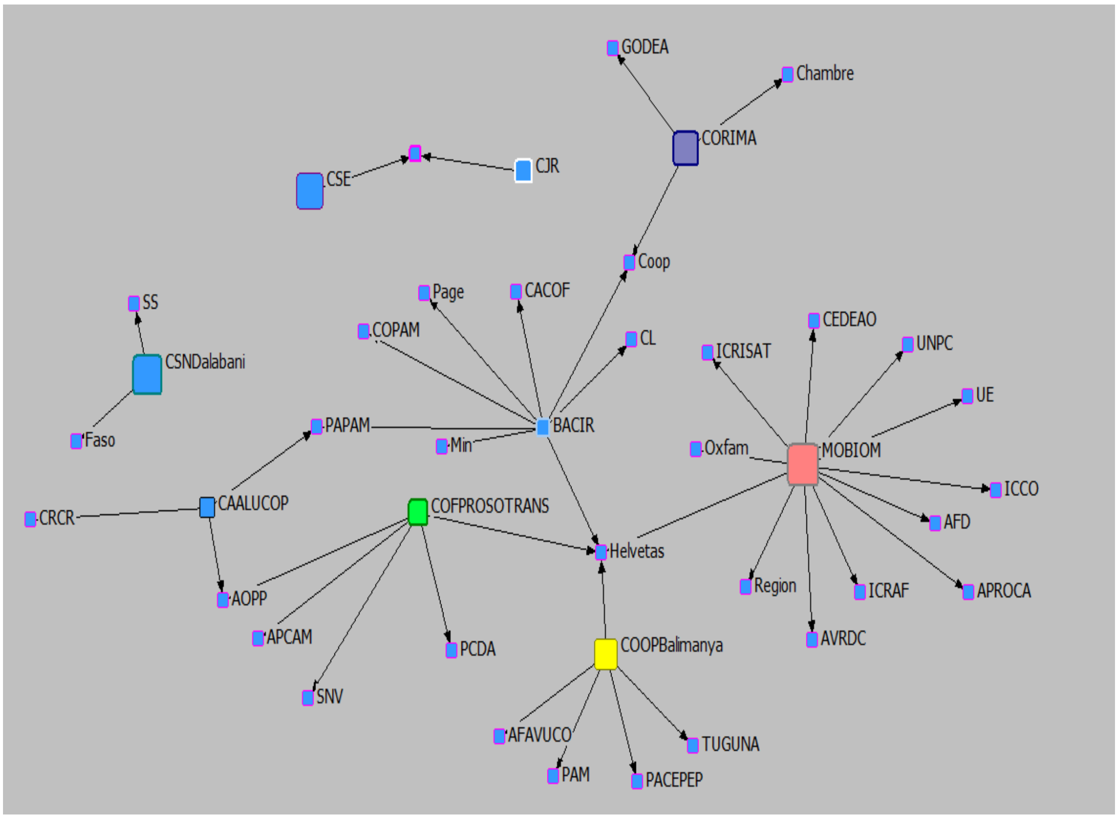


Figure 7: Collaboration network in Bougouni

1.3 Socio-economic analysis of sustainable intensification options

1.3.1 Adoption of multiple sustainable intensification practices, Ghana

A study was conducted with the aim of assessing the adoption of sustainable agricultural practices and technologies in northern Ghana using data collected to establish a baseline for Africa RISING project interventions. Seven sustainable intensification practices (SIPs) were considered in the multivariate analysis, which included intercropping, crop rotation, organic fertilizers (mainly manure), soil conservation practices, chemical fertilizers, improved seeds, and pesticides (including herbicides). These technologies were considered as important components of SIPs in the study areas because poor soil fertility, low yields of existing crop varieties, drought, and pest infestation are the major factors limiting productivity and, hence, it is useful to integrate the applications of these components to alleviate these problems. Initial results are presented.

Farmers use the technologies in isolation of one another or in combination. Out of 128 possible combinations (bundles) of technologies, 97 and 110 are actually observed (including the no technology option) in the case of maize and major crops, respectively. Farmers use multiple SIPs in most of the cases (Fig. 8). This holds true when we consider maize alone or the major crops together. A typical farmer combines 2-3 SIPs while farmers who adopted more than three SIPs are also substantial in number.

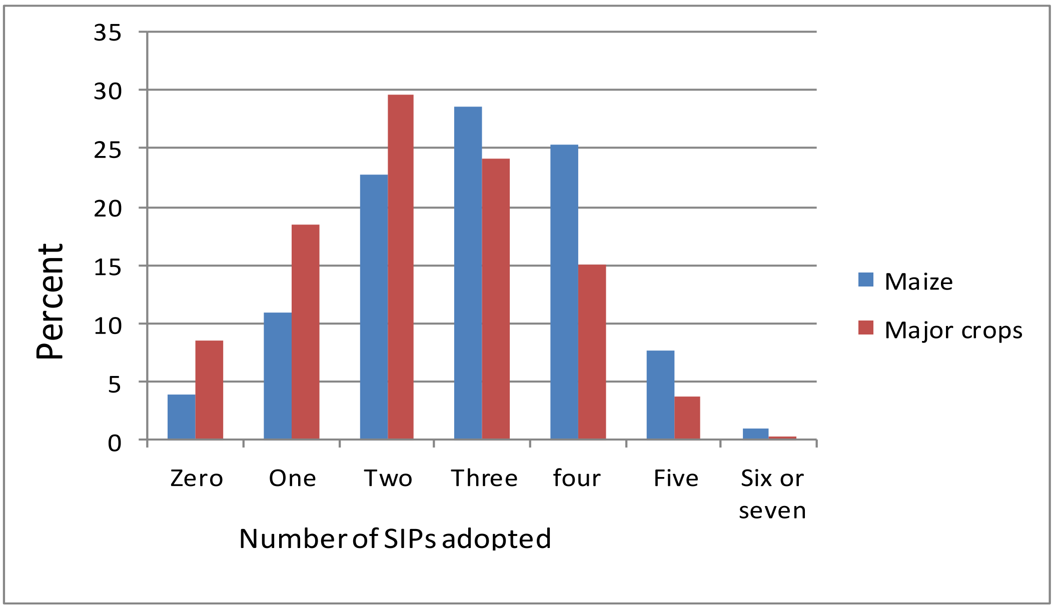


Figure 8: Adoption multiple SIPs in Ghana

1.3.2 Complementarity and substitutability among SIPs

A multivariate probit (MVP) model was estimated using a simulated maximum likelihood method to assess the integrated adoption of SIPs considering seven SIPs as dependent variables for joint estimation.

The likelihood ratio test rejects the hypothesis that the agricultural practices under consideration are independent (Chi2 (21) = 534, p =0000), which shows that the multivariate regression generates more reliable information than univariate regressions. It was found that out of 21 possible pairs 13 are correlated either positively (implying complementarity between the practices) or negatively (implying substitutability) (Tab. 5.). The distribution of the relationships shows that most of the related practices are complementary (pair wise).

Table 5: Complementarity and substitutability among sustainable innovation practices

	IC	CR	OF	IF	SWC	IS	P
IC	-						
CR	0.109 (0.047)**	-					
OF	0.221 (0.055)****	0.263 (0.043)****	-				
IF	-0.197 (0.046)****	0.002 (0.034)	-0.073 (0.042)*	-			
SWC	0.094* (0.048)	0.349 (0.033)****	0.189 (0.043)****	0.164 (0.034)****	-		
IS	-0.029 (0.071)	0.062 (0.053)	0.062 (0.064)	0.412 (0.044)****	0.105 (0.051)**	-	
P	-0.025 (0.048)	0.027 (0.036)	-0.018 (0.044)	0.504 (0.028)****	0.142 (0.035)****	0.056 (0.053)	-

Note: ****, **, * significant at 0.1%, 5%, and 10% levels; IC = intercropping, CR = crop rotation, OF = organic fertilizers, IF = inorganic fertilizers, SWC = soil and water conservation, IS = improved varieties, P = pesticides including herbicides

1.3.3 Effects of SIPs on productivity

The results of multivalued treatment effect estimation are displayed in Figure 9. The results show that the mean maize gross income per hectare monotonically increases across treatment levels i.e. as one goes from no adoption of SIP category through to adoption of four or more SIPs. All the coefficients are statistically significant. Contrasts were made between pairs of SIPs levels. The results show that the estimated average treatment effect (ATE) of adopting two SIPs in contrast to zero/one SIP is apparently positive but not statistically significant.

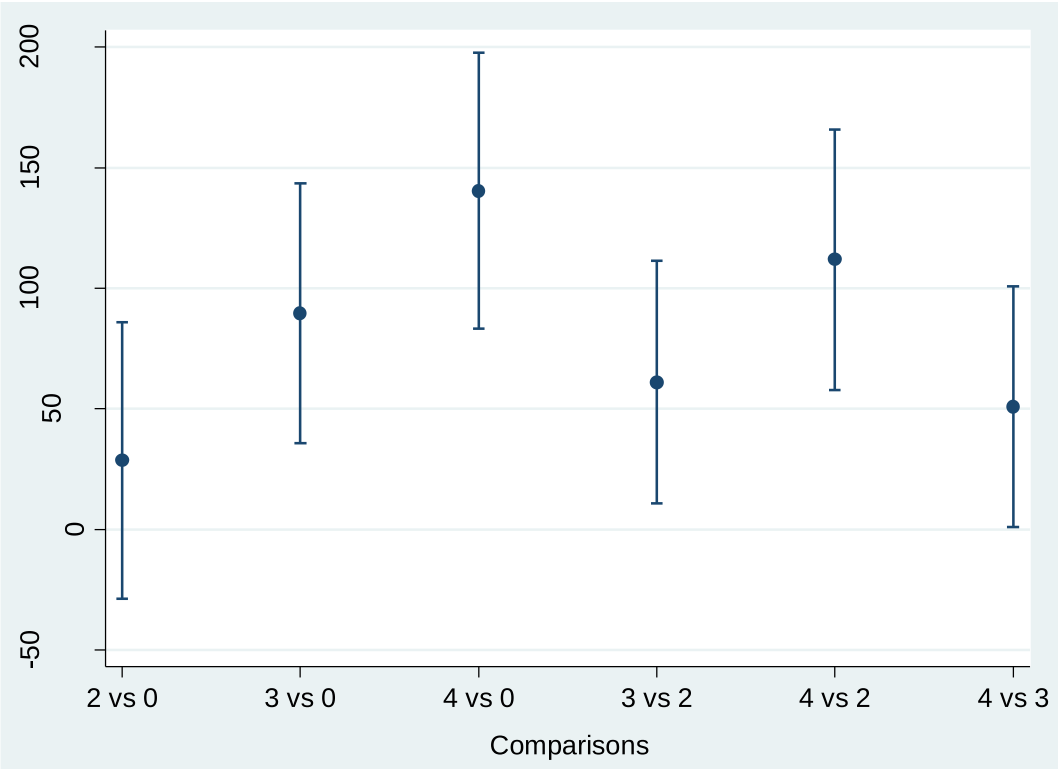


Figure 9: Effects of adoption of multiple SIPs on maize productivity

Quantile estimation results show that the effects of adopting multiple SIPs are more visible when we consider farmers that belong to the middle and upper quantiles than those who belong to the lower quantile (Fig. 10).

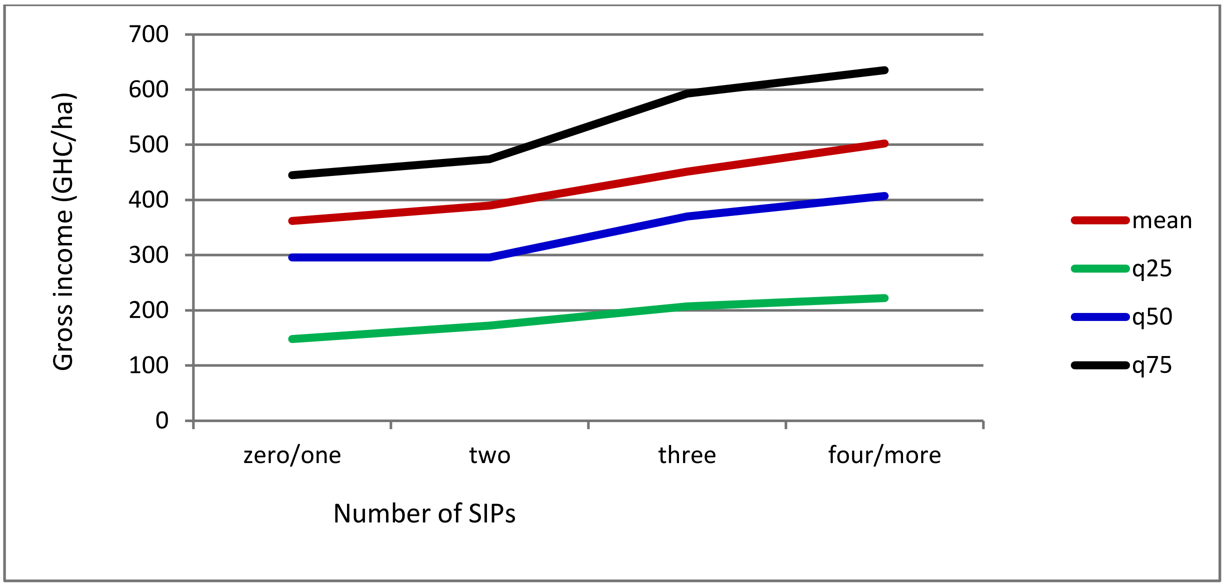


Figure 10: Effects of adoption of multiple SIPs on maize productivity, by quantile and mean

The quantile analysis also shows that ATEs are monotonically increasing from the lowest to the highest intensity of adoption for the three quantiles considered.

1.3.4 Profitability of Africa RISING technologies, Ghana

A study was conducted with the aim of assessing the profitability of agricultural technologies. We considered 102 technologies under trial in Northern Ghana out of which 23 are base technologies (i.e. control) while the remaining technologies are new ones. These technologies (agricultural practices) have been designed to increase the productivity of several crops, namely: cowpea, maize, soybean, groundnut, and vegetables (eggplant, okra, pepper, roselle, tomato). The technologies can be put into three groups i.e. 1) Pest Management (PM, 14 technologies), 2) Soil Fertility Management (SFM, 41 in number), and 3) Cropping System Diversification (CSD) in intercropping and strip cropping (47 in number). Yield data were collected from agronomic trials. We used mean market prices out of the recent three months (December, January, and February). Labor input and costs, land value, and draft power costs were estimated from AR baseline data for the target crops while costs of commercial inputs (seeds, fertilizers and pesticides) were collected from secondary sources for recent transactions.

Table 6 shows that most of the new technologies are as good as the base technologies in terms of three economic indicators i.e. gross margin (GM), benefit-cost-ratio (BCR), and returns-to-labor (RtL). Two technologies performed better than the base technologies in terms of GM and RtL while only one is better in terms of BCR. The mean GM is GHC5113 per hectare and the mean BCR is 4.2 indicating that economic returns of the technologies are far higher than the breakeven point. The mean RtL is 49.1 GHC/personday, which is also far higher than the average daily wage in the study areas (i.e. 5.4GHC/personday). Table 6 shows disaggregated figures for the three groups of technologies.

Table 6: Gross margin (GM), benefit-cost-ratio (BCR) and return-to-labor RTB of some sustainable intensification technologies in Ghana

	GM (Gh₵/ha)		CR		RTB(Gh₵/person days)	
	Mean	SD	Mean	SD	Mean	SD
Pest management	4895	759	5.36	0.55	51.1	6.0
Soil fertility management	2795	1854	2.73	1.35	34.8	20.3
Crop diversification	8240	7532	5.66	4.14	67.0	50.1
Over all	5113	5323	4.2	3.0	49.1	36.3

A closer look at the data shows that the technologies vary in terms of the level of economic returns. The returns are greater than breakeven point for 67 technologies (Fig. 11). Sixty three technologies could generate more than 50% profit indicating that 5 technologies generate only a little more than the breakeven point. On the other hand, 13 technologies are high yielding generating returns of more than 200%. Profits are more sensitive to changes of output prices than changes of input prices or wage rates. In this regard, a 25% increase/decrease in output prices will increase/decrease the mean profitability of the technologies by about 30%. The corresponding changes in profit as a result of 25% changes in input prices and wage rates are about 6% and 3% respectively. Sensitivity also apparently varies by type of technology; SFM technologies are relatively sensitive changes in output prices, input prices and wage rates while the other two are relatively less sensitive.

