

Research Program West and Central Africa

Highlights
2016

Research Program - West and Central Africa – Action Highlights 2016

This program, in partnership with research and development institutions in West and Central Africa, develops and promotes technologies for sustainably enhancing agricultural productivity with a focus on sorghum, pearl millet and groundnut as well as crop-livestock integration under a changing climate. The strategic research within this program targets a range of interventions that span agro-ecological zones to benefit communities and villages, increase the resilience of smallholder agriculture and exploit market demand opportunities.



Reducing malnutrition

- Biofortified crops
 - 2 high-Fe pearl millet cultivars identified for WCA
 - 15 high-Fe and Zn sorghum varieties identified for adaptation in Nigeria
- Standardized grain quality phenotyping in WCA for Fe and Zn through an X-ray fluorescence facility for pearl millet
- 600 farmers (40% women) participated in culinary tests on different varieties of sorghum in 23 villages in Mali
- Poultry feed and broilers costs reduced significantly using sorghum without tannin as an energy source
- Identified nutritionally dense groundnut genotypes, namely ICGV IS 07833, ICGV IS 13980, ICGV SM 08553 and ICGV 5891 with high protein (30%–32%), Zn (46–51 ppm) and Fe (23–34 ppm) content. High oil content (53%–54%) was identified in genotypes ICGV IS 11060, SAMNUT 23, ICGV 00064, ICGV 01276, ICGV IS 07827 and Kampala through evaluation of a large number of groundnut genotypes.



Overcoming poverty and hunger

- Dry season groundnut production in Bauchi state, Nigeria (US\$ cost and return analysis)
 - \$489 cost of production per hectare
 - \$2,679 net return per hectare
- Enhanced seed availability (about 944 tons of different classes of seeds as compared to 300 t per year in the last two years) through the use of small seed packets and dry-season seed production in intervention states under the Tropical Legumes III initiative, and through up-scaling projects in Nigeria leading to increased adoption of improved groundnut varieties, namely SAMNUT 24, SAMNUT 25 and SAMNUT 26.
- Bio-reclaimed Degraded Land (BDL) in Niger
 - \$26 increase in income for participating women
 - 50% increase over those of non-BDL participantsImproved household consumption of nutrient-rich, leafy vegetables, alongside the household income of participating women increasing by FCFA14,345 (\$26), a 50% increase over non-BDL participants.

Preventing environmental degradation

- 20 lead farmers were trained in Bio-reclamation of Degraded Lands (BDL) in Kebbi State, Nigeria. These farmers, in turn, trained their group members to establish BDL farms in their localities
- 10,770 women gained access to land and increased their income through the BDL project, whereby 241 ha of degraded land were converted into productive land in Niger.





Improving farmers' resilience to climate change

- **24,000 smallholder farmers** in five States in Nigeria **increased grain yield from 5% to 46%** through a science-backed climate smart solution. This included dissemination of climate-resilient sorghum varieties (drought- and Striga-tolerant, early maturing and market-preferred with higher nutritive value) and strategic application of organic and inorganic fertilizers
- **2 multi-purpose sorghum varieties** with stay-green traits, drought tolerance, high grain yield and high stover quality are available for human consumption and livestock feed in Mali
- **> 6,000 Ghanaian farmers** made changes in their crop/livestock/other livelihood enterprises following **training** of extension and NGO staff in the **Participatory Integrated Climate Services for Agriculture (PICSA)** approach. The initiative triggered demand from 160+ communities in Mali, Burkina Faso and Senegal, representing a rural population of over 100,000.



Empowering women farmers

- **258 women** were trained in **seed production** techniques in Mali
- Access to **milling machines** for agri-food product processing under self-management of the women's group *Benkola* (Solidarity) improved income-generating activity for women, allowed them to satisfy certain household food needs and strengthened their organizational and leadership capacity. The *Benkola* group, created in 2001 in rural areas of Wakoro, the Dioila circle and Sikasso region has 75 members. With two milling machines (each costing FCFA 2,285,000/ around \$4200), their gross average annual revenue is about FCFA 800,000/\$1500.



11 SUSTAINABLE CITIES AND COMMUNITIES



Building sustainable communities

- **25,536** individuals (12,316 men and 13,220 women) received ICRISAT-supported, short-term improved **groundnut production management training**
- **250 high-level policy actors** were sensitized on the outcomes of **climate change** scenarios in Mali, Ghana and Senegal through participatory scenario planning to stimulate policy influences and social transformation.

Message from the **Director, West and Central Africa**

This report relates impact stories achieved through demand-driven research and innovation for development. ICRISAT believes all people have a right to nutritious food and a better livelihood. In 2016, we celebrated 45 years of scientific research and groundbreaking innovations towards achieving our mission of a prosperous, food-secure and resilient dryland tropics in Asia and sub-Saharan Africa.

Thanks are due to the farmers who kept their faith in our science and solutions alive; our partners who believed that collective action and synergies could multiply benefits for all; and our donors who shared our vision and believed in us. Partnering with you all enabled us to scale impact and improve the livelihoods of the smallholder farmers in this region.

We remain committed to engaging more with policy makers to bring about equitable and sustainable solutions for smallholder farmers in the West and Central Africa region.”

Happy reading

Ramadjita Tabo



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Cover Credit

Agathe Diama, ICRISAT

Nutritious Pearl Millet (*Pennisetum glaucum*) Varieties Enable West-Central Africa to Combat Fe-induced Anemia

Biofortified pearl millet varieties are ready to combat the iron deficiency-induced anemia in nearly half of African women and two-thirds of under-fives.

Thanks to a project funded at ICRISAT-Niger by the HarvestPlus Challenge Program of the CGIAR, three pearl millet varieties with moderately high-Fe content (up to 50 ppm) of have been identified for seed multiplication by NARS (National Agricultural Research System) partners in Niger, Nigeria, Mali, Burkina Faso, Ghana and Senegal.

The World Health Organization (WHO) has stated that Africa and South East Asia are the top two regions lacking progress on nutritional security as two-thirds of children under five and nearly 50% of women are becoming anemic. Although the oldest millet used by ancestors in sub-Saharan Africa, pearl millet is very high in Fe (50–55 ppm) and Zn (45–50 ppm) contents in grain, along with high fiber content (1.2 g/100 g), which makes it healthier than other millets. It is a major source of dietary energy for more than 90 million people in sub-Saharan environments and the cheapest source of dietary Fe and Zn.

ICRISAT's center in Niamey, Niger set out to combat malnutrition issues through the biofortification project on 'Genetically enhanced pearl millet with high grain iron density for improved human nutrition in West and Central Africa'; the principal objective being to breed pearl millet for high Fe and Zn grain content together with high yield through improved plant breeding techniques.

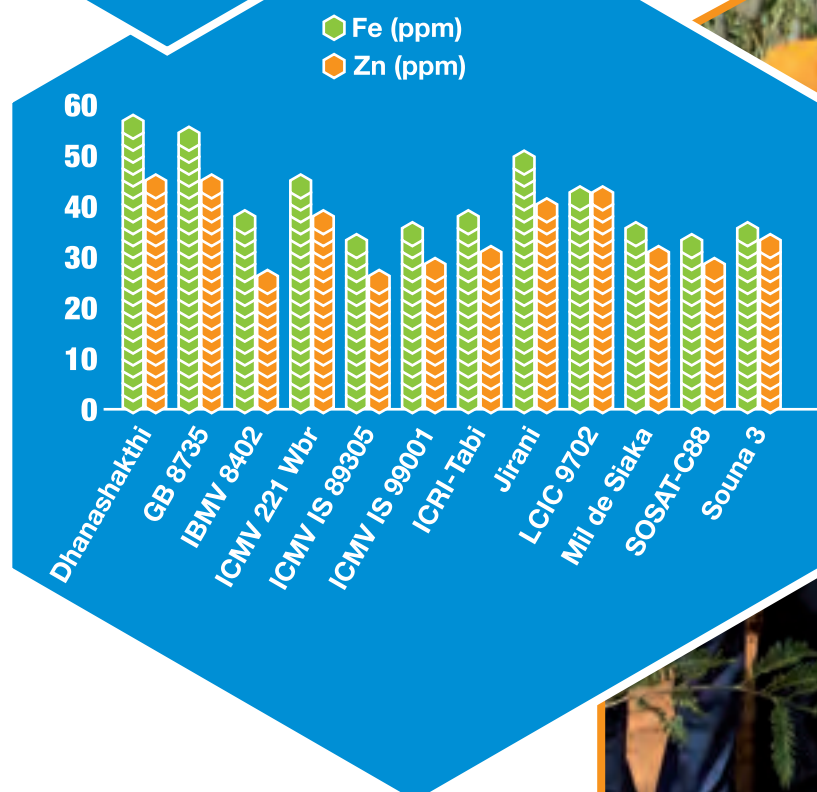
Thirty pearl millet varieties were tested along with local landrace and improved high-yielding checks in a randomized block design with

three replications in the rainy seasons of 2015 and 2016. Trials were conducted in Niger, Mali, Burkina Faso, Senegal, Nigeria and Ghana. Open pollinated grain samples were collected in each test entry plot at all locations and screened at ICRISAT-Niamey for grain Fe and Zn density using the non-destructive energy dispersive X-ray fluorescence (EDXRF) method of spectroscopy.