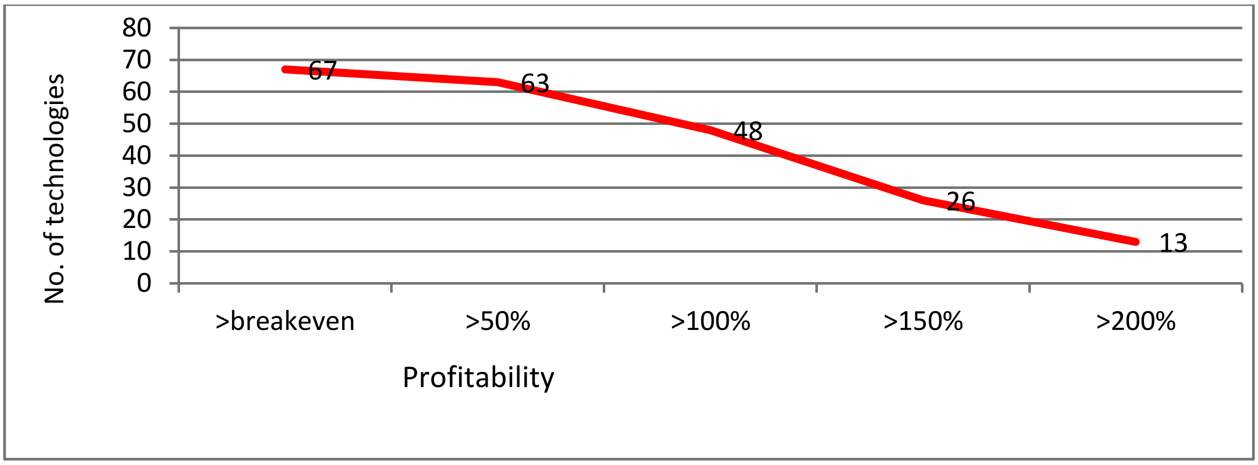


Figure 11: Number of technologies at different profit levels

The results showed that most of the technologies are as profitable as the base technologies. Profits are >50% of the total costs to be incurred for most technologies while they can go even more than 200% for a few technologies. The profitability of the technologies is more sensitive to output price changes than changes in input prices or wage rates. The results are more indicative than conclusive as the analysis is based on only one year worth of data for most of the technologies.

1.3.5 Parameterizing component and whole farm system models and determine trade-offs, Mali

A trade-off analysis for intercropping maize with cowpea was performed for Koutiala District. An *ex-ante* assessment for maize-cowpea intercropping and cowpea grain variety sole cropping was carried out for four farm types. The average number of cattle, crop land size and cereal yields, costs and benefits of the different farm types and the average yields, costs and benefits obtained in the cowpea and maize-cowpea intercropping trials were used.

Results of the trade-off analysis showed that large farms would be able to feed only half of their herd (45 cattle) in the stable during the dry season when intercropping cowpea on 100% of their maize area, while running the risk of not achieving food self-sufficiency, regardless of the intercropping pattern. Intercropping cowpea in only 50% of the maize area of medium farms would provide the fodder for feeding the whole herd (5 cattle) in the stable during the dry season with a minor decrease in food self-sufficiency. This strategy would have positive feedbacks on milk production and reduced calving interval, providing a solution to the constraints voiced by farmers. For low resource endowed farms, the trade-off analysis indicated a 30% income increase by replacing half of the millet area by the cowpea grain variety, with a minor decrease in the level of food self-sufficiency.

2 Integrated systems improvement (Research Output 2)

2.1 Genetic intensification of crop-livestock-vegetable-tree farming systems

2.1.1 Cowpea varieties, Ghana and Mali

In Ghana, 12 genotypes of medium-maturing cowpea lines were evaluated using a randomized complete block design with three replications. Grain yield of the medium-maturing cowpea varieties varied significantly among the genotypes in all regions. In the Northern Region, cowpea line IT07K-211-1-8 showed potential for grain and fodder production (Fig.12).

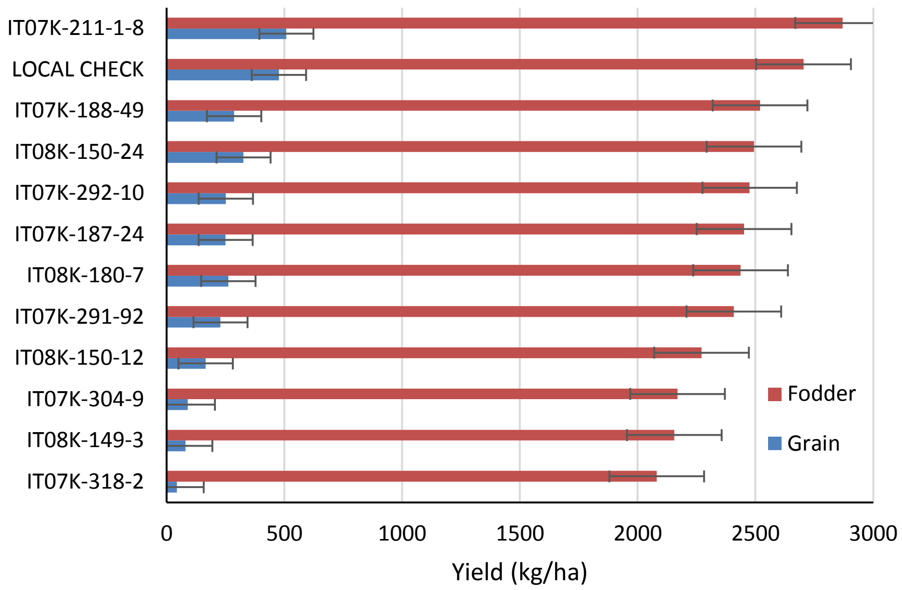


Figure 12: Grain and fodder yields of medium-maturing cowpea varieties in Africa RISING intervention communities, Northern Region, Ghana, 2014

In Mali, five groundnut varieties were compared with the local variety on-farm. Variety ICGV 86015 had significantly higher pod yield than the local (Fig. 13), and it was generally the most preferred variety, with good yields and grain quality. Farmers also mentioned that this variety was easy to harvest even if the plant was partially senesced, the pods came up easily and few remained in the soil.

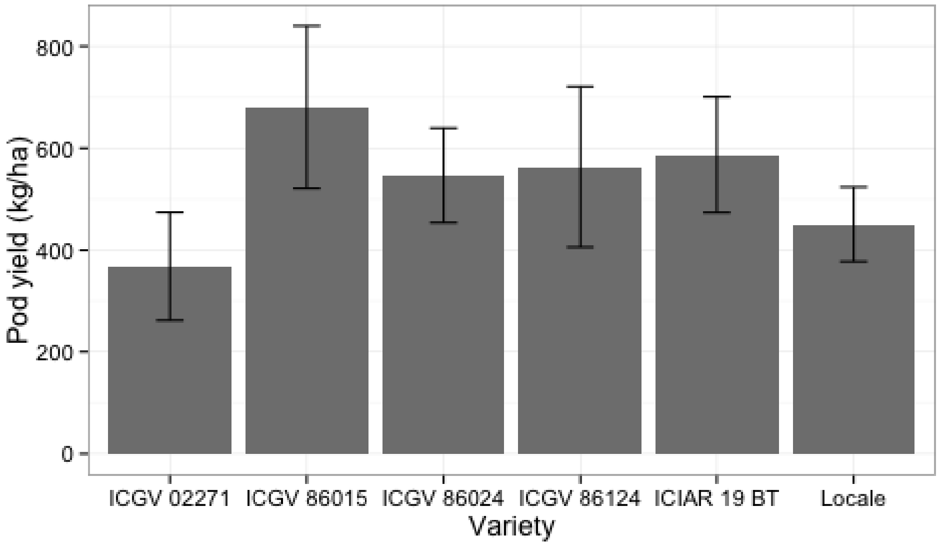


Figure 13: Pod yield of improved and local groundnut varieties on-farm, Mali, 2014

2.1.2 Early- and late-maturing soybean, Ghana

Sixteen early-maturing soybean genotypes were evaluated at Botingli, Siriyiri and Samboligo in the Northern, Upper West and Upper East Regions, respectively. The same number of medium-maturing genotypes was evaluated in Duko (NR), Passe (UWR) and Bonia (UER). Grain yield varied significantly among the early-maturing and medium-maturing soybean genotypes in all the three regions. Grain yield of the early-maturing genotypes was higher than of the late-maturing in all regions, possibly because the rains started late and planting was delayed. For the Northern Region, genotypes with potential for grain and fodder production were the early-maturing genotypes TGX-1990-52F, TGX-1990-57F, TGX1987-10F CHECK and TGX-1990-38F (Fig. 14), and the late-maturing genotypes TGX-1990-80F, TGX-1990-47F, TGX-1991-10F and TGX-1987-10F (Fig. 15).

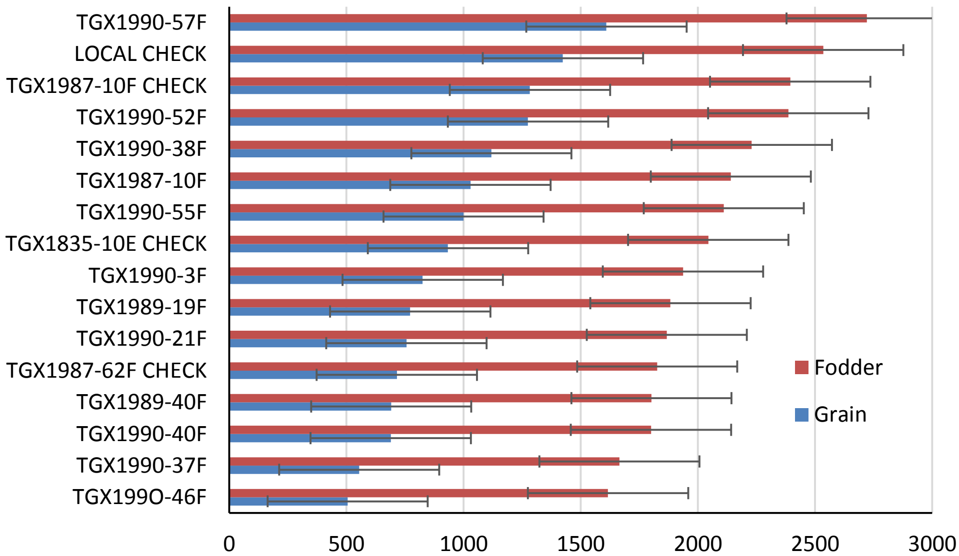


Figure 14: Grain and fodder yields of early-maturing soybean varieties in Africa RISING intervention communities, Northern Region, Ghana, 2014.

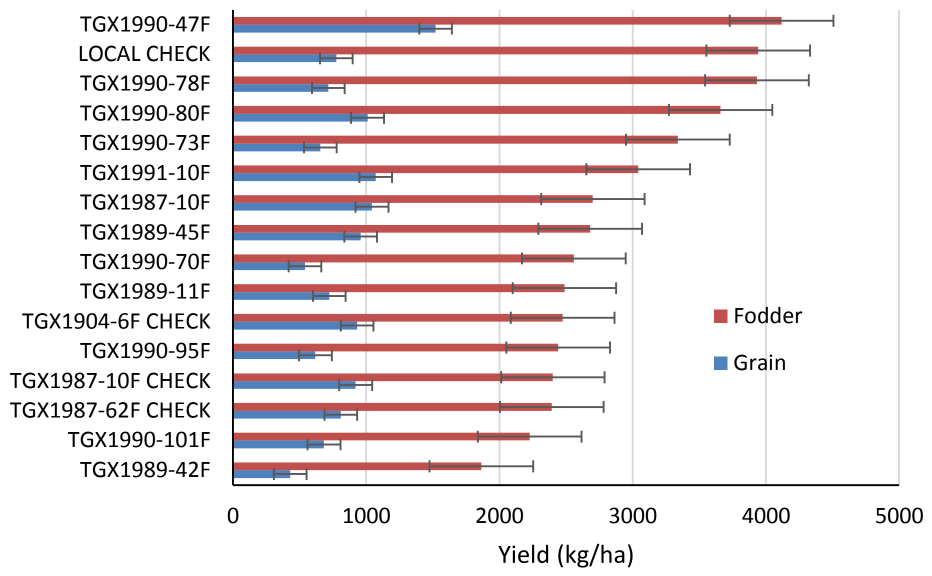


Figure 15: Grain and fodder yields of medium-maturing soybean varieties in Africa RISING intervention communities, Northern Region, Ghana, 2014.

2.1.3 Sorghum hybrids, Ghana

Ten elite sorghum hybrids from ICRISAT-Mali and two local checks (an early-and a late-maturing variety) from SARI were evaluated on-station in the three northern regions (Bonia and Manga in UER; Wa and Piisi in UWR; Damongo and Nyankpala in NR) to identify the most adapted hybrids for release.

Grain yield of the sorghum hybrids varied significantly within location (Tab. 7). Averaged across locations, hybrids Caufa, Fadda and Pablo showed potential for grain production in the Africa RISING intervention communities in northern Ghana.

Table 7: Grain yield of sorghum hybrids at five locations in the three northern regions, Ghana, 2014

Sorghum hybrids	Piisi[1]	Wa[1]	Manga[2]	Damongo[3]	Nyankpala[3]	Mean
Caufa	1478	978	1767	1793	3138	1831
Fadda	1133	1411	2675	1138	2641	1800
Mona	1344	1288	1033	1369	3166	1640
Pablo	1078	1322	2067	1825	2899	1838
Sewa	533	1156	2075	520	1441	1145
Soumalemba	989	2478	2317	758	1866	1682
Yamasa	1189	700	1517	374	1384	1033
Early Local	578	544	1650	1308	2618	1340
Late Local	1289	1400	1458	405	478	1006
s.e.	108.3	184.3	165.6	188.8	311.5	116.5

Region: [1]UWR=Upper West,[2] UER=Upper East and [3]NR=Northern

2.1.4 Okra and roselle varieties, Ghana

Eight genotypes of roselle were evaluated. Table 8 shows that the okra genotypes can be grouped into two types based on the days to flowering (i) early-flowering (42-46 days after planting: Aak, NB-55-Sirvan, NOHK 1003 and NOHK 104) and (ii) late-flowering (52-72 days after planting: farmers' variety, Kozaya and Uunmaana). Variety Kozaya recorded the highest fresh fruit yield, which differed significantly from that of the farmers' variety.

Table 8: Okra fresh fruit yield (FFY), days to fifty percent flowering (DFF) and pest and disease damage scores, Bonia, Upper East Region, Ghana, 2014

			[1]Pest and disease score			
Variety	FFY (kg/ha)	DFF	Podagrica	Leaf damage	Leaf-rot	Whiteflies
Aak	4958	42	1.5	4.5	2.3	1.5
Farmer	5396	63	0.5	3.5	2.0	1.0
Kozaya	7792	52	0.8	3.8	0.0	1.0
NB-55-Srivan	3750	43	1.0	4.5	2.8	2.3
NOHK 1003	4229	46	1.3	4.8	0.5	0.0
NOHK 1004	4521	46	1.5	4.8	1.0	1.0
Uunmaana	1521	72	0.8	3.8	1.3	1.8
Mean	4595	51.7	1.04	4.21	1.39	1.21
s.e.d.	1645.5	0.9	1.043	1.029	0.81	1.226

[1]Score: 1-5, where 1=low incidence and 5=high incidence

Based on the days to fifty percent flowering, the roselle varieties can be grouped into three maturity types (Tab. 9) (i) early-maturing (60-75 days: Bit, Martin and Bisem), (ii) medium-maturing (76-95 days: Bia, Morongoro and Veo) and (iii) late-maturing (more than 100 days: Samada and Dehrouge). The fresh leaf yield of Martin, Veo, Bia, Bisem and Borogoron were significantly higher than that of Bit, Dehrouge and Samanda.

Table 9: Roselle fresh leaf yield (FLY), days to fifty percent flowering (DFF) and pest and disease damage scores, Bonia, Upper East Region, Ghana, 2014

			[1]Pest and disease score		
Variety	FLY (kg/ha)	DFF	Podagrica	Leaf damage	Leaf-rot
Bia	8958	79	1.5	4.0	1.3
Bisem	8458	72	1.5	2.8	1.5
Bit	5271	68	2.0	4.0	1.0
Dahrouge	5896	110	1.3	1.0	1.3
Martin	10333	70	1.5	4.0	2.3
Morongoro	8250	78	1.8	3.3	1.0
Samanda	5375	103	1.3	2.5	2.3
Veo	9583	83	1.5	4.0	1.0
Mean	7766	82.9	1.5	3.2	1.4
S.e.d.	1315	6.31	0.4	0.3	0.6

[1]Score: 1-5, where 1=low incidence and 5=high incidence

Table 10 presents a summary of farmers' assessment of the okra and roselle varieties. Generally, the late-maturing okra varieties were assessed to have better drying and storage, tastier fruits with high slimness during the dry and rainy season than the early-maturing varieties. Based on the farmer assessment and the yield and pest and disease scores, the late-maturing varieties Kozaya and early-maturing variety Aak have potential for genetic intensification of okra-based vegetable production systems in the intervention communities in northern Ghana. For the roselle varieties, the medium-maturing, high leaf and calyx producing variety Martin will be the first choice, followed by Vio, Bia and Morongoro.

Table 10: Farmers' assessment of okra and roselle varieties, Upper East Region, Ghana, 2014

Species	Attribute	Variety					
Okra		Farmer	**NB-55-Srivan**	**Uunmaana**	Kozaya	NOKH 1004	
	Late-maturing	√	×	√	√	×	
	Early-maturing	×	√	×	×	√	
	High yielding	√	√	√	√	√	
	Easy to dry	√	×	√	√	×	
	Slimy-dry season	√	×			×	
	Tasty fruits	√	×	√	√	×	
	Ready market	√	×	√	√	×	
	Very slimy	√	×	√	√	×	
	Long-storage	√	×	√	√	×	
Roselle		Veo	Morongoro	Bia	Dahrouge	Samanda	Martin
	Tasty leaves	√	√				√
	Give energy	√	√				√
	Purifies blood	√	√				√
	High calyx yield	×	×				√
	New - cannot assess			√	√	√	

[1]√ = Applicable; [2]x = Not applicable

2.2 Ecological intensification of crop-livestock-vegetable-tree farming systems

2.2.1 Testing and adapting improved crops and cropping practices, Ghana

Project partners used a ‘Community-based Technology Park’ (Technology park) approach to address the key constraints to increased crop production on farmers’ fields. A technology park is a community-based experimental station consisting of a series of replicated and un-replicated experiments (‘Mother’ trials). Trails were established and managed by researchers and farmers’ groups in the community. The technology parks were used to: evaluate and demonstrate new technologies, provide hands-on training for farmers, facilitate knowledge flow among farmers, train undergraduate and graduate students, and to determine farmer preferences for technologies. About 150 experiments were established in technology parks in the three regions during the 2013-2014 research year.

Farmers’ preferences for technologies within trials in the technology parks were determined during community-based Farmers’ Field Days in all the regions. Male and female farmers’ preferences for technologies within trials in the technology parks were recorded. Results of selected trials are presented.

2.2.2 Testing and adapting improved maize and fertilizer application, Ghana

The effect of two nitrogen (N) fertilizer rates (government recommended (60-40-40 NPK kg/ha) and a higher (90-40-40 NPK kg/ha) on grain and stover yields of six improved maize varieties (extra early: Abontem, TZEE W STR QPM C0; early: Abrohema, Omankwa; medium: Obatanpa and DT SR W C0 F2) was evaluated using a split-plot design repeated in 10 intervention communities. Main-plots were N fertilizer rates, and sub-plots were maize varieties.

The N fertilizer x maize variety interaction did not significantly affect grain and stover yields in all the regions. However, the main effects of N fertilizer and maize variety affected both grain and stover yields. In the Northern Region, yield increased with N fertilizer rates, and was generally higher for the medium than the extra-early maturing maize types (Tab. 11). Both female and male groups selected 90kg/ha N as the preferred fertilizer rate for maize production (Fig. 16). The medium-maturing unreleased DT SR W C0 F2 maize variety was also ranked first by both farmer groups (Tab. 12). The results suggest that N fertilizer rate of 90kg/ha in combination with the medium-maturing maize variety Obatanpa and the unreleased line DT SR W C0 F2 could be used to intensify maize production in the Africa RISING intervention communities in the Northern Region.

Table 11: Grain and stover yields of extra-early, early and late maturing maize varieties as affected by nitrogen fertilizer rate, Northern Region, Ghana

	Yield (kg/ha)	
Item	Grain	Stover
Nitrogen (kg N/ha)		
60	2452.0	3268.9
90	3141.6	4037.8
s.e	135.00	148.23
P-value	0.0056	0.0052
Maize variety		
Abontem[ee]	2322	2887
TZEE W STR QPM C0[ee1]	3168	4113
Mean	*2745*	*3500*
Abrohema[e]	2478	3193
Omankwa[e]	2934	3867
Mean	*2706*	*3530*
Obatanpa[m]	2751	3880
DT SR W C0 F2[m1]	3129	3980
Mean	*2940*	*3930*
s.e	203.9	274.3
P-value	0.0188	0.011

[ee]Extra-early maturing, [e]Early-maturing, [m]Medium variety

Table 12: Farmer groups preferences for technologies in selected trials in Community-based Technology Parks, Savelugu and Tolon Districts, Northern Region, Ghana, 2014

	Female		Male		Total		
	Score	Rank	Score	Rank	Score	Rank	Farmers' reasons
Maize varieties and nitrogen fertilizer rate							
Abontem	11	4	37	4	48	4	
TZ EE W STR	5	5	4	6	9	6	Smaller cobs & grains
Abrohema	5	5	41	3	46	5	
Omankwa	23	3	27	5	50	3	
Obatanpa	40	2	62	2	102	2	Bigger cobs & larger grains
DT ST W CO F2	60	1	63	1	123	1	Bigger cobs & larger grains
Cowpea varieties under insecticide spraying							
Songotra	3	5	17	5	20	6	Smaller grains
Apagbala	9	4	14	6	23	4	
Paditutya	22	2	41	1	63	1	Bigger grains
IT99K-573-1	21	3	21	3	42	3	
Zaayura	3	5	19	4	22	5	
Local	27	1	30	2	57	2	
Groundnut varieties under phosphorus rate							
Chineese	9	4	37	1	46	2	
Azivivi	23	1	27	3	50	1	Early-maturing & high pods
Obolo	19	2	28	2	47	3	
Manipinta	8	5	11	5	19	5	Difficult to harvest
Yenyawso	13	3	15	4	28	4	
Integrated soil fertility management options							
Triple super phosphate (TSP, 60 P_2O_5 kg/ha)	29	2	34	2	63	2	High numbers & bigger pod
Fertisol (F)	23	3	26	3	49	3	
TSP + F	15	4	26	3	41	4	
TSP + F + Boostxtra	31	1	52	1	83	1	High numbers & bigger pods
Farmer practice	11	5	17	5	28	5	Low numbers & smaller pods

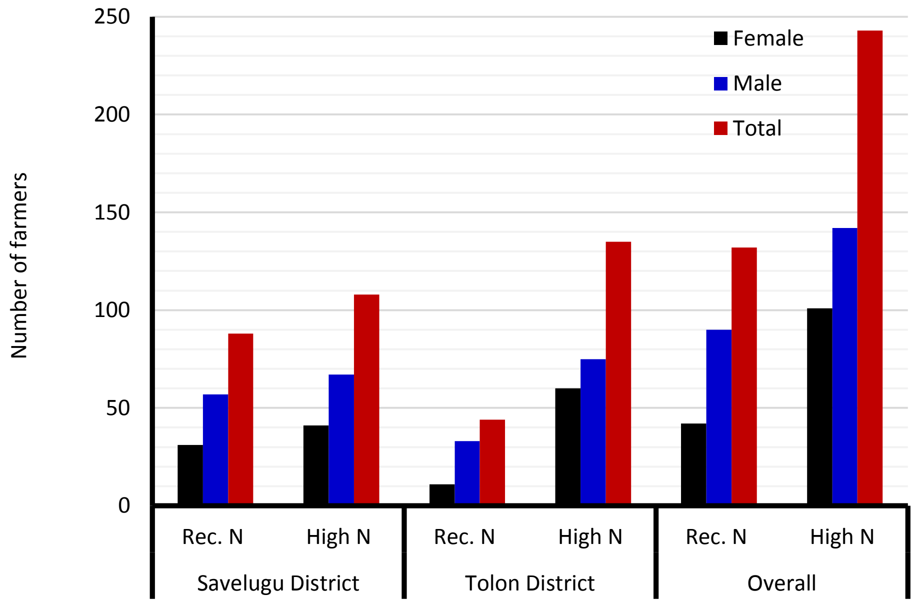


Figure 16: Farmer preferences for government recommended and higher nitrogen fertilizer rates for maize, Tolon and Savelugu Districts, Northern Region, Ghana, 2014

2.2.3 Insecticide spraying and cowpea variety effect on grain yield, Ghana and Mali

In Ghana, the effects of two spraying regimes (once and thrice) on grain and fodder yields of six improved cowpea varieties (Songotra, Apagbaala, Padituya, IT 99 K 573-1-1, Zaayura and local check) was evaluated using a split-plot design replicated in five communities. Spraying regime was main-plots and cowpea varieties were sub-plots.

The spraying regime by cowpea variety interaction had no significant effect on grain and fodder yields. In communities in the Northern Region, spraying thrice during the growing season increased grain yields (Tab. 13). Varieties Padituya, Zaayoura and IT-99K-573-11 had significantly higher fodder yields than Songotra. Male and female farmers selected three spray regimes as the effective pest control method (Fig. 17). However, the female group preferred the local cowpea variety compared to the male group who selected Padituya variety (Tab. 12). Spraying Padituya and the local variety three times during the growing season could intensify cowpea production in the Africa RISING intervention communities in the Northern Region of Ghana. Cost-benefit-analysis is required to support this observation.

In Mali, the effect of a neem-tree extract biopesticide on grain and haulm yields of three cowpea varieties was evaluated on-farm. Applying the biopesticide significantly increased the grain yield of Wulibali variety, but had no effect on haulm yield in all varieties (Fig. 18 and 19).

Table 13: Grain and haulm yield of cowpea varieties as affected by spraying regime, Northern Region, Ghana, 2014.

	Yield	
Item	Grain (kg/ha)	Fodder (t/ha)
Spraying regime		
Once	341	8.97
Thrice	538	8.83
s.e	12.2	1.184
P-value	0.0003	0.078
Variety		
Songotra	464	5.23
Apagbaala	328	8.18
Padituya	494	12.35
IT 99K 573-1-1	421	9.98
Zaayura	404	10.35
Local check	526	7.32
s.e	72.6	1.116
P-value	0.123	0.0011

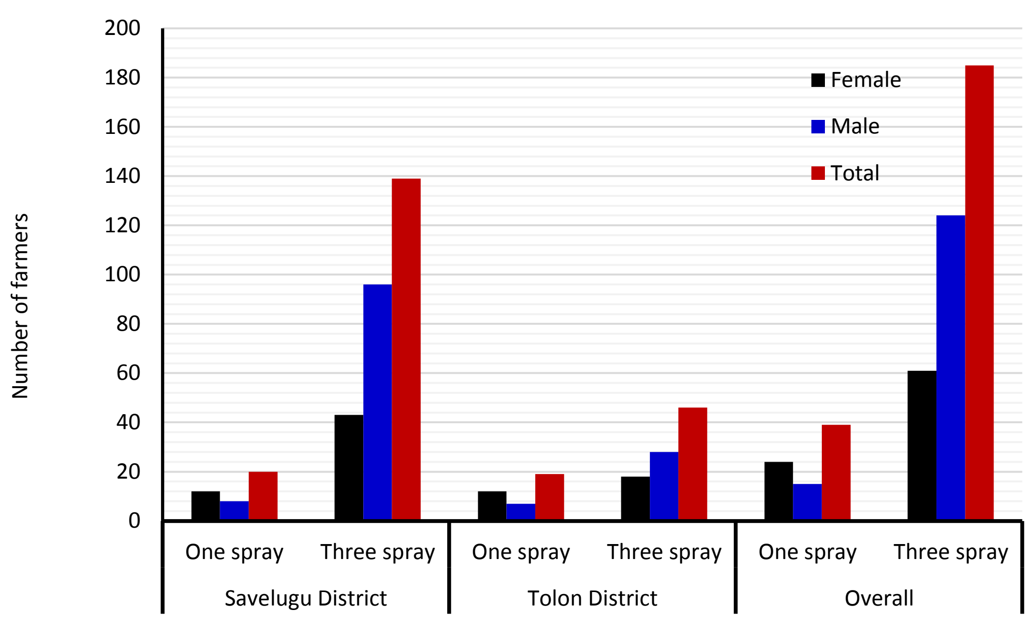


Figure 17: Farmer preferences for the number of insecticide sprays for a cowpea crop during the growing season, Savelugu and Tolon Districts, Northern Region, Ghana, 2014

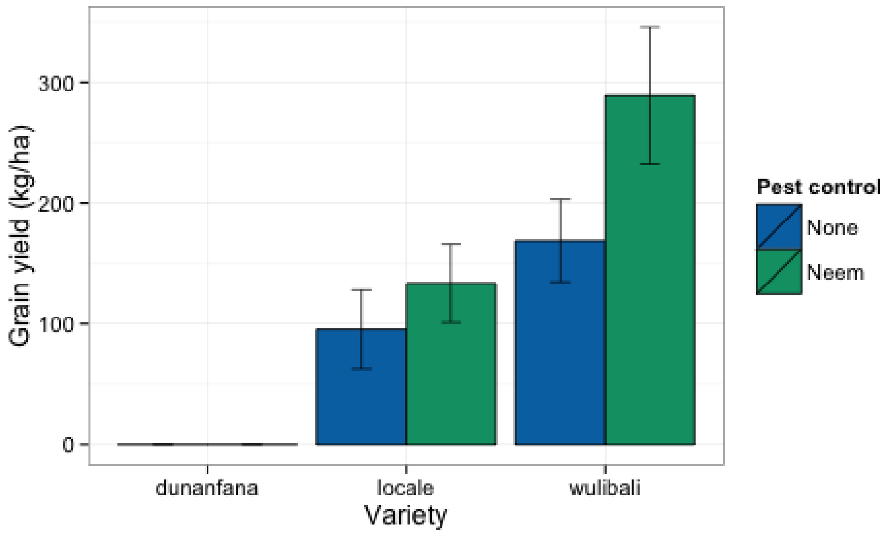


Figure 18: Grain yield cowpea varieties as affected by a neem biopesticide, Mali

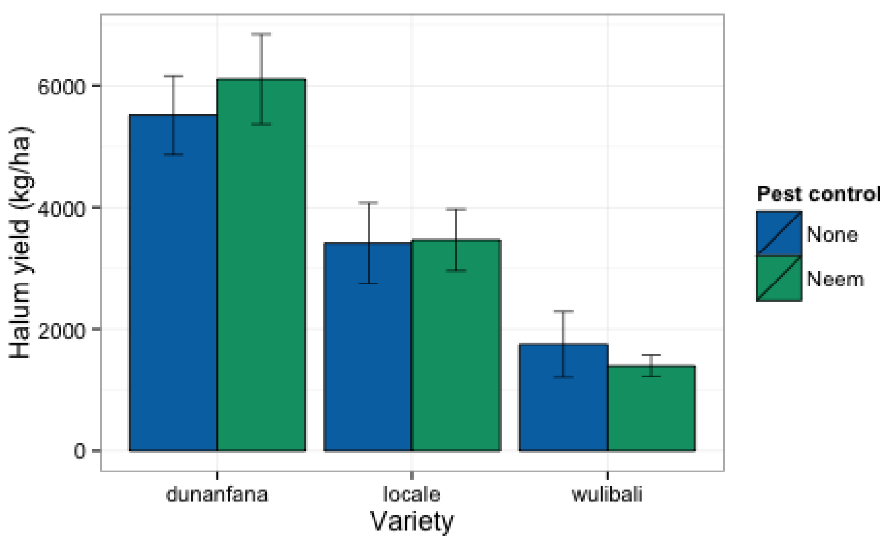


Figure 19: Haulm yield of cowpea varieties as affected by a neem biopesticide

2.2.4 Integrated soil fertility management options to intensify legume production, Ghana

Soybean-maize rotations: A split-plot design replicated in 3-5 communities in all three regions was used to study the performance of two soybean varieties (Jenguma and TGX-1904-6F, main-plots) under five integrated soil fertility management (ISFM) practices: farmer practice, triple superphosphate (TSP) at 60kg/ha, fertizol (F) at 4t/ha, TSP + F, TSP + F + Boostxtra, a foliar spray. Main-plots were soybean varieties, and sub-plots were ISFM options.

Grain and stover yields were not significantly affected by the soybean variety by ISFM option interaction in all regions. In the Northern Region, the main effects of variety affected stover yield, whilst ISFM option affected both stover and grain yields (Tab. 14). Jenguma produced more stover than TGX-1940-5F, whilst the combination of TSP and F and TSP + F + Boostxtra produced more grain than the farmers' practice. Similar effects of the ISFM options were obtained in the Upper West Region (Fig. 20). Both, male and female farmers preferred Jenguma variety (Fig. 21) and TSP + Fertisol + Boostxtra as ISFM option in Northern Region. Thus, farmers in the Northern Region of Ghana could intensify soybean production by using a combination of the Jenguma variety with either TSP + F, or TSP + F + Boostxtra as ISFM option.