Trial plots contained two 4.8-metre rows per entry, spaced 80 cm apart with each row consisting of seven hills at 80-cm intervals. Multilocation testing was conducted under recommended soil fertility management in six countries. Samples of about 20 g of grain from open pollinated varieties (OPVs) were collected from representative plants in each plot at harvest at all testing locations for estimation of Fe and Zn using EDXRF. Selected entries from these samples are yet to be analyzed using the inductively coupled plasma (ICP) method of mass spectrometry. Selected released and popular high-yielding OPVs will be re-evaluated for Fe and Zn density in the 2017 rainy season. High yielding and high-Fe OPVs will be identified for promotion to next-stage testing, possible release and adoption.

Figure 1

Fe and Zn density in popular open pollinated varieties of pearl millet in WCA.



In Niger, Dhanashakti was found to be the cultivar with the highest Fe (57 ppm) content, followed by GB 8735 and Jirani. In Mali, Burkina Faso and Senegal, Dhanashakti and GB 8735 were highest cultivars in Fe with 54-55 ppm, while ICMV 221 Wbr had moderate Fe (45 ppm). In Ghana, highest Fe density was 56 ppm in Dhanashakti, followed by GB 8735 and ICMV 221 Wbr. In Nigeria, Dhanashakti had an Fe density of 52 ppm and 37 ppm Zn, while GB 8735 had 50 ppm Fe and 27 ppm Zn. Despite some degree of genotype × environment interaction, mineral traits are generally stable across environments. Results showed that Dhanashakti is promising for iron in most of the tested countries, thus promotion of this variety along with a local high-Fe variety is strongly required.

Selection of progenies having high Fe and Zn with high yield in S₁ and S₂ progenies from Dhanashakti, GB 8735, ICMV 221 Wbr and SOSAT-C88 for creating higher Fe versions with resistance to downy mildew is in progress.

**** This work has been supported by the HarvestPlus Challenge Program and was undertaken as part of the CGIAR research program on A4NH**

Five hundred WCA germplasm accessions are being tested for genetic diversity and agronomic adaptability to identify newer sources of Fe and Zn. Efforts are also underway in WCA regions to test high Fe pearl millet hybrids (ICMH 1201 and ICMH 1301), which have 40% higher yield than local checks, and high Fe composites such as ICMP 1401 to gain the advantage of heterosis for yield combined with high Fe and Zn content in grains.

The high performance of pearl millet varieties such as Dhanashakti, GB 8735, Jirani and, ICMV 221 Wbr that were found to be high-Fe cultivars (up to 56 ppm) across the multilocation trials in WCA means these cultivars will be proposed as high-Fe cultivars for seed production with NARS partners in Niger, Nigeria, Mali, Burkina Faso, Ghana and Senegal.


Using this biofortification platform, strengthening of the WCA millet program is in progress in terms of variety and hybrid technology. 



Photo 1

Agronomic performance of Dhanashakti at ISC-Sadore.

Credit: Prakash

Gangashetty, ICRISAT



80
70
60
50
40
30
20
10
0

Photo 2

Farmers appreciating multipurpose sweet sorghum in the field, Koulikoro, Mali.

Credit: Baloua Nebie, ICRISAT

First Multipurpose Sweet Sorghum Varieties Released in West Africa for Crop and Livestock Integration

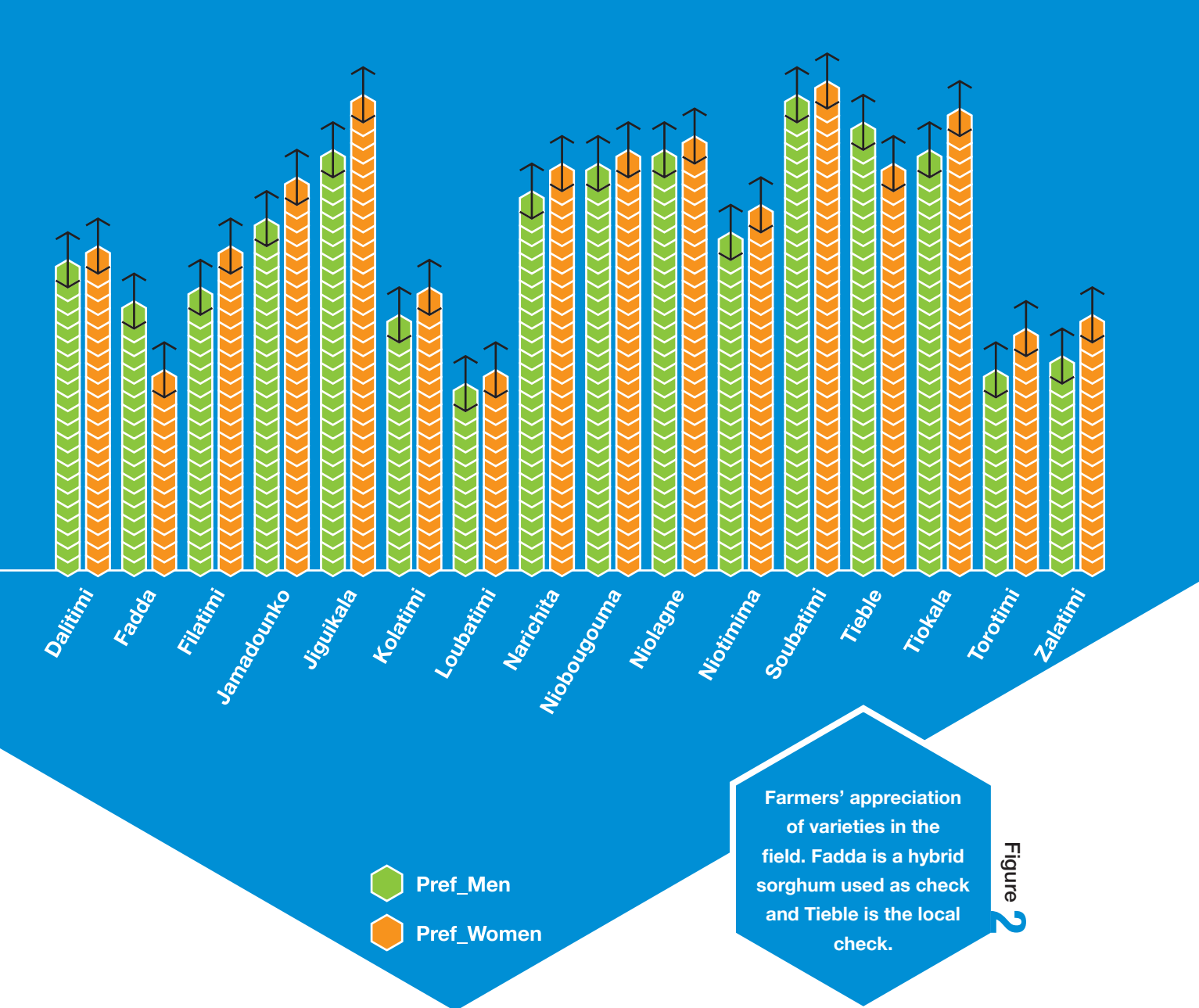
A tasty treat for man and beast is being made even sweeter for all consumers thanks to a breeding program at ICRISAT-Mali.