Table 14: Soybean variety and integrated soil fertility management option on grain and stover yield, Northern Region, Ghana, 2014

	Yield (kg/ha)	
Item	Grain	Stover
Variety		
Jenguma	1753	3900
TGX-1904-6F	1687	3289
s.e	181.3	164.9
P-value	0.276	0.047
Integrated soil fertility management option		
Farmer practice	1211	2617
Triple super phosphate (TSP, at 60 P_2O_5 kg/ha)	1696	3604
Fertisol (F, at 4 t/ha)	1689	3676
TSP + F	2139	4275
TSP + F + Boostxtra	1865	3800
s.e	110.6	219.4
P-value	<.0001	0.0001

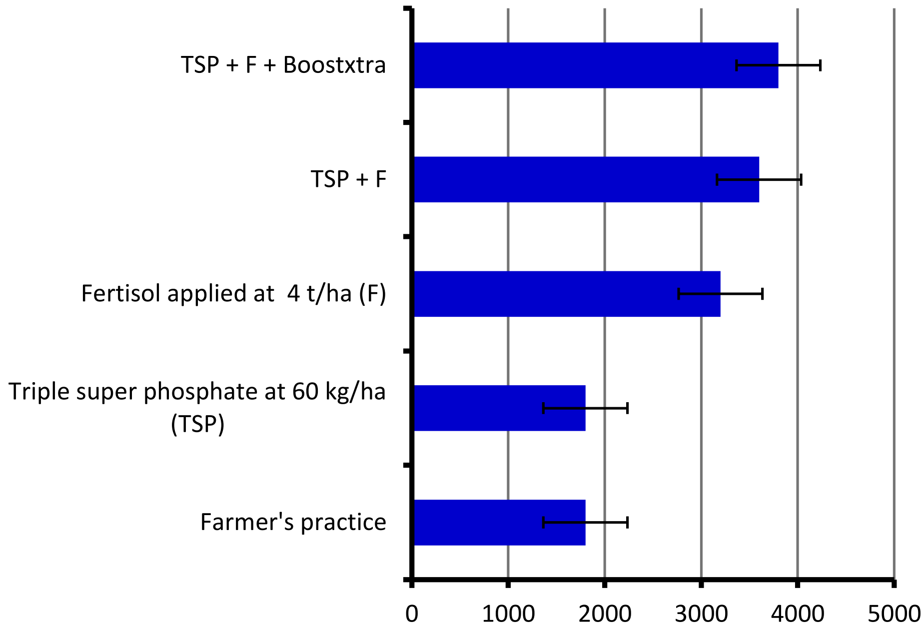


Figure 20: Integrated soil fertility management effects on soybean grain yield in Africa RISING intervention communities, Upper West Region, Ghana, 2014

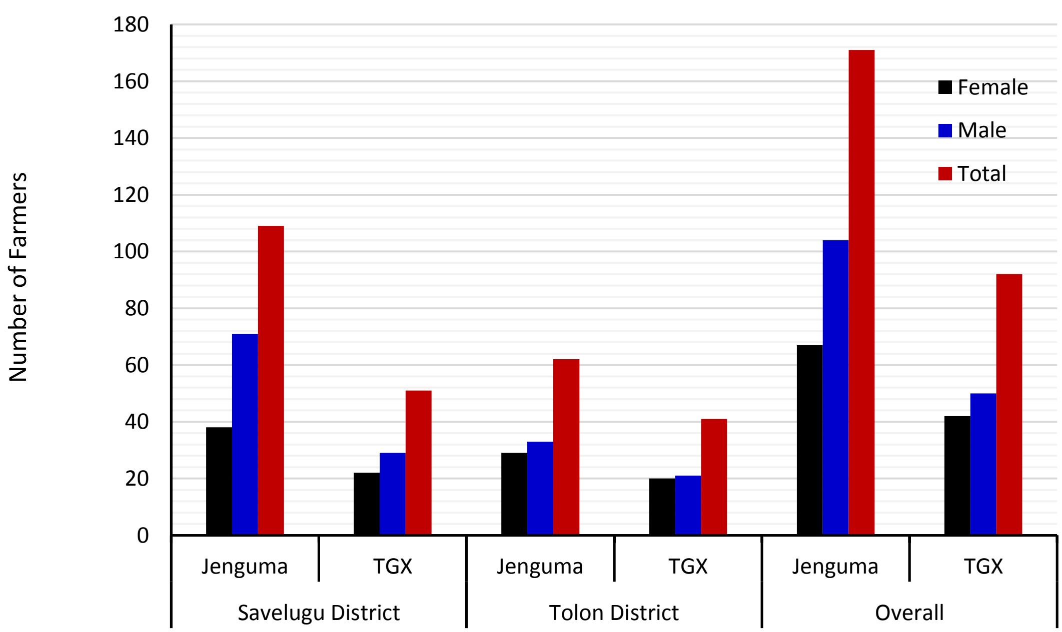


Figure 21: Farmer preferences for soybean varieties under different integrated soil management options, Savelugu and Tolon Districts, Northern Region, Ghana, 2014

Cowpea-maize rotations*:* Recent reports show that Rhizobium inoculation of cowpea has increased cowpea grain yields on-station, but data is limited on how the technology will perform on-farm. A randomized block design, replicated in two intervention communities in the Upper West Region, was used to study maize grain and stover yields in rotation with either cowpea alone or cowpea with Rhizobium and/or inorganic fertilizer. The treatments are listed in Table 15.

Table 15: Maize yield following cowpea with or without soil amendments, Goriyiri, Upper West Region, Ghana, 2014

	Yield (kg/ha)	
Treatment	Grain	Stover
Cowpea only (C, Control)	2900	4334
Recommended fertilizer rate for maize (NPK)[1]	2611	4798
C + Rhizobium ('R)	3467	4656
C + R + Fertisoil (F)[2]	3877	4426
C + R + PK[3]	3289	4570
C + PK+ F	3978	4534
C + R + NPK	4333	5102
LSD (0.05)	1241	NS

[1]Recommended fertilizer rate was 25-60-30kg/ha as N, P_2O_5 and K_2O

[2]Fertisoil was applied at the rate of 4t/ha

[1]P and K were applied at the rate of 60kg/ha P_2O_5 and 30kg/ha K_2O, respectively

Grain yield of maize following cowpea + Rhizobium + NPK was significantly higher than that of maize following cowpea alone and the government recommended fertilizer rate for maize, but similar to the treatments in Table 15. The results suggest that rotating maize with Rhizobium inoculated cowpea in combination with fertisol, NPK and PK could intensify maize production in northern Ghana.

Effect of phosphorus fertilizer rates on groundnut: A split-plot design replicated in four communities in each region was used to evaluate the effect of two P fertilizer rates (government recommended rate of 60kg/ha and a higher rate of 90kg/ha P_2O_5) on grain and haulm yields of five improved groundnut varieties (Chinese, Azivivi, Obolo, Manipinta and Yenyawoso). The P fertilizer rates were main-plots, and sub-plots were the groundnut varieties.

The P fertilizer rate x groundnut variety interaction did not significantly affect grain and fodder yields in all the regions. Grain and fodder yields increased significantly with increasing P fertilizer rate in the Northern Region (Tab. 16). The fodder yield of Manipinata was higher than Yenyawowo. Female farmers preferred the 60kg/ha P_2O_5 rate and the Azivivi variety, while the males preferred the 90kg/ha P_2O_5 kg rate and the Chinese variety (Tab. 12 and Fig. 22). The results suggest that productivity of groundnut by female farmers can be intensified by using a combination of applying 60kg/ha P_2O_5 and Azivivi variety. For male farmers, however, a combination of 90kg/ha P_2O_5 and using Chinese variety could intensify groundnut production.

Table 16: Phosphorus (P) fertilizer rate and groundnut variety effect on grain and haulm yield of groundnut, Northern Region, Ghana, 2014.

	Yield (kg/ha)	
Item	Grain	Stover
P rate (kg/ha)		
60	507	4019
90	795	4733
s.e	61.3	82.7
P-value	0.045	0.008
Variety		
Chinese	663	4555
Azivivi	605	4191
Obolo	744	4414
Manipinta	494	4766
Yenyawoso	748	3953
s.e	102.4	447.2
P-value	0.325	0.084

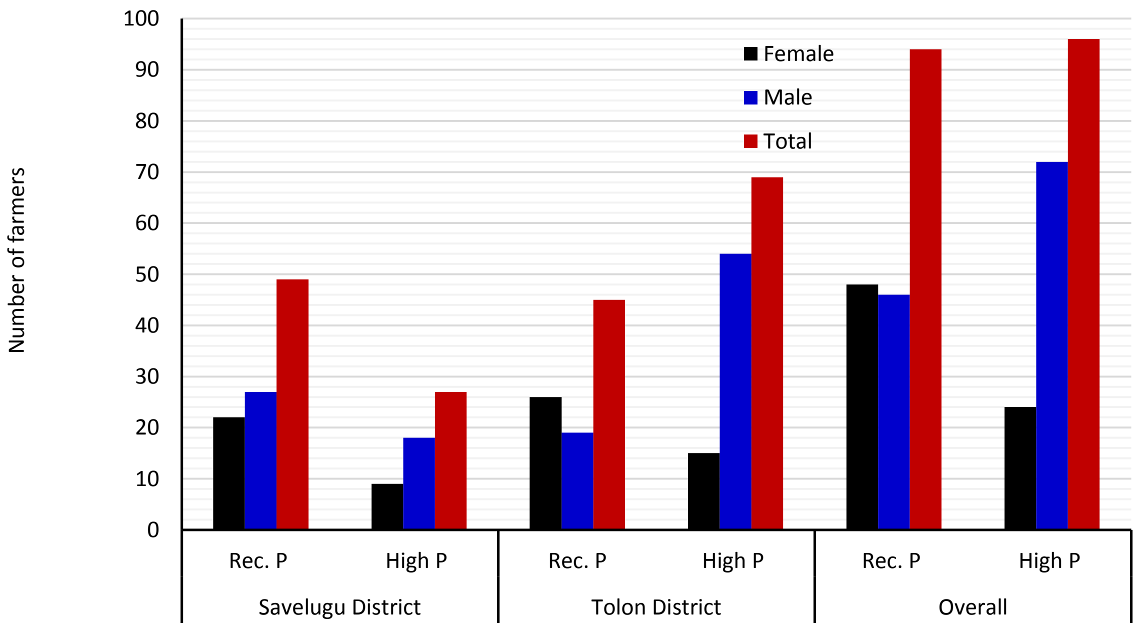


Figure 22: Farmer preferences for government recommended and a higher phosphorus fertilizer rate on groundnut, Savelugu and Tolon Districts, Northern Region, Ghana, 2014

Maize - Legume strip cropping systems: Grain yield, Land Equivalent Ration (LER), Benefit-Cost-Ratio (BCR) and Gross Margin (GM) of pure stands of maize (M), cowpea (C), and groundnut (G) as well as strip stands of maize and the three legumes (2M:2C, 2M:2G, 2M:4C, and 2M:4G) were compared using a randomized complete block design replicated in five communities per region.

The LER of intercrops was greater than one suggesting that the intercrops were more productive than the pure stands (Tab. 17). Similarly, the BCR and GM of the intercrops were greater than the monocrops. The 2M:2C and 2M:4C strip cropping had the highest GM. Female and male farmers preferred the 2M:2C and the 2M:2G strip cropping (Fig. 23).

Table 17: Maize-legume strip cropping effect on grain yield, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM)

Strip cropping system	Grain yield (kg/ha)					
	Maize	Cowpea	Groundnut	LER	BCR	GM (Gh₵)[1]
Maize (M)	2590					
Cowpea (C)		1047				
Groundnut (G)	-	-	944	-	2	979
2M:2C	2702	1105	-	2.2	4.3	2652
2M:2G	2918		428	1.9	3.4	1856
2M:4C	1996	1045	-	2.0	3.2	1982
2M:4G	2819	-	414	1.8	2.3	1178
s.e	284.1	97.7	230.3	0.15	0.66	533.9

[1]3Gh₵= 1US$

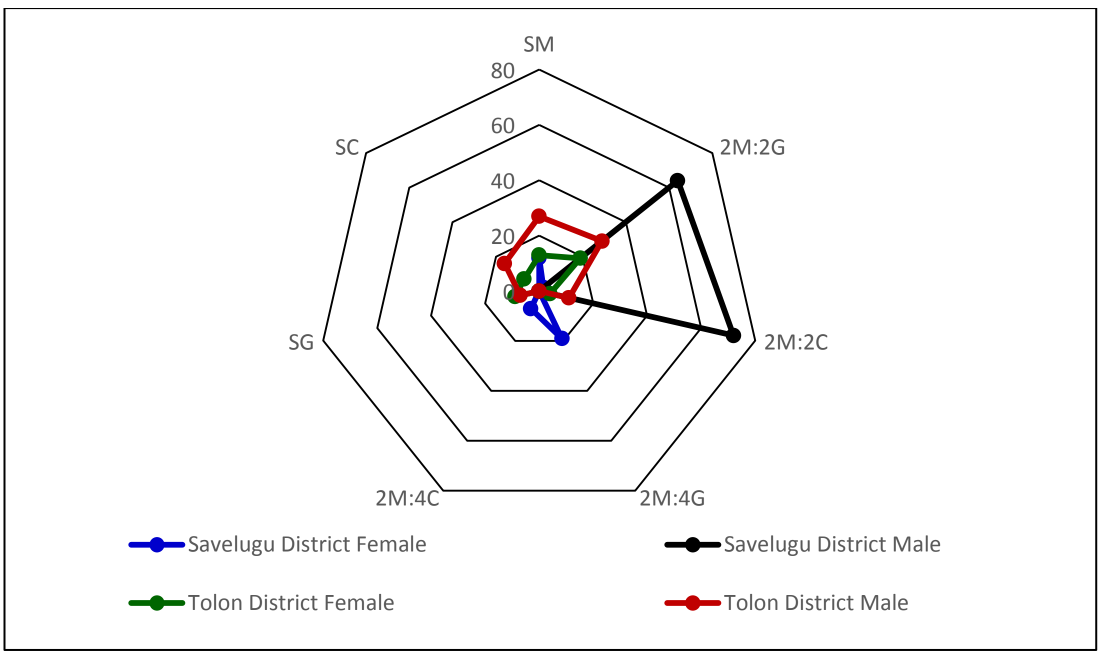


Figure 23: Farmer preferences for maize (M) strip cropped with cowpea (C), groundnut (G) and soybean (S), Savelugu and Tolon Districts, Northern Region, Ghana, 2014

2.2.5 Agronomic practices to intensify cereal-vegetable intercropping systems, Ghana

Five separate trials were conducted to study the profitability of either growing monocrops of vegetables (roselle, okra, pepper and tomato) or vegetable-maize intercrops at different planting densities of the cereal and vegetable components. A randomized complete block design replicated in 3-5 communities in each region was used. In all trials, eight treatments were compared, and maize grain and vegetable fruit or leaf yields, LER, BCR, and GM were measured.

Trial 1: maize-roselle intercrop - treatments 1) pure maize (M) stand at recommended density 67000 plants/ha (MR), 2) pure maize stand at a higher density of 133000 plants/ha (MH), 3) pure stand of roselle (R) at a recommended density of 296000 plants/ha (RR), 4) pure stand of roselle at a lower density of 99000 plants/ha (RL), 5) 1MR:1RR, 6) 1MR:2RL, 7) 2MH:1RR, and 8) 2MH:2RL.

Trial 2: maize-okra intercrop - treatments: 1) MR, 2) MH, 3) okra at a recommended density of 56000 plants/ha (KR), 4) pure stand of okra at a lower density of 37000 plants/ha (KL), 5) 1MR:1KR, 6) 1MR:2KL, 7) 2MH:1KR and 8) 2MH:2KL.

Trial 3: maize-eggplant intercrop - treatments: 1) MR, 2) MH, 3) a pure stand of eggplant planted at a recommended density of 28000 plants/ha (ER), 4) a pure stand of eggplant planted at lower density of 18500 plants/ha (EL), 5) 1MR:1ER, 6) 1MR:2EL, 7) 2MH:1ER, and 8) 2MH:2EL.

Trial 4: maize-pepper intercrop - treatments: 1) MR, 2) MH, 3) a pure stand of pepper at a recommended density of 28000 plants/ha (PR), 4) a pure stand of pepper at lower density of 18500 plants/ha (PL), 5) 1MR:1PR, 6) 1MR:2PL, 7) 2MH:1PR and 8) 2MH:2PL.

Trial 5: maize-tomato intercrop - treatments: 1) MR, 2) MH, 3) a pure stand of tomato at a recommended density of 28000 plants/ha (TR), 4) a pure stand of tomato at a lower density of 18500 plants/ha (TL), 5) 1MR: 1TR, 6) 1MR:2TL, 7) 2MH:1TR, and 8) 2MH:2TL.