And the latest improved varieties of sweet sorghum can be used to supply juice for syrup, bioethanol and beer production as well as being enjoyed in more traditional grain forms by growers and as fodder by their livestock.

Sorghum, occupying more than 27 million ha in West Africa along with pearl millet, is principally grown for its grain used for human consumption, but the stover is increasingly used in livestock feeding. Sweet sorghum constitutes a minor crop, grown in general around houses with the juicy and sweet stem either sold or self consumed by the growers as treats. Livestock enjoy the stover for its sweetness and high digestibility.

As a result, ICRISAT-Mali started a sweet sorghum breeding program to develop varieties combining higher grain yield as well as greater stover yields and qualities while maintaining juicy and sweet stems. The first set of these lines was evaluated using a farmer participatory approach and the farmers' preferred varieties registered in the West African regional catalogue in 2016, and released in Mali.

Sweet sorghum landraces were obtained from the ICRISAT Genebank for evaluation and used in the breeding program. Some of these varieties (ICSR 93034, SPV 422 and IS23541) and Malian sweet sorghum landraces (F60, F221) were crossed to grain sorghum to develop multipurpose sweet sorghum. The Genebank's sweet sorghum and the new sweet sorghum developed were then tested on-station



and two years successively on-farm in five agro-ecological zones in Mali, for their agronomic performance and their adaptation to farmers' conditions and needs.

In 2015 and 2016, around 560 farmers appreciated varieties and voted in the field for each variety with white, yellow and red cards. Farmers' preference was then calculated as follows:

Farmers' appreciation was mainly based on number of grains per panicle/grain yield, variety duration, number of green leaves, etc. Photo 2 shows farmers appreciating/voting for new varieties in their field.

$$Preference (\%) = \frac{[(NWC \times 1)] + [(NYC \times 0.5)] + [(NRC \times 0)]}{[NWC + NYC + NRC]} \times 100$$

Where,

NWC: number of white cards
 NYC: number of yellow cards
 NRC: number of red cards

Achievements

Six Ethiopian sweet sorghum from the ICRISAT Genebank were identified in 2010–2012 thanks to farmers' assessments to be mainly used for human consumption, livestock feeding and bioethanol production through Mali Biocarburant SA, which is also producing biodiesel from *Jatropha curcas* plants. Some of these varieties included in the trials in 2015 and 2016 were again appreciated by 67% of farmers (*Tiokala* and *Jigikala*) (Figure 2). *Zalatimi* was less appreciated because of its red grain but this colour is well appreciated in the zones where sorghum beer is made.

Among the new multipurpose sweet sorghum varieties developed using grain sorghum and sweet sorghum landraces from ICRISAT's Genebank, *Soubatimi* was the most preferred by farmers (75%) because of its high grain yield (3 tons on-station and 2 tons on-farm) and its 'stay-green' trait. This variety was the most preferred both by men and women across all zones (Koutiala, Beleko, Dioila, Koulikoro and Kita). *Jigikala*, the second most appreciated variety, attracted 67% of farmers, almost the same as the local check *Tieble* (66%). *Loubatimi* recorded

the lowest appreciation in terms of agronomic performance but was identified for its grain quality.

Table 1 presents some traits and performances of the first multipurpose sweet sorghum varieties released in Mali, in the 800-1000 mm rainfall zone.

Both new varieties, *Soubatimi* and *Loubatimi*, were registered in the West African seed catalogue; breeder and foundation seeds were produced on station in 2016 (Photo 3). At least 10 ha of certified seed production by farmers are projected for the 2017 rainy season.

Varieties	Pedigree	Specific trait (Brix = sugar concentration in the juice)	Grain yield on station (t/ha)	Other traits
Jigikala	IS23562	Brix ≥ 15%	2	Juicy, stay-green
Kala wassa	IS23555	Brix ≥ 15%	2	Juicy, stay-green
Tiokala	IS23525	Brix ≥ 15%	2	Juicy, stay-green
Pitikala	IS23541	Brix ≥ 15%	2.4	Juicy, stay-green
Siaroukala	ICSR 93034	Brix ≥ 13%	2	Juicy, stay-green
Zalatimi	IS23519	Brix ≥ 16%	2.5	Juicy, stay-green
Loubatimi	F ₂ ((F ₃ SPV 422/Lata)/TIEBLE)-1/3-3	Brix = 16%	2	Juicy, stay-green, <i>Striga</i> resistant
Soubatimi	BCF ₂ ((F ₃ Soumba/ ICSR 93034)/Soumba)-1-1/6-1	Brix = 16%	3	Juicy, stay-green

Acknowledgments

We acknowledge farmers from Beleko, Dioila, Kita, Koulikoro, Koutiala and their respective cooperatives/unions, which conducted these trials. We also acknowledge the McKnight Foundation for the financial support through the projects: "Dual-Purpose Sorghum and Cowpeas" and "Seed systems III".

The first set of eight multipurpose sweet sorghums was registered in the regional seed catalogue. Breeder seed and foundation seed of these varieties are available for sharing with breeding programs, farmers' seed cooperatives and seed companies. Ongoing efforts set out to diversify the sweet sorghum pool, including hybrids and varieties with high micronutrient content in the grain and in the syrup made from the stem juice. 🍯

Table 1

Characteristics of multipurpose sweet sorghum varieties registered in the West African seed catalogue in 2016.



Photo 3

Soubatimi foundation seed production in off-season.

ICRISAT

Credit: Baloua Nebbe

Mobile Phone Climate Information Services Strengthen Smallholder Resilience to Climate Change in Mali

Farmer decision making for their fields has been boosted by the introduction of daily weather forecasts and technical advice to mobile telephones in selected rural areas in Mali.

The systems being tried out by ICRISAT and NGO partners have still to develop to overcome the illiteracy barrier for many potential users but early results from testing, including training on reading SMS messages, are showing that action based on received forecasts can go as high as 95% in some districts around Mopti.

The current systems for broadcasting climate information and rural area development support are mainly under the authority of the state, but the general nature of the climate information and technical messaging is poorly adapted to the specific conditions of communities. Recent technology developments and the liberalization of the telecom sector have favored the emergence of private telephone companies that are increasingly interested in the use of mobile telephony for dissemination of climate information and also for providing support services and advice either for free or on payment.

The project activity aims to assess the effectiveness of using mobile phones for disseminating daily rainfall forecasts and also as a tool for providing technical advice in order to facilitate or guide related decision-making in daily activities for strengthening communities' adaptive capacity to climate variability. Two mobile telephone communication systems developed by the call company Orange Mali were used: (i) the *Sandji* program for disseminating daily and localized rainfall forecasts through sending and receiving of text messages, and (ii) the *Sènèkèla* platform for the provision of agricultural advisories through exchange with an agro-advisory service.

Testing of these programs was carried out with the network of Community Mobilization Officers (AMC) in 60 villages supervised by the NGO AMASSA Afrique verte. A monitoring group for each program (*Sandji* and *Sènèkèla*) with 10 to 15 farmers was set up in each village. With the support of the project on Strengthening community initiatives for resilience to climate extremes (RIC4REC), all farmers in the groups have subscribed to the program and trained on reading SMS messages, filling scorecards and related benefits of having forecasts for decision-making.

Month	District
August	Bankass
	Douentza
	Koro
	Mopti
	Youwarou
	Total % forecast
September	Bankass
	Douentza
	Koro
	Mopti
	Youwarou
	Total % forecast
October	Bankass
	Douentza
	Koro
	Mopti
	Youwarou
	Total % forecast
Total % of forecasts for period of study	



Daily forecast effectiveness

Analysis of 39,595 Sandji SMS received by farmers for the daily rainfall forecast in six districts of Mopti indicated that 75% of rain or no rain forecasts proved in line with the real conditions (Table 2). The highest percentage of compliance between forecasting and reality was obtained at Douentza with 86%, 90% and 95% in August, September and October respectively. In contrast, the lowest percentage of compliance was observed in the Youwarou circle with 53% and 62%, for the months of August and September respectively.