Table 18: Intercropping maize with roselle effects on maize grain and roselle leaf yields, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM) in Africa RISING intervention communities, Northern Region, Ghana, 2014

	Yield (kg/ha)				
Cropping system	Maize grain	Roselle leaf	LER	BCR	GM (Gh₵/ha)[4]
MR[1]	1924	-	-	1.8	1362
MH[2]	2430	-	-	2.3	2069
RR[3]	-	2812	-	3.6	10691
RL[4]	-	2831	-	3.6	10787
1MR:1RR	1509	1280	1.2	1.5	1590
1MR:2RL	1247	1603	1.2	1.8	2868
2MH:2RR	1926	1045	1.2	1.5	1303
2MH:2RL	1479	1588	1.1	1.8	2370
s.e	160.4	208.6	0.07	0.30	1137.1
P-value	0.0045	0.0003	ns	0.0003	0.0001

[1]MR= maize at recommended density, [2]MH= maize at higher density, [3]RR= roselle at recommended density, [4]RL= roselle at lower density and ns= not significant at 5%, [4]1US$= 3 Gh₵.

Table 18 above shows the results of the maize-roselle trial in the Northern Region. Maize grain and roselle leaf yields were higher for the pure stands at the recommended and higher densities. The pure stands of roselle were more profitable than the pure stand of maize and the maize-roselle intercrops. The GM for the 1MR:2RL and 2MH:2RL was significantly higher than the sole maize and the other intercrops.

The pure stands of okra gave significantly higher returns than the pure maize and maize-okra treatment (Tab. 19). Maize at a higher density was more profitable than the intercrops. The most profitable intercrop was 2MH:2KR, which can be used to intensify the cereal-vegetable cropping systems.

Table 19: Intercropping maize with okra on maize grain and okra fruit yield, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM) in Africa RISING intervention communities, Northern Region, Ghana, 2014

	Yield (kg/ha)				
Cropping system	Maize grain	Okra fruit	LER	BCR	GM (Gh₵/ha)[4]
MR[1]	2368	-	-	2.2	1983
MH[2]	3522	-	-	3.3	3599
KR[3]	-	2632	-	3.1	5489
KL[4]	-	2597	-	3.1	5385
1MR:1KR	1898	1214	1.3	1.6	1280
1MR:2KL	1779	1063	1.3	1.3	906
2MH:2KR	2989	852	1.2	2	1961
2MH:2KL	2873	1011	1.2	1.8	1658
s.e	243.5	323.2	0.08	0.44	953.9

[1]MR= maize at recommended density, [2]MH= maize at higher density, [3]KR= okra at recommended density, [4]KL= okra at lower density and ns= not significant at 5%, [4]1US$= 3 Gh₵.

The BCR and GM of the pure eggplants was significantly higher than the pure maize and the intercrops; whilst that of the MH varied significantly from the MR and the intercrops (Tab. 20). For the intercrops, the GM of 1MR:2EL was significantly lower than the others.

Table 20: Intercropping maize with eggplant on maize grain and eggplant fruit yield, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM) in Africa RISING intervention communities, Northern Region, Ghana, 2014

	Yield (kg/ha)				
Cropping system	Maize grain	Eggplant fruit	LER	BCR	GM (Gh₵/ha)[4]
MR[1]	3020.0	-	-	2.9	2,896
MH[2]	3145.0	-	-	3	3,071
ER[3]	-	10.67	-	8.3	14,219
EL[4]	-	9.12	-	7.1	11,908
1MR:1ER	2344	3.29	1.1	2.4	2,559
1MR:2EL	2395	2.46	1.1	2	1,943
2MH:1ER	2313	3.23	1	2.3	2,290
2MH:2EL	2046	3.62	1	2.4	2,594
s.e	265.5	1.63	0.01	0.35	548.3

[1]MR= maize at recommended density, [2]MH= maize at higher density, [3]ER= eggplant at recommended density, [4]EL= eggplant at lower density and ns= not significant at 5%, [4]1US$= 3 Gh₵.

The GM of the pure stand of pepper was significantly higher than that of the other options (Tab. 21). The high density maize option had significant greater GM than the intercrops, which did not differ in GM. The results suggest that a pure stand of pepper is more profitable than pepper-maize intercrops.

Table 21: Intercropping maize with pepper on maize grain and pepper fruit yield, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM) in Africa RISING intervention communities, Northern Region, Ghana, 2014

	Yield (kg/ha)				
Cropping system	Maize	Pepper fruit	LER	BCR	GM (Gh₵/ha)[4]
MR[1]	1254	-	-	1.2	424
MH[2]	1892	-	-	1.8	1316
PR[3]	-	1378	-	2.8	3699
PL[4]	-	1626	-	3.3	4693
1MR:1PR	704	939	1.2	1.4	798
1MR:2PL	786	774	1.1	1.4	785
2MH:2PR	1311	600	1.1	1.2	532
2MH:2PL	1255	613	1.1	1.2	531
s.e	137.4	113.1	0.05	0.19	370.7

[1]MR= maize at recommended density, [2]MH= maize at higher density, [3]PR= pepper at recommended density, [4]PL= pepper at lower density and ns= not significant at 5%, [4]1US$= 3 Gh₵.

The sole tomato stands gave significantly higher BCR and GM than the pure stands of maize and maize-tomato intercrops (Tab. 22). Among the intercrops, 1MR:2TL had significantly higher GM than 2MH:2TR. The results suggest that sole cropping of tomato may be more profitable the sole maize and maize-tomato intercrops.

Table 22: Intercropping maize with tomato on maize grain and tomato fruit yield, land equivalent ratio (LER), benefit cost ratio (BCR) and gross margin (GM) in Africa RISING communities, Northern Region, Ghana, 2014

	Yield (kg/ha				
Cropping system	Maize	Tomato	LER	BCR	GM (Gh₵/ha)[4]
MR[1]	2128	-	-	2	1,646
MH[2]	2023	-	-	1.9	1,499
TR[3]	-	4026	-	11.7	18,548
TL[4]	-	3641	-	10.6	16,624
1MR:1TR	1602	1396	1.1	2.6	2991
1MR:2TL	1493	1391	1	2.9	3634
2MH:2TR	1755	900	1.1	1.9	1601
2MH:2TL	1508	1076	1	2.1	2127
s.e	133.4	279.7	0.02	0.73	1272.7

[1]MR= maize at recommended density, [2]MH= maize at higher density, [3]TL= tomato at recommended density, [4]TL= tomato at lower density and ns= not significant at 5%, [4]1US$= 3 Gh₵.

2.2.6 Agronomic practices to raise and intensify sesame production, Ghana

Sesame, a major oilseed crop, has recently been introduced into some communities in northern Ghana as a cash crop. Data is limited on good agronomic practices to raise and intensify production under on-farm conditions. Two trials were conducted to test and adapt agronomic practices for sesame production.

In the first trial, a split-plot design replicated in three communities was used to test the effect of three planting times (mid-July, late-July and mid-August; main-plots) and insecticide spraying regimes (spraying once, twice and thrice during the growing season; sub-plots) on growth and grain yield.
A second trial compared the effects of two N rates (60 and 90kg/ha) and five cropping systems [pure stands of maize (M) and sesame (S), and maize-sesame intercrop with sesame planted on the same day as maize (M+S), one week after maize planting (MS1) and two weeks after maize planting (MS2)] on grain yield, LER and percent of land saved estimated as: [(100-1/LER) x 100]. A split-plot design replicated in four communities per region with N rates as main-plots and cropping systems as sub-plots was used.

The interaction between planting time and spraying regime had no significant effect on plant height and grain yield. Increasing the number of spraying per the cropping season significantly increased the plant height and grain yield (Tab. 23). Time of planting had no significant effect on plant height and grain yield, although grain yield tended to increase with delayed planting date suggesting that moisture has effect on grain yield. A combination of mid-August planting and spraying three times during the cropping season could raise and intensify sesame production in the Northern Region.

Table 23: Planting time and spraying regime effects on performance of sesame, in Africa RISING intervention communities, Northern Region, Ghana, 2014.

Item	Plant height (cm)	Grain yield (kg/ha)
Sowing date (SD)		
Mid-July	50	45
Late July	51	55
Mid-August	51	58
s.e	1.2	6.6
P-value	ns	ns
Spraying regime (S)		
Once	47	33
Twice	51	56
Thrice	54	69
s.e	0.9	3.7
P-value	0.0002	0.0001

The N rate by time of under-sowing sesame interaction had no significant effect on grain yields of maize and sesame, but grain yield of both crops increased with increasing N rate (Tab. 24). Maize grain yield increased, whilst that of sesame declined as the time of under-sowing sesame increased. The LER ratios for all intercrops were greater than one, indicating higher productivity of the intercrops than the pure stands. The results suggest that, planting maize with sesame on either the same day or one week after planting the maize could raise productivity in maize-sesame cropping systems in the Northern Region.

Table 24: Nitrogen rates and time of under-sowing sesame effect on grain yield, land equivalent ratio (LER) and percent land saved (PLS) in Africa RISING intervention communities, Northern Region, Ghana, 2014

	Grain yield (kg/ha)			
	Maize	Sesame	LER	PLS[1]
Nitrogen rate (N, kg/ha)				
60	528	62	-	-
90	1175	73	-	-
s.e	91.7	9.8	-	-
P-value	0.0155	ns	-	-
Cropping systems				
Maize (M)	844	-	-	-
Sesame (S)		103	-	-
M + S on same day as M	696	80	2.2	43
M + S sown 1 week after planting M	877	52	2.3	39
M + S sown 2 weeks after planting M	989	35	2.1	36
s.e	84.7	12.5	0.30	7.5
P-value	ns	0.0062	ns	ns

[1]Percent land saved was (PLS) estimated as: (100-1/LER)*100.

2.2.7 Intensifying rice production through variety and fertilizer management, Ghana

In Upper East Region, a five N fertilizer rates (0, 30, 60, 90 and 120kg/ha N) by two rice varieties (Gbawee and a farmers' variety) factorial treatment arrangement in a randomized complete block was used to determine the effect of N fertilizer on grain yields of improve rice variety (Gbawee) and a farmers' variety in Bonia, Nyangua and Samboligo. The fertilizer N was applied as urea in two equal doses at planting and six weeks thereafter. Triple superphosphate (60kg/ha P_2O_5) and muriate of potash (60kg/ha P_2O_5) were applied at planting.

Gain yield of both rice varieties showed a non-linear response to increasing N fertilizer rate, reaching a maximum between 90-120kg/ha N (Fig. 24, 25, 26). The improved variety produced more grain than the local variety at all locations. Regression analysis showed that grain yield (Y) of the Gbawee variety at the three locations could be predicted with the following equations: $Y_{Bonia}= -1.98 + 3.42x – 0.322x^2$, $r^2 = 0.97$; $Y_{Nyangua} = -1.32 + 2.28x – 0.214x^2$, $r^2 = 0.94$; and $Y_{Samboligo} = -0.97 + 1.68x – 0.158$, $r^2 = 0.95$.

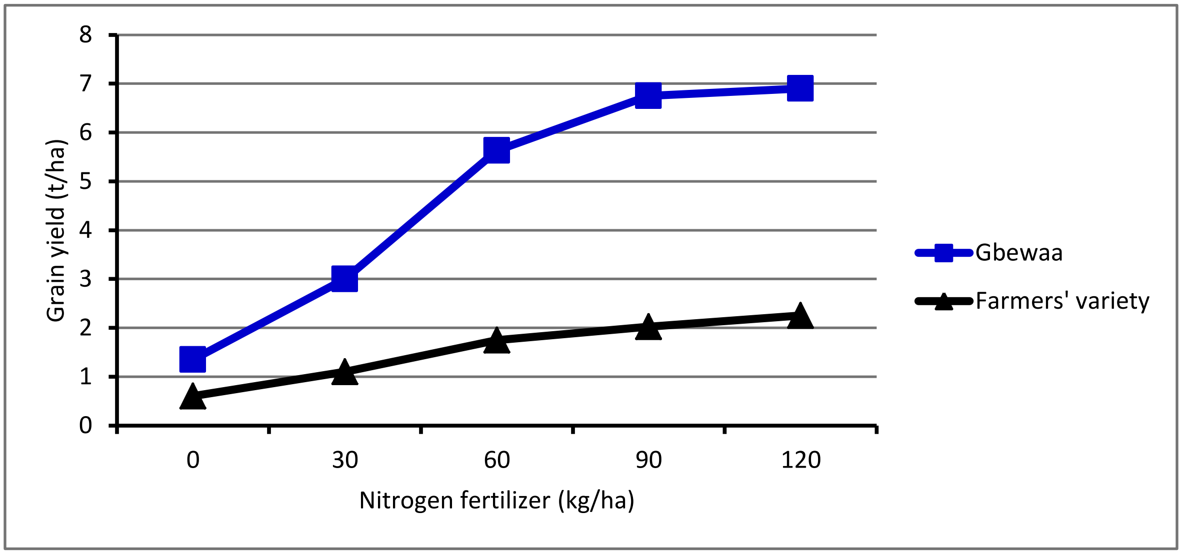


Figure 24: Rice grain yield as affected by variety and nitrogen fertilizer, Bonia, Upper East Region, Ghana, 2014

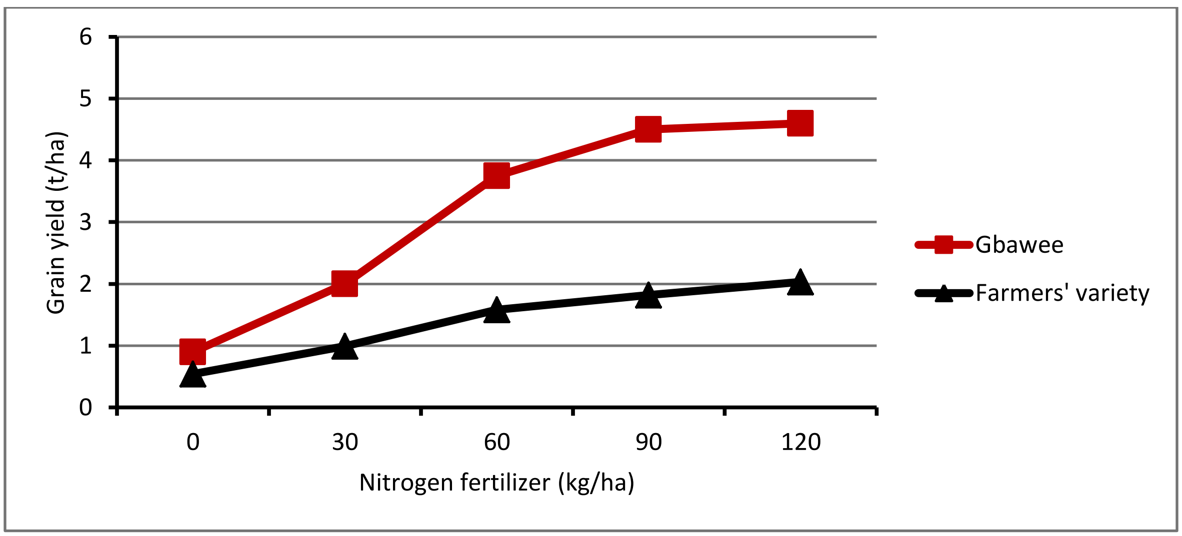


Figure 25: Rice grain yield as affected by variety and nitrogen fertilizer, Nyangua, Upper East Region, Ghana, 2014

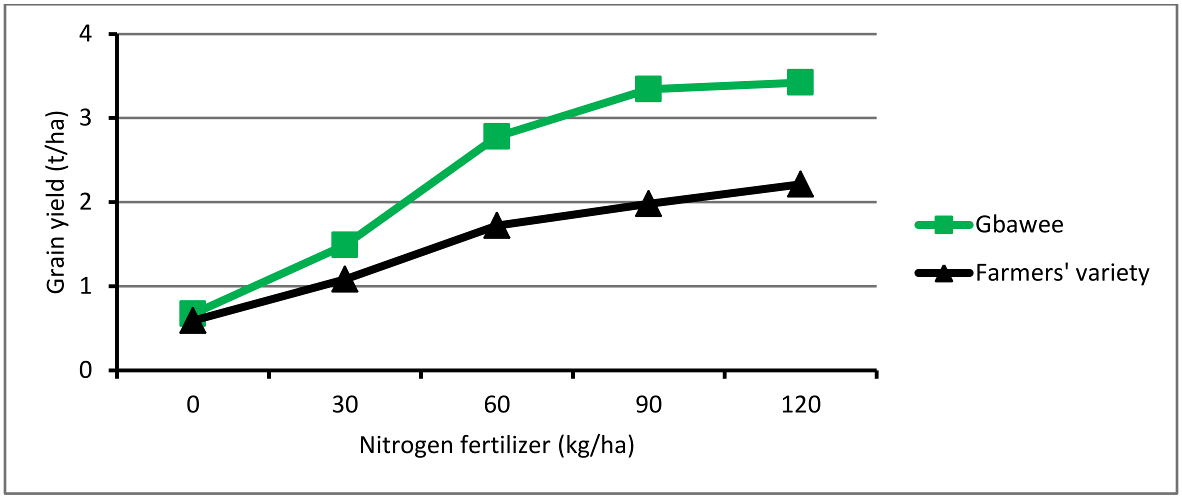


Figure 26: Rice grain yield as affected by variety and nitrogen fertilizer, Samboligo, Upper East Region, Ghana, 2014

2.2.6 Productivity of hybrid maize - cowpea production systems, Ghana

Productivity of hybrid and open-pollinated maize grown in association with erect and spreading cowpea types was evaluated on-farm in Africa RISING intervention communities in the Northern Region. A split-split plot design with four replicates was used. Main-plots were erect cowpea (Songotra), spreading cowpea (Sanzi) and no cowpea (sole maize). Sub-plots were four maize varieties – 3 hybrids (Pan 53, Etubi, Mamaba) and one open-pollinated variety (Obatampa). Grain yield and net returns were estimated.