Effective forecast (%)	Non-effective forecast (%)	Number of SMS	Effective forecast of rain (%)	Effective forecast of no rain (%)	Non-effective forecast of rain (%)	Non-effective forecast of no rain (%)
68.43	31.57	3865	38.91	29.52	22.15	9.42
85.64	14.36	932	34.73	50.91	5.68	8.68
70.29	29.71	3029	38.79	31.50	21.56	8.15
73.77	26.23	2714	35.67	38.10	16.80	9.43
53.20	46.80	1810	12.32	40.88	42.10	4.70
70.27	29.73	12,350	32.08	38.18	21.66	8.08
66.28	33.72	5299	23.22	43.06	27.99	5.74
90.29	9.71	1834	16.25	74.05	6.92	2.78
65.78	34.22	4263	16.63	49.14	29.16	5.07
77.15	22.85	2407	20.11	57.04	14.50	8.35
62.17	37.83	2670	8.05	54.12	34.87	2.96
72.33	27.67	16,473	16.85	55.48	22.69	4.98
78.41	21.59	4636	7.25	71.16	16.98	4.62
94.68	5.32	620	10.16	84.52	3.87	1.45
81.82	18.18	2613	9.11	72.71	13.09	5.09
82.45	17.55	1419	13.95	68.50	9.94	7.61
70.76	29.24	1474	4.34	66.42	15.33	13.91
81.62	18.38	10,762	8.96	72.66	11.84	6.54
74.74	25.26	39,585	19.30	55.44	18.73	6.53

Table 2
Analysis of forecast events from August to October 2016 in the district of Mopti.



In relation to the 75% compliance, 19% represents the predicted rainfall (rain expected and it has rained) and 56% represents forecasts of no rain (it will not rain and it did not rain). On the other hand, it is also observed that 25% of forecast rain or no rain was not consistent with the reality on the ground. Highest percentage of non-conformity was obtained at Youwarou in August, September and October. Of the 25% non-compliance, 19% represents rainfall

predictions that were not effective (rainfall is predicted but there was no rain) and 7% represents predictions of no rain (it will not rain but it rained).

Knowing daily rainfall forecasts helped farmers with decision-making on their daily farming activities such as land preparation, especially at the beginning of the rainy season, for plowing, weeding, and either cancelling or reprogramming certain

field activities. On the other hand, if the forecast indicates no rainfall event, farmers feel safe to participate in activities such as weekly markets, phytosanitary activities or application of mineral fertilizer. Women were mostly interested because laundry activities or cereal drying in open spaces during potential rainfall periods can be planned accordingly.

Perspectives

Although an increasing number of people are using mobile phones in Mali, particularly in rural areas, their use in agriculture remains limited because of the lack of opportunities adapted to the specific constraints of local communities. For such opportunities to be widely adopted or integrated into farmers' habits, it is firstly necessary to facilitate access to the system by facilitating a subscription system and also by replacing SMS messages with voice messages because illiteracy is common in the majority of communities in rural areas, and potential users therefore have difficulty in reading forecasts by SMS. Moreover, given the low income of farmers, reducing the SMS price would motivate communities to easily adopt the system.

To strengthen farmer's resilience to climate change, especially those who face daily rainfall variability affecting cropping systems in Mali, use of mobile phones remains an innovative opportunity for localized and individual broadcasting of daily climate forecasts and also as an exchange platform for agro-advisory services covering the main constraints related to farming activities. ●

Acknowledgments

The UK aid program BRACED (Building Resilience and Adaptation to Climate Extreme and Disasters) provided funding for RIC4REC (Strengthening community initiatives for resilience to climate extremes) through International Relief and Development (Blumont/IRD). Implementation was also carried out through a national NGO partner Groupe de Formation, Consultation et Etude (G-FORCE), Amassa Afrique Verte, the Association des Femmes Ingénieurs du Mali and Orange Mali.

Photo 5

Training of farmers on using a mobile phone for climate information forecast in the village of Sido.

ICRISAT

Credit: Bouba Traore,



Climate-Smart Village Approach boosts Senegalese Livelihoods

Climate-smart agricultural technologies and practices are helping women and men farmers in Senegal cultivate cross-season for worthwhile returns to lift them out of poverty.

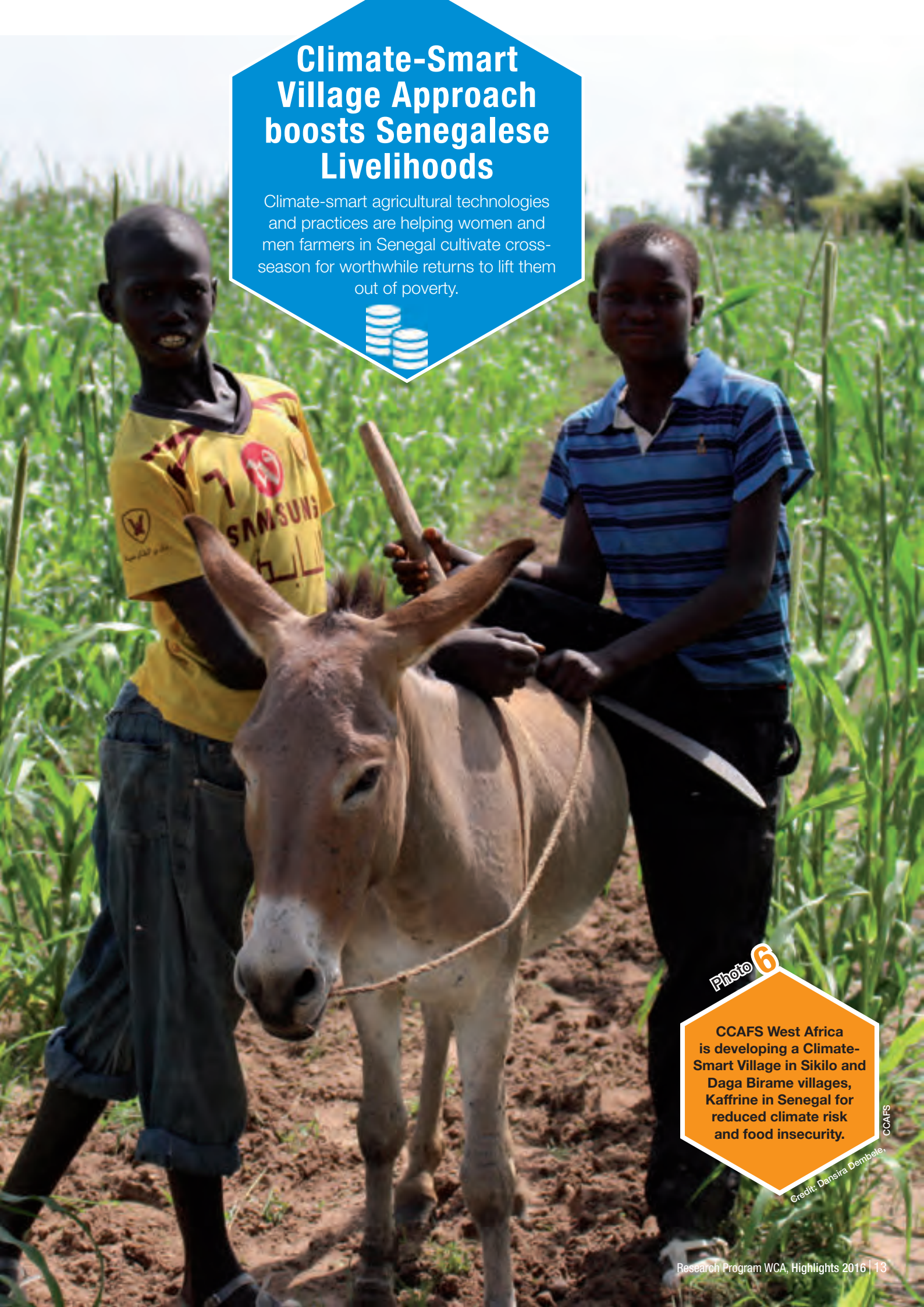


Photo 6

CCAFS West Africa is developing a Climate-Smart Village in Sikilo and Daga Birame villages, Kaffrine in Senegal for reduced climate risk and food insecurity.

Credit: Dansira Dembele,

CCAFS

Climate change and variability is thought to interact with multiple stressors of the agriculture sector in Senegal, which threatens the sector's ability to contribute significantly to the national economy and to the food security needs of the expanding population. Adoption of 'smart' innovations eases the impact of hydro-meteorological shocks caused by seasonal uncertainties of rainfall induced by climate change.

Within its international development agenda, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) uses its agricultural research for development of climate-smart villages (CSV AR4D) approach to participatory test and scale up

to improve the adaptive capacity of farming systems and reduce climate-related risks. In Daga Birame, a village in the Kaffrine region of Senegal, the CSV approach led to the testing of extended-season gardening and several other CSA options with positive effects on food security and evolving livelihood indicators since 2011.

In this report, we provide a summarized synthesis of how seasonal gardening tested at the Daga Birame CSV AR4D site and integration of high-value, non-timber forest products (NTFPs) into development of CSA interventions have made promising significant contributions towards rural livelihood improvement.

The climate-smart village approach (Figure 3) was used to test in an integrated and participatory manner several CSA technologies and practices in Daga Birame (Figure 4). Detailed description of the CSV set up is reported by Sanogo et al. (2016)¹. Periodic assessments of CSA technologies based on farm productivity and livelihood indicators are carried out to accentuate implications on food security and livelihoods.

Thanks to the implementation of the CSV approach, women engaged in cross-season gardening have witnessed increased income while also contributing to nutritional diversity. The gardens are rainfed during the rainy season while clean energy (solar power) irrigation is used during the dry season. Since 2015, the women's groups have produced watermelon (*Citrullus lanatus*), okra (*Abelmoschus esculentus*), mint (*Mentha spicata*) and pepper (*Capsicum annum*). Watermelon

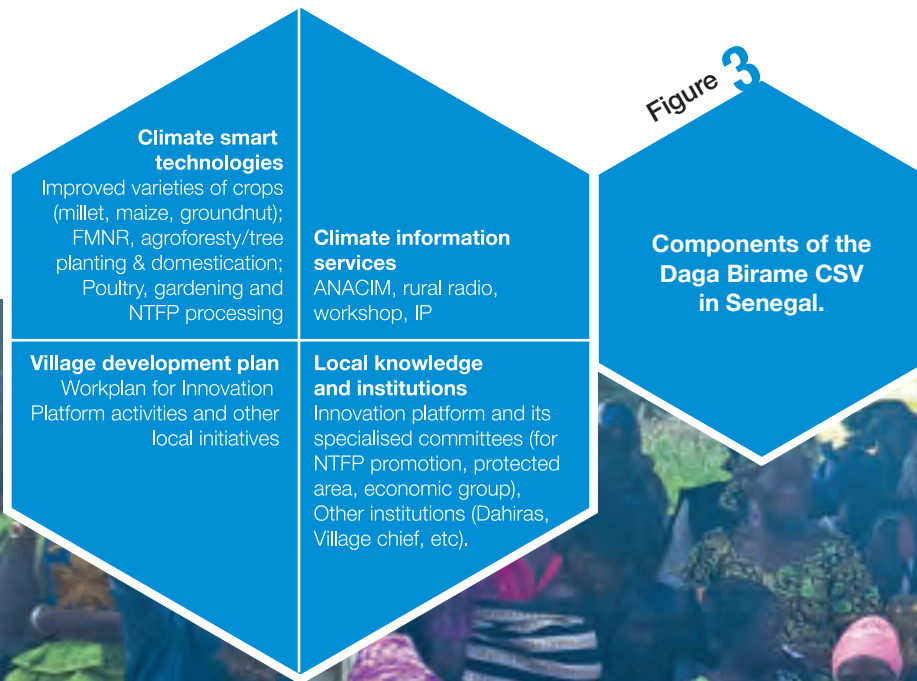



Photo 7

Processing the baobab fruit for powder is an important income-generating activity for many women in Daga Birame. In 2015, they produced 82 bags of 500 g and sold them for 171 euros each.

Credit: Dansira Dembele, CCAFS

and okra generated US\$85 and US\$22, respectively, per season in 2016 while mint was grown only for self consumption.

An NTFP promotion committee composed of women was established to process baobab fruit into powder with the aim of generating income, and it reported that 29 kg of baobab powder were sold in 2015, resulting in US\$191 of income for the women's association. Such income could help purchase food provisions and rescue community members during poor harvest years. It could also help the women farmers invest in resilience sustaining activities for the community. 



Future resilience

With markets and climate variation driving rapid change in farming practices in the savannah in West Africa (Ouédraogo et al., 2016)², seasonal gardening may become an important agriculture innovation and a poverty reduction strategy, particularly for women in Daga Birame. In addition, evidence suggests the design and promotion of CSA interventions that foster the production of high value NTFPs and crops may create new vistas of income generation opportunities for the Daga Birame agrarian community. So far, the emerging results perfectly align the fundamental strategies that have been built into Senegal's Program for Accelerated Agricultural Development (PRACAS) and the Emerging Senegal Plan (PSE). With continued gathering of evidence, the success of this project will help develop district level policies and should positively influence rural communities in Senegal to build more resilient livelihoods.

Food nutrition and income are likely to make significant gains from seasonal gardening tailored to both market and household needs. Value addition to conserved trees (such as the baobab), and to other NTFPs such as *Ziziphus mauritiana* and *Tamarindus Indica*, may also provide a significant safety net and reduce the vulnerability of farmers to climate-related risks.

Figure 4

CSA practices tested at the Daga Birame CSV in Senegal.

CSA Practices

Tree planting	300	No/Reduced Tillage	20
<i>Ziziphus mauritiana</i> , <i>Adansonia digitata</i> , <i>Tamarindus indica</i> , etc		Maize, Millet	
Farmer-Managed Natural Regeneration	20	Integrated Nutr. Mgt	20
Maize, Millet, Groundnut		Maize, Millet	
Improved Varieties	20	Inorganic Fertilizer	20
Maize, Millet		Maize, Millet	
		Season gardening (Group)	
		Watermelon, Okra, Mint, Pepper	
		Income Diversification	20
		Poultry	

Acknowledgments

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¹ Sanogo D, Camara BA, Diop M, Ndiaye O, Ky-Dembélé C, Bayala J, Dayamba SD, Zougmore R, Ouédraogo M, Partey ST. (2016). Developing a Climate-Smart Village for Reduced Climate Risk and Food Insecurity in Daga-Birame, Senegal. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). <http://hdl.handle.net/10568/78211>

² Ouédraogo M, Zougmore R, Moussa AS, Partey ST, Philip K Thornton PK, Kristjanson P, Ndour NYB, Somé L, Naab J, Boureima M, Diakité L and Quiros C. (2016). Markets and climate are driving rapid change in farming practices in Savannah West Africa. *Regional Environmental Change* 17: 437-449



Smallholders in Mali Adjust Crop Management Decisions Thanks to Satellite Monitoring



Farmers and scientists in Mali are learning first-hand how satellite technology can be used to interpret crop performance and alter decision-making on-farm.

“When I saw on the STARS images my cotton crop’s poor response to the application of the Sabunyuman fertilizer I was completely dismayed,” says Usman Sania Berthe, a cotton planter in Sukumba, Mali. *“But during later group discussions, I remembered that I was late in applying the recommended dose at the recommended date. That a satellite way out in the sky could lead me to this realization is flabbergasting. For sure, next season I will do my best to be prepared, if fertilizer is available in due time.”*

Smallholder systems are characterized by enormous yield gaps. Variability in environmental conditions and management practices result in high landscape heterogeneity, and monitoring productivity across scales remains a daunting challenge. Modern information technologies including remote sensing can help monitor crop performance at levels of granularity increasingly compatible with smallholder farming. This may open practical support applications for precision agriculture, demonstrating that increased productivity and enhanced livelihoods are also possible in complex cropping systems. ICRISAT research under the ‘Spurring a Transformation for Agriculture through Remote Sensing (STARS)’ project focuses on analysis of the potential of remote sensing to retrieve crop status information at sub-field scales in heterogeneous smallholder rainfed production systems.

The study measures the sensitivity of satellite sensors to on-farm fertility treatments applied to five locally important crops in Mali’s cotton belt: cotton, maize, peanut, pearl millet and sorghum. Vegetation index sensitivity to fertilization is analyzed at the field scale, along with the amplitude and timing of strongest plant responses. Spatial variance components are quantified with respect to fertilization and also within and between field variability associated with management, soil characteristics and position in a catena or grouping of co-evolving soil types.