Grain yields (Fig. 27) and net returns (Fig. 28) varied significantly among the cropping options. Land Equivalent Ratios of the intercrops were greater than one, suggesting that productivity of the intercrops was higher than the monocrops. Sole and intercrops of Pan 53 maize hybrid with either erect or spreading cowpea types could result in higher returns on investment.

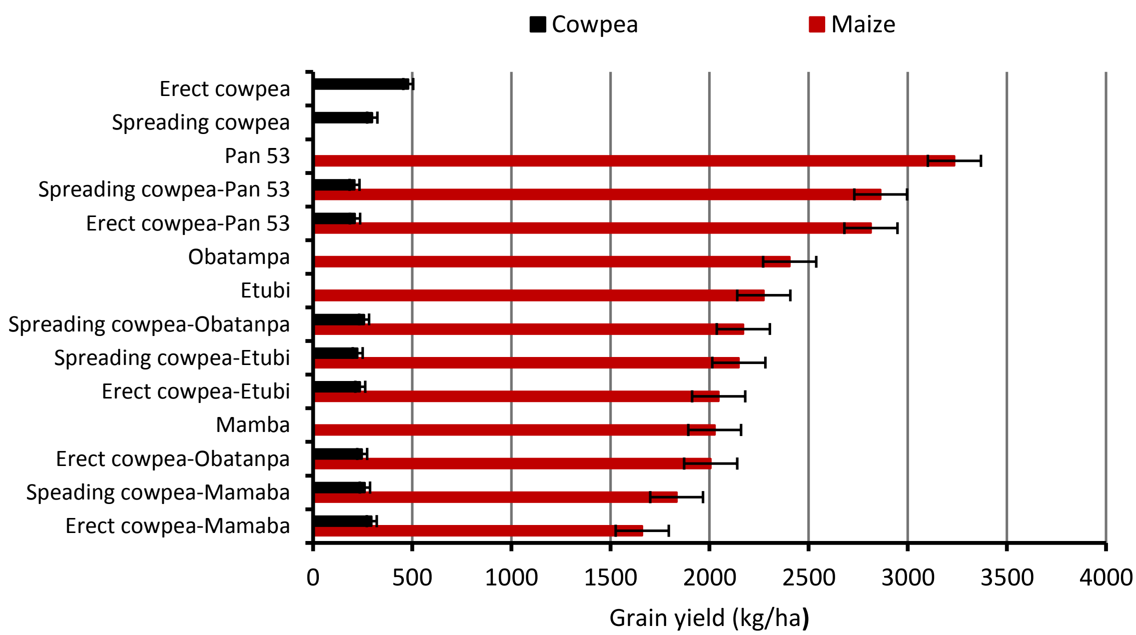


Figure 27: Hybrid maize and cowpea grain yield in pure stands and mixtures, Northern Region, Ghana, 2014

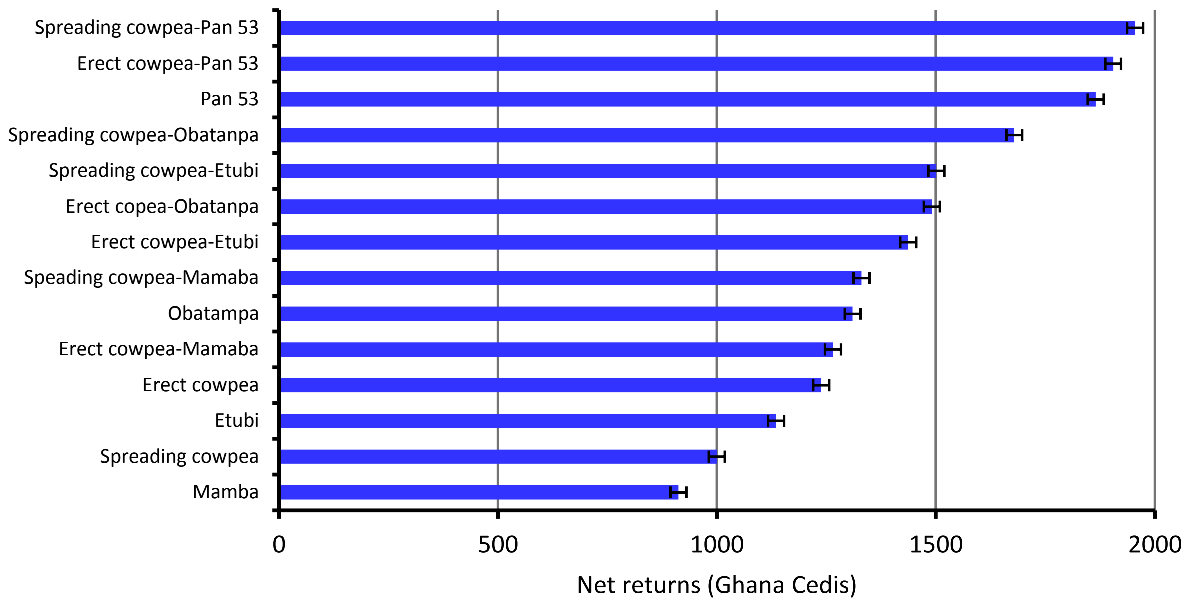


Figure 28: Net returns form hybrid maize and cowpea pure stands and mixtures, Northern Region, Ghana, 2014

2.2.7 Combination of livestock management and agronomic options to intensify small-scale maize production, Ghana

Farmers tether sheep and goats on fallow land to recycle manure and urine for crops, but data on the effect of sheep and goats stocking density (SSD) on grain yield and soil properties in such systems is limited. A split-split plot design with 9 replications in 3 communities (Gia, Nyangua and Samboligo) in Upper East Region was used to evaluate the effect of SSD, maize planting density (MPD) and nitrogen (N) fertilizer level on grain yield. Main-plots were SSD (0, 400 and 200 head ha^{-1}) on farmland overnight, sub-plots MPD (6.93, 10.40 and 138.67 plants/ha) and sub sub-plots were N fertilizer rate (0, 60, 90kg/ha N). Grain and stover yield were measured. Agronomic efficiency (AE) and Partial Factor Productivity (PFP) indices were estimated as: AE=Y-Y_0/F and PFP= (Y_0/F) +AE, where F=amount for fertilizer applied (kg/ha), Y=crop yield with applied nutrient and Y_0=crop yield with no nutrient applied.

Table 25: Sheep stocking density and nitrogen effects on maize grain yield

	Nitrogen rate (kg/ha)		
Stocking density (head/ha)	0	60	90
0	1.13	1.56	1.65
200	1.67	2.15	2.48
400	1.78	2.7	2.54
s.e.		0.088	
P-value		0.009	

Sheep stocking density and nitrogen fertilizer affected maize grain yield and nitrogen use efficiency (Tab. 25, 26). The stocking density of 400 with 60kg/ha N gave the highest grain yield and best N use efficiency. Crop-livestock farmers can stock sheep at 400 heads/ha and a planting density of 10.40 x 10^3 plants to intensify maize production.

Table 26: Sheep stocking density effects on nitrogen use efficiency

	Nitrogen rate (kg/ha)			
	Agronomic efficiency		Partial factor productivity	
Stocking density (head/ha)	60	90	60	90
0	7.2	5.8	26	1.84
200	8.1	9.1	35.8	27.6
400	15.5	8.5	45.1	28.2

2.3 Soil, water and land management

2.3.1 Documentation and validation of local conventions and participatory conflict management, Mali

Discussions were held with people from local administrations and state technical services, and traditional institutions in six communities. Additionally, 165 farmers were interviewed in the six communities including 53 women on their participation in the elaboration, implementation, monitoring and evaluation of local conventions.

Participation by the community members in elaboration and implementation processes of local conventions was very low in the project communities and tended to be dominated by a group of individuals, often community leaders and elites. The results also suggested that women are marginalized in the processes (Tab. 27, 28). Most existing local conventions governing access, use and management of natural resources are oral and informal (see annex 1). A manuscript on “Community Participation in Decentralized Management of Natural Resources in the Sudano-Sahelian Zone of West Africa” was prepared for submission to World Development Journal and is currently under internal review.

Table 27: Level of knowledge of local conventions by the respondents in Bougouni and Koutiala Districts

District	Average	Male	Female
Bougouni	3.16±1.21	3.47±0.96	2.50±1.44
Koutiala	1.70±1.44	1.81±1.46	1.57±1.38

Rating (0 = none, 1 = low, 2 = average, 3 = good, 4 = very good)

Table 28: Participation in the elaboration processes of existing local conventions in the study sites by gender

Variable	Bougouni		Koutiala	
	Male (N=52)	Female (N=24)	Male (N=59)	Female (N=30)
Diagnosis	1.52±0.22 [a]	0.50±0.22 [b]	0.98±0.18 [a]	0.27±0.13 [b]
Awareness	1.40±0.21 [a]	0.46±0.21 [b]	0.86±0.17 [a]	0.20±0.10 [b]
Resource mobilizations	0.07±0.06	0	0.31±0.10 [a]	0.07±0.05 [b]
Formalization	0.27±0.06 [a]	0.08±0.08 [b]	0.37±0.09 [a]	0.07±0.05 [b]
Development	0.56±0.12 [a]	0.04±0.04 [b]	0.53±0.12 [a]	0.07±0.05 [b]

The score for the level of participation was 0 = none, 1 = low, 2 = average, 3 = high, 4 = very high. Means in the same row with different superscript letters are statistically different at P <0.05

2.2.2 Establishing and characterization of watershed area for integration of research, Mali

Villages in the watersheds of Koutiala and Bougouni Districts were characterized biophysically. Thirty-one years of daily climate data (1980-2010), including: rainfall, maximum and minimum temperature, solar radiation, wind speed and relative humidity was collected from Koutiala weather station located in Koutiala District (latitude 12.38N, longitude 5.47W and elevation 367masl). The data was analyzed seasonally.

As shown in Figure 29, the computed long term mean daily climatic values were: rainfall (2.3mm), maximum temperature (34.3 °C), and minimum temperature (21.7°C), solar radiation (20.2 MJ/m^2), wind speed (2.3m/s) and relative humidity (30.6%). The historical maximum rainfall recorded was 97mm (on 02/08/1998) and the average number of rainy days in a year was 193.

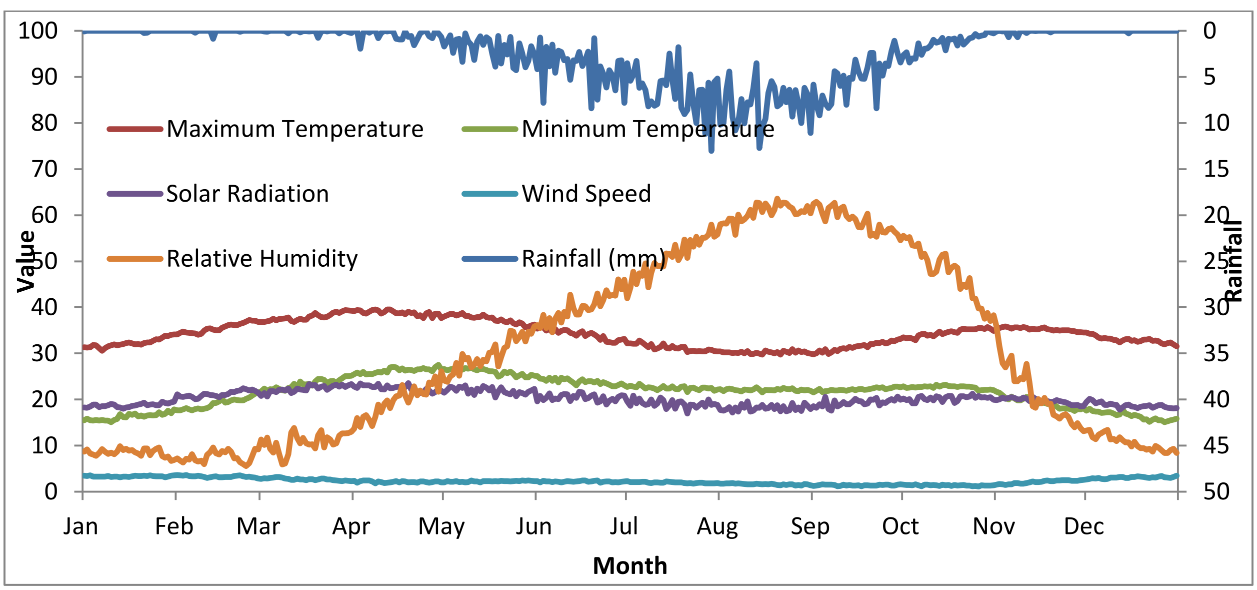


Figure 29: Seasonal variation of climatic data in Koutiala District (Data from 1980-2010)

Figure 30 shows the seasonal pattern of potential evapotranspiration computed using the Penman equation and rainfall. The computed mean annual rainfall and potential evaporation respectively were 845mm and 1752mm. This implies that the PET is more than twice the mean annual rainfall, making it difficult to have open surface water storage. The seasonal rainfall pattern rainfall starts in May, peaks in August and ends in October. Potential evaporation was higher than rainfall for 9 months of the year (October to June).

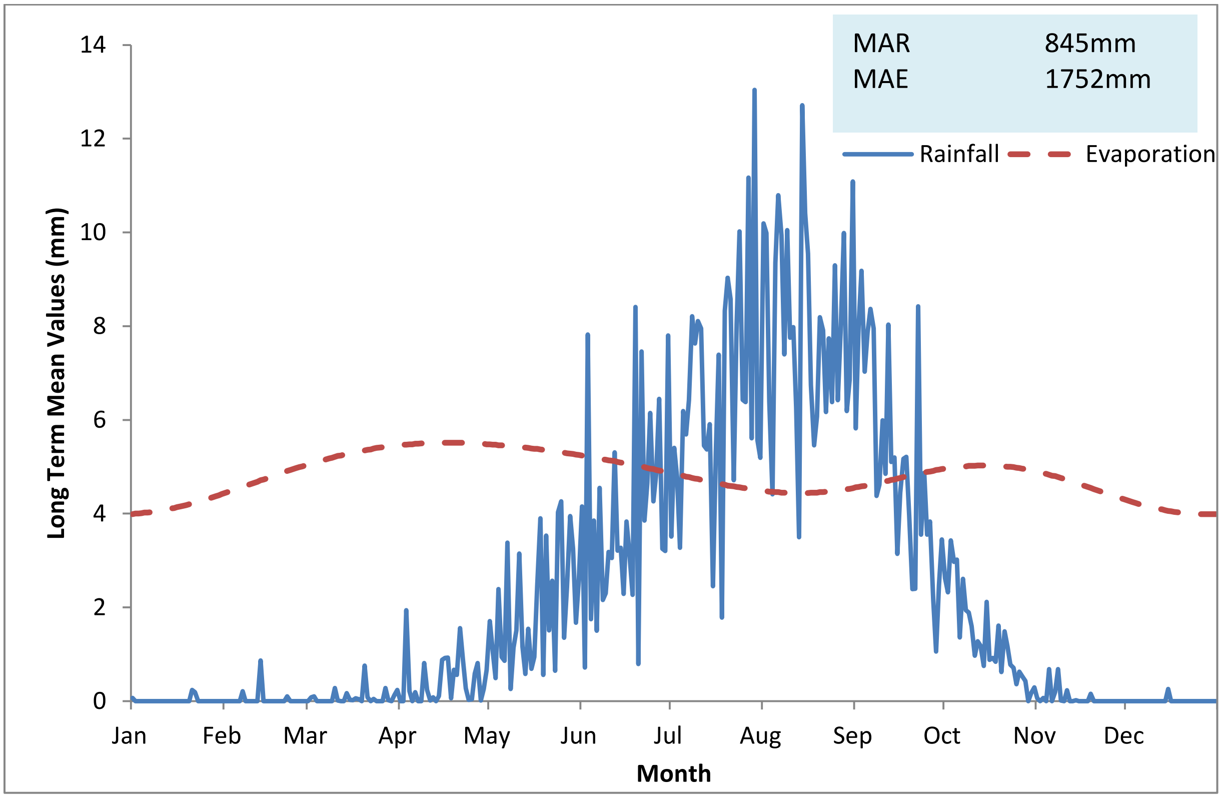


Figure 30: Seasonal rainfall and evaporation (data from 1980-2010, Koutiala weather station)

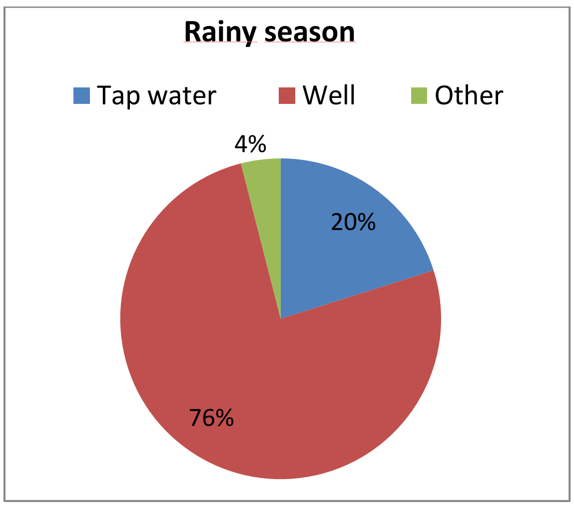
2.2.3 Water management, Mali

All shallow water wells in Dieba, Flola, Madina and Sibirila and 30% of wells in Yorobougoula were inventoried and geo-referenced.
Shallow wells were the most widely sources of water during dry and rainy seasons for domestic, livestock and irrigate water demands, accounting for 77% of water sources in the watershed villages of Bougouni/Yanfolila and Koutiala (Fig. 31). In Bougouni/Yanfolila Districts, the first well was constructed in Madina village (in 1954). Sibirila had the maximum number of constructed wells (Fig. 32).