Plant growth was assessed in 48 smallholder fields (average size: 1.4 ha) distributed across a catena. In each field, six 225 m² fertilization plots were installed, within each of which five 4 m² quadrats were sampled fortnightly for crop condition, development stage, chlorophyll content, fractional cover, leaf area index (LAI) and plant height. Synchronously, time series of very high resolution (VHR) satellite and unmanned aerial vehicle images were collected, ortho-rectified and atmospherically corrected to calculate the Normalized Difference Vegetation Index (NDVI).



Strong relationships between NDVI and plant growth parameters were observed at plot scales, implying that NDVI directly reflects differences in plant conditions associated with soil fertility and management patterns. On average, crops clearly responded to fertilization impacting NDVI, but large within-field and within-plot variability indicated that many other factors influence NDVI response to crop growth. A field-level variance decomposition model applied during the crop-specific time window when NDVI response is strongest (e.g. late August for groundnut (peanut); early October for sorghum) showed that at best 50% of intra-field variance is attributable to fertilization levels, in only half of the fields monitored.

At the landscape scale, the effect of fertilizer applications on crop NDVI response was proportionately small (< 35% total variation)

compared to the effect of other management practices (sowing, weeding) and catena position. Large differences in temporal signatures between fields of a given crop species were observed. NDVI response can therefore be only partially benchmarked against a fertilization reference within the field. Standard precision agriculture methods based on NDVI comparisons within one field are of limited use in these heterogeneous landscapes, and accounting for other sources of variability is a prerequisite before fertilizer response can be monitored at scale.



Photo 8

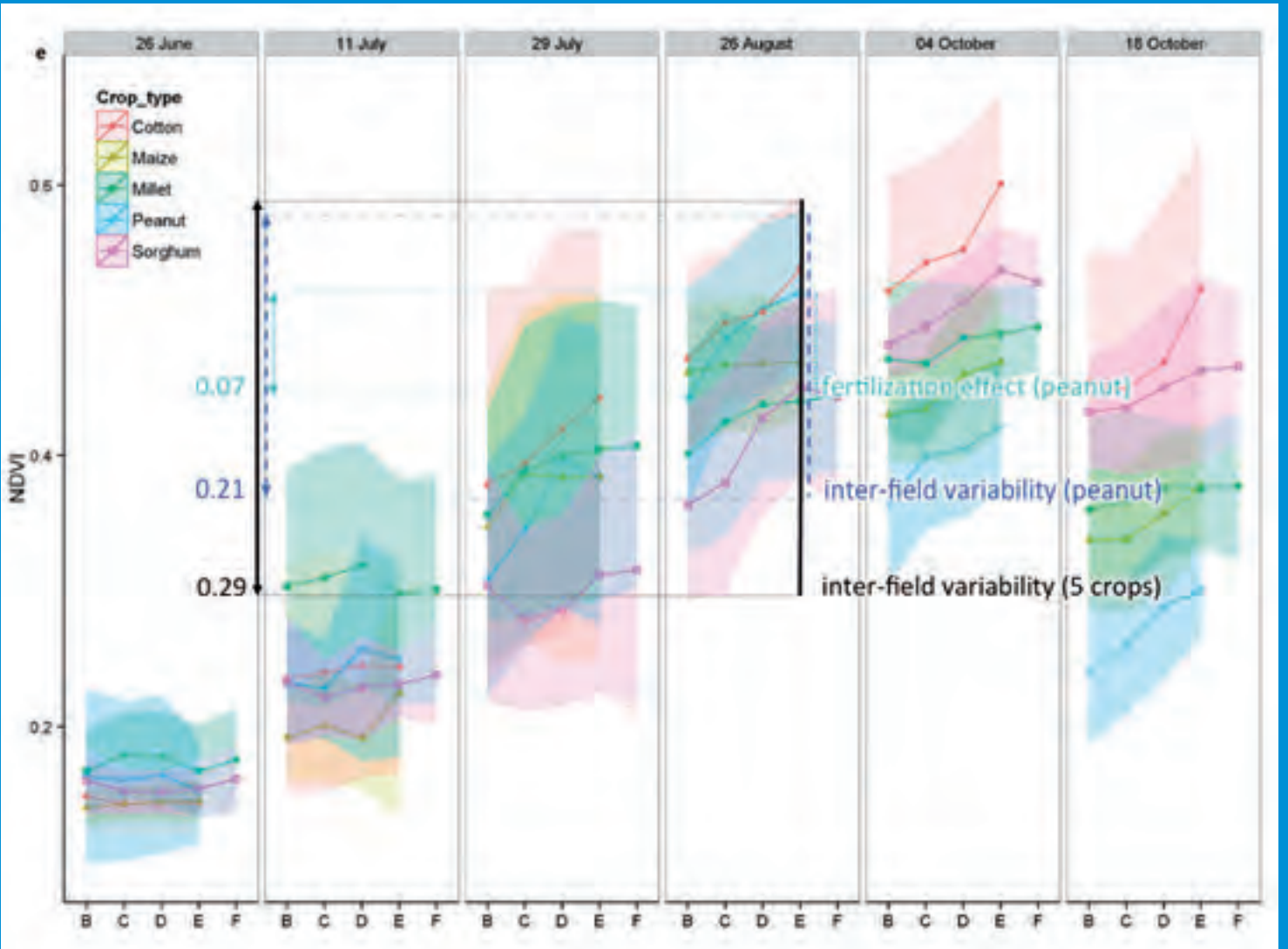
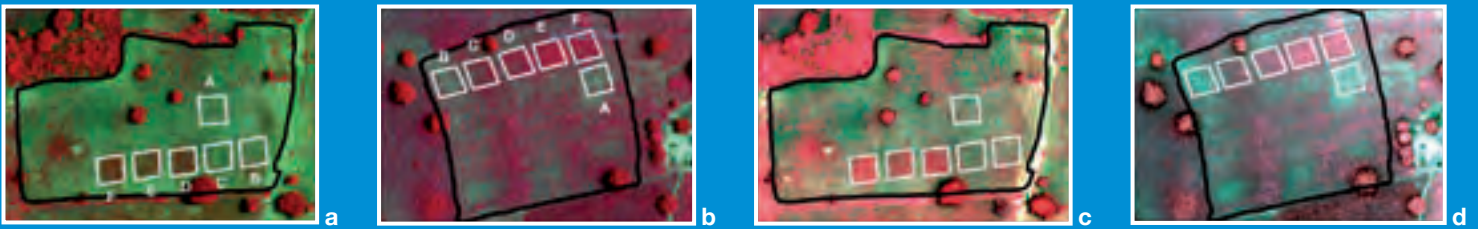
Sukumba (Mali)
women farmers marvel at ICRISAT's SenseFly eBeeAg unmanned aerial vehicle collecting imagery to calibrate relationships between satellite vegetation indices and plant growth variables sensitive to fertilization levels over a smallholder cotton field.

ICRISAT
Credit: PCS Traore

Towards fertilizer gap estimates from satellite

Landscape-scale variability in smallholder farming practices (other than fertilization proper) and soil properties are overriding, confounding factors to resolve before crop fertilizer response can be monitored at scale, and before inferences can be subsequently drawn from crop spectral signatures about fertilization gaps and nutrient use efficiencies. The advent of concomitant high spatial resolution and high return frequency Earth Observation systems is being exploited to that purpose under the European Space Agency's Sentinel-2 Agriculture project, to which Mali contributes the first developing country pilot as a spin-off to the STARS project.

Monitoring crop growth in heterogeneous, smallholder agricultural parkland landscapes is now possible with time series of very high-resolution imagery. Fertilization impacts NDVI as a proxy of crop response. However, assessing fertilizer response at scale requires prior stratification of the production environment (e.g., catena classes) and field management (e.g., sowing practices). 🍀



a-d: Digital Globe's GeoEye satellite at 2 m resolution (a,b) and the SenseFly eBeeAg UAV at 10 cm resolution (c,d) capture crop canopy response to fertility treatments in smallholders' fields of millet on sandy soil (a,c) and sorghum on loamy soil (b,d), but also reveal the expression of multiple other factors of heterogeneity. **e:** a seasonal time series from Digital Globe satellites displays the NDVI time response to increasing fertilization (B-C-D-E-F) for five dominant crops and illustrates how, on a landscape scale, fertilization practice explains less variation in NDVI than crop type and other management factors.

Figure 5

Acknowledgments

The Spurring a Transformation for Agriculture through Remote Sensing (STARS) project is supported by the Bill & Melinda Gates Foundation (BMGF).

Groundnut's major contribution to rural cash earnings in Mali and Nigeria is being cemented by efficient science delivery and enhanced genetic gains.

Its importance made it a priority crop for ICRISAT's crop improvement program that works with partners to scale up the transfer of improved groundnut production technologies, including improved varieties. These efforts also span technology demonstrations, capacity building and strengthening groundnut seed systems.

Building on previous successes, the program is going through an improvement process to increase its efficiency in science delivery and to enhance genetic gains. This includes increasing the scale of crossing and yield-testing programs, mechanizing field operations and digitizing data collection, analysis, storage and sharing processes.

Groundnut is grown as a food and cash crop in West and Central Africa; and the region accounts for more than 70% of groundnut production in Africa. As a food crop for home consumption in various forms, grain may be ground, boiled, roasted, or turned into paste. As a cash crop, groundnut contributes significantly to farmers' household cash earnings, and it is a major source of employment, particularly for women and youth, accounting for 21% of rural cash earnings in Nigeria and about 50% in Mali.

Development of **Multiple-Stress Tolerant Groundnut Genotypes** for Enhanced Productivity and Production

In some countries like Nigeria, small-, medium- and large-scale groundnut oil processing businesses create employment opportunities for locals and profit for the processors. Groundnut haulm and cake are very important livestock feeds. Furthermore, the biological nitrogen fixing capacity of groundnut plays an important role in ameliorating soil fertility, thereby increasing productivity of cereals cultivated in association with or in rotation with it for improved food security.

The ICRISAT-WCA Groundnut Breeding program develops improved groundnut varieties; provides technical support and shares breeding lines with national groundnut improvement programs. It also works with partners on promoting and popularizing improved groundnut production technologies including improved varieties to increase groundnut productivity and production for enhanced nutrition, health and income of smallholder farmers.

Breeding pipeline

A breeding pipeline for traits of interest is maintained by developing and advancing segregating populations. New crosses are made each year to develop F_1 populations for priority traits. Off-season and main season plots, as well as screen houses, are utilized to speed up the process of advancing segregating (F_2 , F_3 , F_4 , F_5 and F_6) populations. In 2016, new populations totaling 200 (50 for drought, 50 for foliar disease and short duration, 50 short duration and for aflatoxin tolerance, and 50 medium duration) were developed. More than 325 F_2 - F_6 populations were planted for advancement.

Testing for release

Four preliminary variety trials (PVT) with 122 advanced breeding lines were conducted in 2016, and one regional variety trial with 16 advanced breeding lines to evaluate the performance of advanced breeding lines for target environments. The first PVT, comprising 36 varieties with drought, aflatoxin and rosette resistance, revealed highly significant difference in pod yield between the varieties. The pod yield ranged from 468 to 1998 kg/ha (mean=1488 kg/ha). The second PVT trial comprising 36 short-duration varieties with resistance to aflatoxin and drought showed highly significant difference in pod yield between the varieties. The pod yield ranged from 420 to 1562 kg/ha (mean=1080 kg/ha). The third PVT trial comprising 25 short-duration groundnut varieties with resistance to early leaf spot and drought showed highly significant difference in pod yield between the varieties. The pod yield ranged from 726 to 1924 kg/ha (mean=1470 kg/ha). The fourth trial comprising 25 drought-resistant varieties with foliar disease resistance showed highly significant difference in pod yield between the varieties tested. The pod yield ranged from 1208 to 2401 kg/ha (mean=1984 kg/ha). The regional variety trial comprising 16 varieties was conducted in Ghana (6 locations), Burkina Faso (2), Mali (6) and Nigeria (5). For the trial conducted at ICRISAT-Samanko station in Mali, a highly significant difference was observed in pod yield between the varieties tested. The pod yield ranged from 1010 to 2326 kg/ha (mean=1755 kg/ha).

Enhancing genetic gain and efficiency

The number of crosses made per season and the number of advanced breeding lines in yield testing trials have significantly increased since 2014 to enhance genetic gain. A rapid generation advancement process is being used for segregating generations by exploiting multiple crops in one year using a single seed descent and bulking approach.

Advances in efficiency include the program using barcoding in 2017 for plot labelling in the field and seed inventory in storage. It is also in the process of acquiring a pod stripper and sheller for trial plots, and a near-infrared spectroscope for grain and haulm quality analysis. Handheld devices are being used to collect data for transfer to computers. Efforts are being made to migrate all the breeding data since 2008 to a Breeding Management System for ease of pedigree management, designing of crosses, yield trials and data collection, analysis, storage and sharing, which will further facilitate economical and accelerated variety development. It will also enable employing advanced statistical analysis of multi-environment yield trials data to account for non-genetic effects and reduce errors in selection decisions. ●

Best-bet varieties

In 2016, the program shared 129 advanced breeding lines (57 to Burkina Faso, 12 to Mali, and 60 to Nigeria) for multilocation, national performance trials and farmer participatory variety selection trials to identify high-yielding and farmer-preferred best-bet varieties.

Identified best-bet varieties included in:

Mali

- ICIAR 19BT
- ICGV 03181
- ICGV 00350

Burkina Faso

- ICGV 86015
- ICGV 91317
- ICGV 91328
- ICGV 93305
- ICIAR 19 BT
- Fleur 11

Nigeria

- Short duration - ICGV-IS 07999
- ICGV 94379
- TAG 24
- ICGV 86024
- Medium duration - ICGV 01276
- ICGV IS 09992
- ICGV 08540
- ICGV 07539

Ghana

- ICGV-IS 08837
- ICGV 13071
- ICGV 13075
- ICGV 91279
- ICGV 13015
- ICGV 13110

Release of some of these best-bet varieties is expected in 2017/18.



Good Crop Management Practices Help Reduce Aflatoxin Contamination in Groundnut Before Storage in Mali

Clearing the road to higher quality groundnut production is being demonstrated in farmer participation plots that use improved varieties in combination with management practices to reduce crop contamination.



It has been shown in certain regions of Mali that aflatoxin contamination in traders' stocks can reach 120 parts per billion (ppb) and in groundnut markets up to 250 ppb, considerably higher than international standards for human consumption set at 4 ppb in the European Union and 20 ppb in the United States.

As a result, the project, "Increasing Groundnut Productivity of Smallholder farmers in Ghana, Mali and Nigeria", funded by USAID under the Feed the Future initiative, investigated during the 2015 cropping season in Mali the effect of good crop management practices in reducing aflatoxin contamination in groundnut before storage. Infection can take place at any production stage, including cultivation, harvesting, drying, storage, transportation and marketing by a variety of moulds, commonly *Fusarium*, *Aspergillus* and *Penicillium* species. Mould infection contributes to losses in quantity, quality and economic value of groundnut available for consumption or trade. Not only is groundnut quality reduced, toxic metabolites are deposited when the colonizing fungi are mycotoxigenic, and conditions favor toxin production. Aflatoxins are toxic fungal metabolites that accumulate in stored produce when storage conditions favor proliferation of aflatoxigenic fungi.

Despite its key role as Mali's main grain legume, groundnut productivity remains low, with unshelled yield of less than 1 ton/ha compared with a global average of 1.5 tons/ha and over 3 tons ha⁻¹ in USA and China. While improved varieties developed by ICRISAT and national research institutions exist, they are not often available to smallholder farmers because of the low supply of certified seeds and lack of information about these varieties. Resulting low adoption of improved production technologies leads to low crop productivity compounded

by inappropriate postharvest and storage practices that further predispose harvests to quantitative and qualitative losses, especially contamination by aflatoxin.

Participatory demonstration plots consisting of improved technology and farmers' local practices were established in three regions (Sikasso, Koulikoro and Mopti). Basal application during land preparation was 100 kg/ha diammonium phosphate (18-46-0) fertilizer. Gypsum was applied at the rate of 400 kg/ha at 35–40 days after sowing. The improved technology mainly included the use of tolerant varieties, appropriate fertilizer, harvesting at 70–80% maturity and drying pods at 8% moisture content. A total of 224 groundnut samples, 112 each from plots split evenly between improved technology and farmers' practices were collected and analyzed. The aflatoxin concentration in seeds was measured using the enzyme-linked immunosorbent assay (ELISA).