The minimum well depth is 2.5m in Yorobougoula and the maximum depth is 34.5m in Sibirila in Bougouni/Yanfolila watershed villages (Fig. 33). In these villages majority of wells have a depth range from 6.5m to 10.5m. In Koutiala watershed villages, the minimum recorded depth of well was 2.5m in Zanzoni village and the maximum recorded depth was in 150 m in Namposela village. Majority of wells have depths in the range of 6.5m to 10.5m (Fig. 33). The diameter of analyzed wells range from 0.9m to 2m, and on average 41% of wells have diameter in the range of 1 to 1.2m.

The water level in the shallow wells during the dry season ranged from 5.5 to 13.5m. In the rainy season, the water levels in 50-79% of the wells rose to a range of 4 to 8m. The trend in Koutiala watershed villages is the same.

It was observed that the potential evapotranspiration was two times higher than the mean annual rainfall in the watershed villages due to the arid conditions. This suggests that surface water storage systems may not work properly. However water can be stored under the ground through recharging the subsurface moisture zone. Water is available at an accessible depth in both rainy and dry seasons, hence the issue of water scarcity reported by the rural communities in the watershed villages is probably associated with access. This would require introduction of appropriate water lifting systems in the area from the shallow wells.



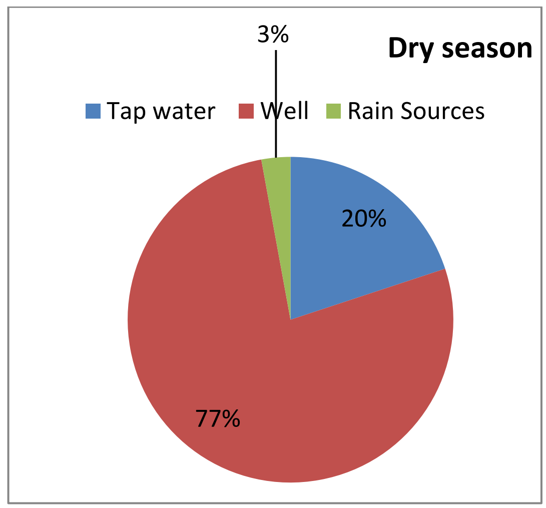
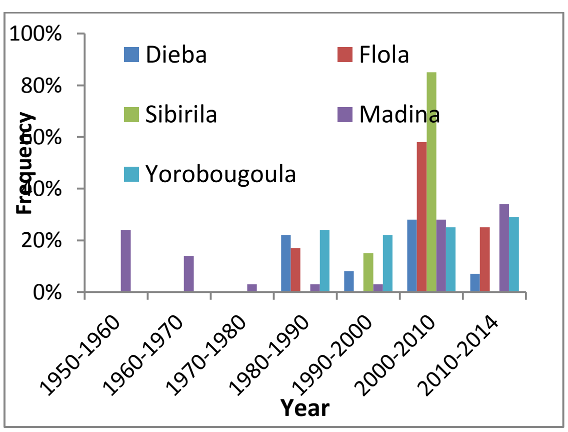


Figure 31: Sources of water during the rainy and dry seasons, Mali



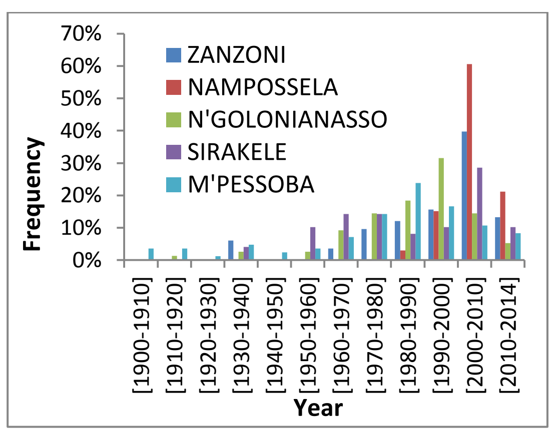


Figure 32: Construction of wells in the watershed villages, Mali

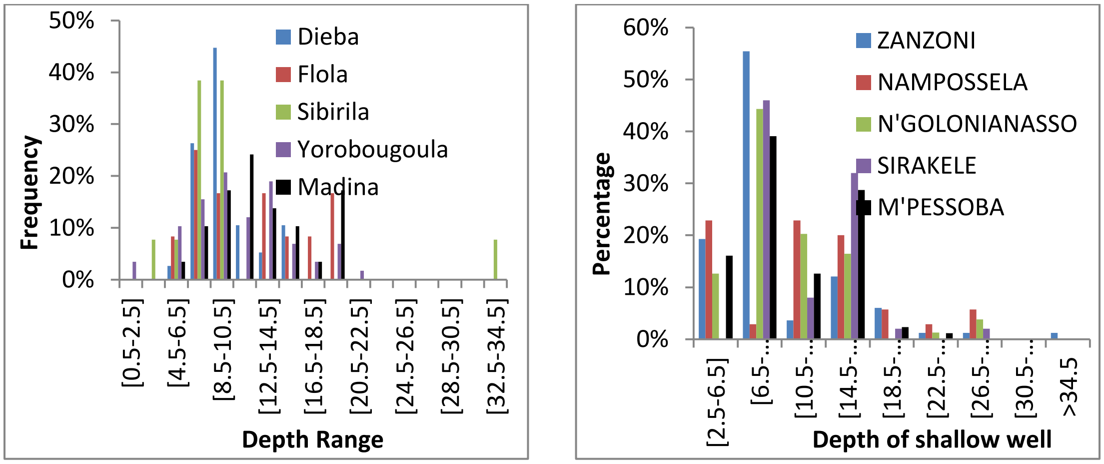


Figure 33: Depth of water in shallow well in the watershed villages, Mali

2.4 Improving nutrition, food storage, value addition and mycotoxin management

2.4.1 Reducing post-harvest losses in cowpea and maize on-farm, Ghana

Two trials involving grain maize (Trial 1) and cowpea (Trial 2) were conducted to assess the influence of method of storage and grain protection on grain quality of maize and cowpea for 12 months of storage in farmer storage units. The trials began in November 2013 to coincide with the main harvesting season.

The estimated post-harvest losses (%) of maize and cowpea after 12 months of storage in the Northern and Upper East Regions are summarized in Tables 29 and 30, respectively. Wide variation in losses was noticed between Northern and Upper East regions, with the losses being higher in the northern than the Upper East. Grains stored in PICS sacs and plastic drums recorded no or very minimal damage. Postharvest weight loss was higher in the grain maize and cowpea stored in jute sacs with or without protection across locations. There was no significant difference between Phostoxin and Actellic Super, but the two types of protection were consistently better than the control.

Table 29: Storage and protection method effects on percent losses of maize after 12 months' storage

Region	Storage method	Protection method	Community: Botingli	Gbanjong	Tibali	Tiborgnayili	Mean
Northern	Jute sack	Control	69.8	75.6	39.5	70.5	63.9
		Actellic Super	72.6	74.4	61.8	67.2	69.0
		Phostoxin	76.3	77.2	56.5	69.7	69.9
	PICS bag	Control	0	0.5	0	0.29	0.2
		Actellic Super	0.19	0.2	0.5	0.19	0.3
		Phostoxin	0	0.19	0	0.23	0.1
	Plastic drum	Control	0	0.31	0.4	0.19	0.2
		Actellic Super	0	0.3	0	0.21	0.1
		Phostoxin	0	0.3	0	0.7	0.3
		$LSD_{0.05(SxPxC)}$			4.52		
			Community: Bonia	Tekeru	Samboligo		
Upper East	Jute sack	Control	6.64	1.08	17.94		8.6
		Actellic Super	0.95	0.39	0.56		0.6
		Phostoxin	0.46	2.08	7.56		3.4
	PICS bag	Control	1.38	0.1	0.4		0.6
		Actellic Super	0.37	0.93	0.14		0.5
		Phostoxin	0.27	0.89	1.18		0.8
	Plastic drum	Control	0.07	0.31	1.7		0.7
		Actellic Super	0.37	1.2	0.56		0.7
		Phostoxin	0	0.87	7.56		2.8
		$LSD_{0.05(SxPxC)}$		ns			

Table 30: Storage and protection method effects on percent losses of cowpea after 12 months' storage

Region	Storage method	Protection method	Community: Botingli	Gbanjong	Tibali	Tiborgnayili	Mean
Northern	Jute sack	Control	72.8	78.1	60.2	72.3	70.9
		Actellic Super	74.4	74.4	52.8	76.5	69.5
		Phostoxin	72.9	57.8	71.1	68.5	67.6
	PICS bag	Control	0	5.8	2.7	1	2.4
		Actellic Super	0	11.4	0	12.1	5.9
		Phostoxin	0	7	0	10.9	4.5
	Plastic drum	Control	0	9.2	6.8	17.9	8.5
		Actellic Super	0	10.5	0	18.2	7.2
		Phostoxin	0	4.1	5.5	0	2.4
		$LSD_{0.05(SxPxC)}$			6.62		
			Community: Bonia	Tekeru	Samboligo		
Upper East	Jute sack	Control	99.9	99.9	17.7		72.5
		Actellic Supper	73.8	72.4	46.1		64.1
		Phostoxin	95	62.3	62.3		73.2
	PICS bag	Control	8.4	9.8	3.94		7.4
		Actellic Super	5.02	0.22	5.12		3.5
		Phostoxin	0.26	0.24	4.2		1.6
	Plastic drum	Control	8.3	7.3	13.2		9.6
		Actellic Super	7.6	0.25	0.37		2.7
		Phostoxin	0.26	0.26	2.62		1.0
		$LSD_{0.05(SxPxC)}$		ns			

2.4.2 Improving household nutrition, Ghana

The report on the household nutrition survey conducted at the Africa RISING intervention communities in Ghana under the leadership of the University for Development Studies was summarized into a booklet. Three papers were submitted to international refereed journals by partners in UDS and the Food Research Institute. To address one of the recommendations of the Africa RISING external review team, a workshop was organized for the Ghana and Mali nutrition teams from 14-16 January 2015 to discuss and plan joint activities.

2.4.3 Aflasafe GH01 evaluation to manage aflatoxin, Ghana

Ten districts within 3 agroecological zones in Ghana were selected for field evaluation of the aflasafe product for Ghana. A total of 60 fields comprising 30 maize and 30 groundnut fields were treated with aflasafe in the three northern regions. A total of 288 field soil samples (top 2 cm) were collected from treated and control plots prior to aflasafe application and 3 months after application in each field for laboratory analysis. Further, a total of 144 crop (72 maize and 72 groundnuts) samples were taken during harvest from treated and control plots**.** Representative sub-samples were subjected to aflatoxin analysis to examine the extent of aflatoxin contamination in each treated and control samples.

Soil samples were collected from the field prior to application of aflasafe. The samples are being analyzed to determine the community structure and population of *Aspergillus* Section Flavi in these fields prior to introduction of the aflasafe biocontrol strains. The presence of aflasafe strains in soil three months determines the ability of the strains to survive in the soil over a long period while the presence in crop samples determines the ability of the strains to move from the soil to colonize crop samples.

In maize, 100% of the maize samples treated with aflasafe have aflatoxin concentration below 20ng/g, which is the acceptable limit for the USA, whilst in the untreated fields only 84% of the samples had aflatoxin concentration below the 20ng/g. In groundnut, 100% of the groundnut samples treated with aflasafe have aflatoxin concentration below 20ng/g, which is the acceptable limit for the USA, whilst, in the untreated fields only 83% of the samples had aflatoxin concentration below the 20ng/g. The 100% compliance in the treated fields is as a result of aflasafe application.

Microbiological analysis on soil samples collected before application has since commenced to determine the community structure of *Aspergillus* section Flavi resident in soils prior to aflasafe application and their VCGs in relation to those of the aflasafe strain mixtures applied on each plot. A total of 8040 isolates (12 isolates per sample) belonging to *Aspergillus* section. Flavi has been obtained and further characterized morphologically into *A. flavus* (L-strain), *A. parasiticus*, S-morphotypes and *A. tamarii.*

Also *nit* mutants have been developed from 6355 L-atoxigenic strains obtained from the soil, maize and groundnut crop samples. Complementation of the *nit* mutants with Ghana testers is in progress to determine the presence and proportion of the released strains in the samples. So far a total of 27120 complementations have been completed. The analysis is still in progress.

3. Scaling and delivery (Research Output 3)

In Ghana, Farmers' Field Days were organized in each of the 25 communities at the end of October 2014. Participants visited the community-based Technology Parks to look at the technologies on display. The participants were then grouped into males and females, and preferences of the groups were recorded. A total of 1463 participants consisting of 664 males (45%) and 799 females (55%) participated in the community-based Farmers' Field Days in Ghana (Tab. 31). Similar field days and scaling activities were conducted in Mali.

Table 31: Male and female participants at in pre-harvest Farmers' Field Days in Africa RISING intervention communities in northern Ghana, 2014

		Field day participants			Composition (%)	
Region	Community	Male	Female	Total	Male	Female
Upper East	Bonia	51	53	104	49	51
	Gia	30	62	92	33	67
	Nyangua	32	70	102	31	69
	Tekuru	47	48	95	49	51
	Samboligo	51	60	111	46	54
	Sub-total	**211**	**293**	**504**	**42**	**58**
Northern	Duko	31	45	76	41	59
	Jana	23	11	34	68	32
	Kpallung	13	36	49	27	73
	Tibali	16	19	35	46	54
	Gbanjong	22	29	51	43	57
	Tibogunayili	19	19	38	50	50
	Tingoli	22	54	76	29	71
	Cheyohi No. 2	30	35	65	46	54
	Sub-total	**176**	**248**	**424**	**42**	**58**
Upper West	Natorduori	30	16	46	65	35
	Goriyiri	11	23	34	32	68
	Papu	20	18	38	53	47
	Goli	25	30	55	45	55
	Gyili	18	9	27	67	33
	siriyiri	16	10	26	62	38
	Guo	46	46	92	50	50
	zanko	33	25	58	57	43
	Nyagli	47	33	80	59	41
	Passe	31	48	79	39	61
	Sub-total	**277**	**258**	**535**	**52**	**48**
	Grand total	**664**	**799**	**1463**	**45**	**55**

Community-based Farmers' Field Day organized during 15-23 October, 2014

4. Capacity building and knowledge exchange

Individual and group trainings were integral parts of the project activities during the reporting period. Nineteen graduate students jointly supervised by staff of Africa RISING and national or international universities were attached to the project for their dissertation research during the reporting period (Tab. 32).

A short-course on '*Statistics and Statistical Computing Using SAS Software'* run by the IITA Biometric Unit was organized for early career scientists from Ghana during 16-20 March, 2015.

Table 32: Graduate students attached to Africa RISING West Africa during the reporting period

Student	Sex	Country	University	Degree
Mary Awuni	Female	Ghana	University for Development Studies, Ghana	MSc
Martha Agyri	Female	Ghana	KNUST, Ghana	MSc
Shaibu Mellon	Male	Ghana	University for Development Studies, Ghana	MSc
Daniel Apalibe	Male	Ghana	University for Development Studies, Ghana	MSc
Joseph Clottey	Male	Ghana	University of Ghana	MSc
Emmanuel Gyakah	Male	Ghana	University of Ghana	MSc
Mohammed Shaibu	Male	Ghana	University of Ghana	MSc
Haruna Abdulai	Male	Ghana	KNUST, Ghana	MSc
Richard Amponsah	Male	Ghana	KNUST, Ghana	MSc
Raphael Azayiga	Male	Ghana	KNUST, Ghana	PhD
Abdul R Nurudeen	Male	Ghana	KNUST, Ghana	PhD
Sarfo K Goodman	Male	Ghana	KNUST, Ghana	PhD
Solomon Konlan	Male	Ghana	University for Development Studies, Ghana	PhD
Clarisse Umutoni	Female	Mali	Cheik Anta Diop University, Dakar, Senegal	PhD
Daniel Agbetiameh	Male	Ghana	KNUST, Ghana	PhD
Mary Ollenburger	Female	Mali	Wageningen University, Netherlands	PhD
Katja Kuivanen	Female	Ghana	Wageningen University, Netherlands	MSc
Xu Youfei	Male	Mali	Wageningen University, Netherlands	MSc
Shaibu Mellon	Male	Ghana	Wageningen University, Netherlands	MSc

5.

5. Project implementation issues

The IITA commissioned reviewers were very impressed by the work carried out and the progress made towards the objectives of Africa RISING.

A few issues came out clearly in their evaluation:

i. The team considered R4D Platforms at district and community levels a major vehicle to ensure a bottom-up approach in our research thus ensuring community engagement, joint research priority setting and learning, and faster dissemination of appropriate SI technologies, while the team recognized the efforts the project had made to establish and facilitate new or strengthen existing platforms they highlighted that the process was not yet completed and the roles of the platforms were not yet fully apparent. They recommended the project to provide facilitation support to the platforms.

ii. The establishment of Community-based Technology Parks in Ghana during the previous field season for research, demonstration and training of farmers was considered to be an appropriate approach. Therefore, the team recommended that this approach should also be followed in Mali where scattered trails implemented rather independently by the project partners did not allow for integrated research and joint learning.

iii. Lack of cost-benefit analyses of the Africa RISING technologies and a general lack of gender sensitive research was also stressed. These issues are now addressed by the agricultural economist who had joined the research team only recently at the time of the review and the new gender specialist.

iv. The team noted poor communication between the Mali partners, which hinders that activities are implemented in an integrated manner.

v. The role of NARS in Africa RISING, especially SARI and Ghana and IER in Mali, should be strengthened for ownership and hence sustainability.

The full evaluation report can be downloaded here: https://cgspace.cgiar.org/handle/10568/56585

As a follow-up of the review, the Project Coordinator called for two meetings with the Mali team to discuss issues of leadership, communication, transparency in decision making, and others which were either noticed by the reviewers or brought to her attention by project members. At both meetings misunderstandings that led to misperceptions could be eliminated and solutions for current shortcomings have been identified.

6. Synergies with other USAID funded projects

6.1 Mali

Global Climate Change Adaptation (GCC)

The collaboration between the Global Climate Change Adaptation (GCC) and Africa RISING Mali projects is wide and continuous. The Mali Research Coordinator of Africa RISING is the ICRISAT Principal Investigator of the GCC. Also, the GCC has taken into consideration the comments from the mid-term evaluation of the Mali Africa RISING. Based on this, the GCC will create Technology Parks in three easy accessible project locations. Locations have been chosen based on farmers' vulnerability, exposure to and perception of climate change, and availability of the community to be the base for the capacity building on a wider territory. Further to that, staff of the two projects is working together on a daily basis. The technologies used in Africa Rising are shared with the staff of the GCC. Also, Africa RISING staff is supporting the capacity building of the GCC staff by sharing information and participating in missions.

Farmer Managed Seed Enterprises in Mali (FARMSEM)

The FARMSEM project was funded as a compliment to Africa RISING based on results from the Africa RISING year 1 quick-win activities. The first year results of trials conducted by seed producer cooperatives in Koutiala and adjacent districts in Sikasso Region with the new sorghum hybrids, generated demand for the seed and interest to engage in hybrid seed production and sales. The cooperatives also engaged in the production of seed of other crops important for the intensification of sorghum based systems, especially cowpea. The project is now active also in Mopti Region, where cooperatives focus on pearl millet and cowpea seed production During 2014, a total of 9 cooperatives in the Sikasso Region, and 13 cooperatives in Mopti Region were trained in seed marketing, production of a certified (sorghum hybrids, pearl millet and cowpea varieties), effective use of Apron Star seed treatment, financial management of cooperatives, and general management of functioning cooperatives. In addition, for all communes with a seed cooperative and rural radio stations a training program with the radio programmers was held about the new varieties and hybrids and their respective advantages. The cooperatives produced in 2014 a total of 20t of hybrid sorghum seed, 10t of sorghum variety seed, 90t of pearl millet seed (Mopti Region) and 23t of cowpea seed. Each cooperative has developed a marketing strategy for their seeds; orders for seed have started to come in and may surpass availability. Thus this project is directly contributing to the up scaling of production technologies identified by Africa RISING project activities in Mali. This project in addition has facilitated the rapid start-up of the larger technology dissemination grant also funded by USAID-Mali, ARDT_SMS.

Africa RISING's large-scale diffusion of technologies for sorghum and millet systems (ARDT_SMS)

The project aims at disseminating sorghum and millet technologies developed and validated by Africa RISING and FARMSEM. The Coordinator of Africa RISING West Africa will be a member of the Steering Committee of this project.

Summary of activities and achievements:

i. **Establishment of Farmers Field Schools (FFS) in Mopti and Sikasso Regions:** All ToT plots for FFS have been harvested and threshed in the 34 communes (24 communes in Mopti and 10 in Sikasso Regions). From a survey carried out by CRS among leader producers who are participating in the FFS activities, it has been noticed that the trainers and producers appreciated integrated Striga and soil fertility management techniques (ISMSF) the most because they resulted in the highest grain yield (millet and cowpeas) and the economic gain compensates for the financial investment and physical effort. The fertilizer rate appreciated by farmers is 1/1g micro-dose (same amount of fertilizer and seeds applied in the planting hole) applied at the sowing time as it is less costly because the fertilizer and seeds are applied at the same time. In terms of improved millet varieties, Torognou is favored by producers in all of the targeted districts in the Mopti Region, because it is early maturing, highly productive, and has large grains. In the Sikasso District, 100% of the covered communes preferred the Soumalemba sorghum variety, while in Koutiala District, all collaborating communes preferred Pablo and Fadda sorghum varieties because of their high yields and their tolerance to drought. For cowpeas, producers preferred Korobalen variety because it has the highest yield and it is early maturing.

ii. Establishment of several plots for the demonstration of sorghum hybrid seed production

iii. **Culinary tests:** According to the culinary tests' results, Pablo variety (sorghum) is strongly preferred by farmers in Sikasso Region.

iv. **Farmers' study tours:** Three study tours for exchanging experiences were organized around hybrid seed production fields of sorghum and demonstrations plots located at Faragouaran, Konio, Oure and CAA Samanko. These visits have combined more than 659 producers and students of which 190 were women.

v. **Media activities:** A documentary on the production and use of sorghum hybrid seed was produced and broadcast by national media (TV and radio stations). Also, an audio CD was produced with local radio stations in Bougouni District, Sikasso Region (Banimonotié and Kafokan).

vi. **Staff recruitment:** The recruitments mentioned in the previous report are still in progress. The filling of the communication and agronomist positions is subject to availability of funds in other projects with who the positions will be shared.

vii. **Establishment of Project Steering Committee:** The Steering Committee has not yet been formed by the end of the reporting period.

Small-scale Mechanization Consortium

Africa RISING WA participated in the development of a proposal led by Georgia Institute of Technology for a small-scale mechanization consortium under the Sustainable Intensification Innovation Lab. This Consortium has Mali as one of the target countries.

6.2 Ghana

ADVANCE II

The two parties have agreed to collaborate in the following areas:

- Multi-locational evaluation of the effects of inoculation and associated agronomic practices on soybean grain yield
- Cowpea as a cover crop for integrated soil fertility management.

An MOU between ACDI/VOCA and IITA will be signed to formalize the collaboration.

Reduction of Postharvest Losses Innovation Lab

Africa RISING in Ghana and the Innovation lab had several meetings to explore areas of common interest and mutual benefit. A MoU is under development to establish the following joint activities:

- Exchange of scientific information and develop specific cooperative programs and projects
- Linking IITA and KSU scientists
- Annual consultative meetings and personnel visits between both parties
- Exchange of research materials, publications and other materials of common interest
- Inclusion of results of collaborative research, either in full or in summary, in either party's reports
- Pilot testing of various storage technologies
- Pilot testing of PHL-IL Ghana low cost moisture meter
- Testing of ZeroFly® Storage Bags from Vestergaard Frandsen, Switzerland
- Improvement of the design and drying time of locally built solar dryers
- Collection of baseline aflatoxin data
- Conducting of Aflasafe related experiments and trials
- Training of farmers and stakeholders in grain storage
- Training of MSc students in entomology

Small-Scale Irrigation Innovation Lab (SSIIL)

IWMI, the implementing partner of SSIIL in West Africa and Africa RISING partner in Ghana, identified one out of the 25 Africa RISING intervention communities matching the selection criteria of the SSIIL intervention sites. It was agreed that joint activities would be carried out at Duko in Northern Region. Some of SSIIL's technologies will be tested by IWMI under Africa RISING and hence included in the work plan for the next field season. Agreement has also been achieved on sharing data of mutual interest and design further activates to generate data for validation of the models developed by Texas A&M.

Agricultural Technology Transfer Project (ATT)

Several discussions were held with ATT management but no concrete collaboration has been elaborated yet.

7. Publications

Glover-Amengor M, Agbemafle I, Larmkie L, Hagan, Mboom F, Gamor G, Larbi A and Hoeschle-Zeledon I. 2014. Chronic malnutrition in children 0-59 months in selected communities in northern Ghana: a cross-sectional study. Archives of Public Health (under review)

Kuivanen K, Michalscheck M, Descheemaeker K, Adjei-Nsiah S, Bedi-Mellon S, Groot J and Alvarez S. 2015. A comparison of statistical and participatory clustering of smallholder farming systems – a case study in Northern Ghana. Journal of Rural Studies (submitted)

Saaka M, Larbi A and Hoeschle-Zeledon I. 2014. Factors contributing to positive deviance in the growth of children aged 6-36 month in rural Northern Ghana. Jacobs Journal of Food and Nutrition (accepted)

Saaka M, Larbi A, Mutaru S and Hoeschle-Zeledon I. 2015. Magnitude and factors associated with appropriate complementary feeding among children 6-23 months in northern Ghana. Paediatrics and International Child Health (submitted)

Sugri I, Osiru M, Larbi A, Buah S, Nutsugah S, Asieku Y and Lamini S. 2015. Aflatoxin management in Ghana: Current prevalence and priority strategies in maize (Zea mays L.). Journal of Stored Products and Post-Harvest Research (under review)

Descheemaeker K, Alvarez S, Paas W, and Groot J. Hypothesis-based typologies for capturing diversity (poster, Integrated Systems Conference, March 2015), http://www.slideshare.net/humidtropics/descheemaeker-typologies

Kuivanen, K et al., A comparison of farm typology approaches in northern Ghana (poster, Integrated Systems Conference, March 2015), http://africa-rising.wikispaces.com/file/view/Poster.Kuivanen.pdf/550042600/Poster.Kuivanen.pdf

8. Annexes

Annex 1: Summary of the different types of existing local conventions on natural resources management in the study sites

District	Interviewed Group	Name of the local convention	Written/ Oral	Date of establishment	Natural resources addressed and key conventions issues	Coverage
Koutiala	Local administrative authority	SIWAA	Written	May 1997 (formalization date)	Land, common pasture, forest, transhumance, conflict management, bush fire, hunting.	Inter-District
	Sirakéle Community	CPC	Oral	Since the creation of the village	Forest - protection of sacred trees and community forest, regulation of harvesting of tree products by indigenes and foreigners, rules for harvesting Néré and shea butter, periods for harvesting wild fruits.	Village
		CGC	Oral	Since the creation of the village	Conflict over land, pasture, transhumance - processes for mediation and resolution of conflict among the indigenes and foreigners over land, water and grazing, fines and sanctions for the offenders, permission for grazing crop residues after harvesting whether for transhumant herders or community members, conditions of accepting transhumant herders in the community, duration of stay of transhumant herders in the territory, period for entering grazing lands, protection of livestock corridors.	Village
		CGPE	Written	2007	Water – rule of access to the watering point, management of watering point and charges for use by foreigners, processes for conflict	Village

District	Interviewed Group	Name of the local convention	Written/ Oral	Date of establishment	Natural resources addressed and key conventions issues	Coverage
					mediate over watering point	
	Namposséla Community	SIWAA	Written	1989	Land - rules of land ownership, rules of access to community land and acquisition by foreigners, protection of sacred land, organization and clearing modalities. Communal pastures – rules of access and use, management of communal pastures, protection from cropping. Forest – rules for cutting and sale of wood, quotas for harvesting forest resources for use as timber and fire wood. Transhumance - Demarcation of livestock routes in the community, arrival date of transhumant herders and duration of stay in the community. Conflict management – processes for mediation and resolution of conflict among the indigenes and foreigners over land, water and grazing. Bush fire - agenda for controlled bush fire and prohibition of uncontrolled bush fire, fine for uncontrolled bush fire Hunting - protection of some wildlife species, precision about species that could be hunted, date for community group hunting.	Inter-District
		KOMO	Oral	Since the creation of the village	Fishing: Protection of fish species, restriction of fishing in certain period of the year, fixing of the period of fishing by community leaders and communication to community members	Village

District	Interviewed Group	Name of the local convention	Written/ Oral	Date of establishment	Natural resources addressed and key conventions issues	Coverage
		CAT	Oral	Since the creation of the village	Land use and management - land tenure and security, condition of access to land by foreigners, and transfer of land among the community members	Inter-Village
	Zanzoni Community	CGT	Oral	Since the creation of the village	Transhumance – protection of livestock routes in the community, conditions for receiving transhumant herders in the village territory, arrival date and duration of stay in the community, resolution of conflict between herders and the community members, permission to graze crop field by the transhumant herds	Village
		CGC	Oral	Since the creation of the village	Conflict over land use, communal pasture and water - processes for mediation and resolution of conflict among the indigenes and foreigners over land, water and grazing; fines for the offenders and compensation for the victims in case of damage to crops	Village
		CTT	Oral	Since the creation of the village	Land use and management - land tenure and security, condition of access to land by foreigners, and transfer of land among the community members	Village
		CGF	Oral	2003	Forest - conditions of cutting and sale of fuelwood, rules and roles for monitoring of community forest	Inter-district
Bougouni	Local administrative authority	CGRN	Written	November 2010	Land, common pasture, forestry, water, conflict, bush fire, wild resources (fauna and flora, wild fruit)	Inter-district
		CPC	Oral	Since the creation of the village	Wild fruit harvest	Inter-village
		CAP	Oral	2006	Land use and forest - land tenure and	Inter-Village

District	Interviewed Group	Name of the local convention	Written/ Oral	Date of establishment	Natural resources addressed and key conventions issues	Coverage
					security, condition of access to land by foreigners, protection of sacred forest, rules for cutting of trees in community forest and protection of certain tree species	
	Sibilira Community	CGF	Oral	1993	Forest – rules for cutting trees for fuel-wood and prohibition of sale of fuel-wood	Village
		CGPC	Oral	2011	Pasture - access and use of grazing areas, prohibition of cropping on grazing land conflict management - processes of conflict resolution, precision of sanctions.	Village
	Yorobougoula Community	CGRN	Written	November 2010	Land, pasture, forest – modalities for exploitation of forest resources, protection of pasture for animal, harvesting of forest product, rules for sale of woods, conditions of harvesting wild fruits and fixing of harvesting period of wild fruits. Water, conflict management, bush fire – access to watering points, processes for conflict mediation, rules for controlled bush fire, sanctions for uncontrolled bush fire. Hunting - management modalities: hunting license, fixation of hunting period, and rules for ritual hunting)	Inter-District
		CGF	Oral	2007	Forest - management of protected area. hunting, bush fire – rules for controlled bush fire	Inter-Villager
	Diéba Community	CGF	Oral	Since colonial period	Forest - conditions for cutting of fuel wood	Village
		CGP	Oral	In the 1960s	Pasture - access and use of grazing area	Village

District	Interviewed Group	Name of the local convention	Written/ Oral	Date of establishment	Natural resources addressed and key conventions issues	Coverage
		CGM	Oral	Since the creation of the village	Ponds with various fish species - management system, fixing period for fishing	Village

Acronyms: SIWAA (SIWAA Convention); CGPE: Convention on management of watering points, CGT: Convention on land allocation - land tenure security, CPC: Convention on the regulation of wild fruits, CGC: Convention on conflicts management, KO-MO Convention on collective fishing, CGT: Convention on transhumance management, CTT: Convention on land tenure, CGF: Convention on forestry management, CGRN: Convention on natural resource management, CAP: Convention on Protected Areas, CGPC: Convention on rangeland and conflicts management, CGP: Convention on rangeland management, CGM: Convention on standing pools management.