The overall analysis showed that samples from improved technology plots had an average of 3.94±5.23 ppb of aflatoxin, which is significantly less ($p < 0.01$) than the samples from the farmers' practices plots with an

average of 12.71±15.10 ppb. Furthermore, considering data from each region, significant differences were also observed between improved technology and farmer' practices, though the difference was only significant at 10% in Mopti region which is drier than the other two regions. Toxigenic fungi of the genera *Aspergillus*, *Fusarium* and *Penicillium* that have implications on safety and quality of stored groundnut are often classified as storage fungi that can survive and grow under a variety of environmental conditions at some stages including storage.

It was concluded that improved varieties with good crop management practices can help reduce aflatoxin contamination in groundnut before storage. A holistic approach combining tolerant varieties, crop management practices, capacity development and public awareness is recommended for the reduction of aflatoxin contamination in groundnut. However, sampling should continue to gather many years' data to confirm the tendency and the performance of good crop management practices on aflatoxin contamination. ●

Strategic Strengthening of Mali Groundnut Production and Seed Systems through an Inclusive Business Model

Photo 9

Madame
Fanta Diamoutene,
a groundnut producer in
Sikasso region, Mali.

ICRISAT
Credit: Agathe Diama



Interventions by ICRISAT to stimulate dissemination of improved groundnut seeds and technology research are gathering pace through an inclusive business model linking farmers, NGOs and crop processors.

As a result, nearly 460 tons of quality seed of four improved groundnut varieties were produced and injected into Mali's seed system during the 2015 and 2016 crop seasons, building farmers' access to quality seed and increasing the availability of seed at community level.

Despite its food security and economic importance to smallholder farmers, groundnut yield is low and estimated at less than 1 ton per hectare under farmers' conditions. This is attributed to the low adoption of improved technologies caused by weak seed systems that have led to inadequate access to seeds of improved varieties. The limited access to quality seed is attributed to lack of public sector capacity to produce enough breeder and foundation seeds of improved varieties for distribution to seed producers. Besides, only a few actors in the seed system are promoting the multiplication of foundation, and certified and quality declared seed.

Seed systems, involving both formal and informal components, have evolved. The formal seed system is that in which the responsibility for producing breeder and foundation seeds is led by international and national public institutions (e.g., ICRISAT and Mali's Institute of Rural Economy - IER). However, registered and competent seed companies are encouraged to produce foundation seed under close supervision by ICRISAT and IER. The informal seed system involves community-based seed systems (CBSS) and farmer-based organizations (FBOs) to overcome the shortages of good quality seed and hasten the diffusion of improved varieties of groundnuts among the farming communities.

This CBSS approach is being used to complement the conventional seed system to enable farmers to meet their seed requirement. It aims to foster a sense of ownership of main seed production activities by farmers' organizations and local village communities in such a way that the communities produce their own seed and sell surpluses to others. The CBSS initiative by ICRISAT along with its partners started in 2007 with farmer groups in Wacoro (Dioila), Bougoula and Sanambélé in

Photo **10**

**Mr Lassana Kouma,
President and
Director General
of SAMA-AGRI with
groundnut butter
processed by
his label Datiga.**

Credit: Agathe Diama,
ICRISAT





Photo 11

Participants in the Increasing Groundnut Productivity of Smallholder Farmers project during on-farm activities in Mali's Sikasso region.

Credit: Agathe Diama, ICRISAT



Koulikoro region of Mali. It is being scaled up to other communities in Sikasso, Kayes, Koulikoro and Mopti regions of Mali through a USAID-supported groundnut scaling project. More than 85 communities are engaged in quality seed production for four improved varieties (Fleur 11, ICGV 86015, ICGV 86024 and ICGV 86124).

To build farmers' capacity in seed and grain production, and their marketing skills, various interventions were adopted, including participatory varietal selection, on-farm demonstrations, farmers' field days, trainings, media communications, seed fairs, seed production and seed quality monitoring. Smallholder seed producers are linked for contract seed production with private seed companies supported by ICRISAT providing technical support for quality seed production.

A Mediated Model for NGOs is also being implemented, whereby 15 NGOs are involved in diffusing improved varieties and good agronomic practices to the farmers. Seeds produced are sold in small packs (1–15 kg) by private seed companies as farmers cannot afford to pay the full unsubsidized cost of large commercial packs. Seed exhibitions were organized at project sites and media campaigns and training manuals are being used to enhance public knowledge on seed production systems through information, education and communication.

Functional business linkages between the private and public sectors were created along the groundnut value chains. Currently, the largest groundnut processor in Mali (SAMA-AGRI) has been linked with the project partners, seed producers and seed companies.

The availability of good quality seed of adapted varieties in the project target sites is now stimulating interest among many farmers to grow groundnut for both consumption and commercial purposes. In conclusion, the use of integrated seed systems through an inclusive business model successfully improved availability of quality groundnut seed in Mali. ●

Aflatoxin Contamination of Groundnut (*Arachis hypogaea*) Products in Northern Ghana

Awareness of aflatoxin contamination is being raised in northern regions of Ghana to combat the adverse economic, health and nutritional consequences, especially among rural communities.

Groundnut pastes, generally made from low quality, damaged grains, are the most frequent carrier of toxins that can induce potentially fatal liver cancer, cirrhosis and hepatitis in consumers. Hitherto, the extent of the problem has been poorly understood and appreciated, but the USAID-funded Groundnut Technology Scaling Project, being implemented by ICRISAT and local partners, is creating greater awareness of aflatoxin and its management using participatory field demonstrations, sensitization and training of value-chain actors.

Aflatoxins are mycotoxins produced by *Aspergillus flavus*, which contaminate basic food products and exhibit a variety of adverse effects including acute aflatoxicoses, death, liver cancer, cirrhosis and hepatitis in consumers of such products. Adverse economic, health and nutritional consequences are particularly felt by rural communities.

Samples of groundnut products were collected between December 2015 and January 2016 in the 21 project districts. Pod samples were collected from the project's demonstration plots as well as from farmers' stores while kernels and groundnut pastes were obtained from local markets in the study districts:

- 300 samples of groundnut pods, kernels and pastes were collected from farm stores and markets in the Northern, Upper West and Upper East Regions
- 1 kg pod samples were collected at harvest from each of 400 demonstration plots set up by project partners in the various project districts
- Samples were sent to the Food Technology/Biotechnology Laboratory of the University for Development Studies at Tamale where they were analyzed using the Aflatoxin Mobil Assay.

Results from the analyses and their implications are being disseminated to stakeholders through fairs, review meetings, school visits, trainings and radio broadcasts. Signs of rising awareness having impact are already discernible. Pod samples derived from 2015 demonstration plots had aflatoxin levels ranging from 1.1 to 19.72 ppb. In 2016, aflatoxin levels were generally lower, ranging from 1.46 to 6.92 ppb, an indication that the project demonstrations are probably having the desired effect of reducing aflatoxin contamination.

No clear trend of significant varietal differences in aflatoxin susceptibility has so far been established but NkatieSari appeared to show the least mean contamination (2.57 ppb) for the two years across locations, while SAMNUT 22 had the highest contamination level of 4.81 ppb.

Among the different groundnut products, pastes had the highest levels of aflatoxin across regions, followed by kernels and pods (Figure 6). Groundnut pastes are usually produced from low quality (shriveled, broken, damaged) grains that are more prone to aflatoxin contamination, hence the higher levels of aflatoxin in such products.

At least 35 basic schools and 30 women groups have been sensitized, and 36 radio programs organized on groundnut nutrition and aflatoxin management using results from the studies as evidence and base information. "These findings have clearly exposed the dangers we face with aflatoxin contamination, and we would ensure that we discuss this subject in all our development broadcasts henceforth as a regional radio station," remarked Emmanuel Kye-eeboh, radio host at URARADIO, Bolga during a recent review meeting.

Most groundnut products sampled showed aflatoxin levels higher than the European Union's acceptable limit of 5 ppb, with pastes being the worst affected. This calls for more intensive sensitization of groundnut value-chain actors, especially the processors, as well as rigorous monitoring of groundnut products to minimize the risks of human and livestock poisoning from aflatoxin contamination. ●

60

50

40

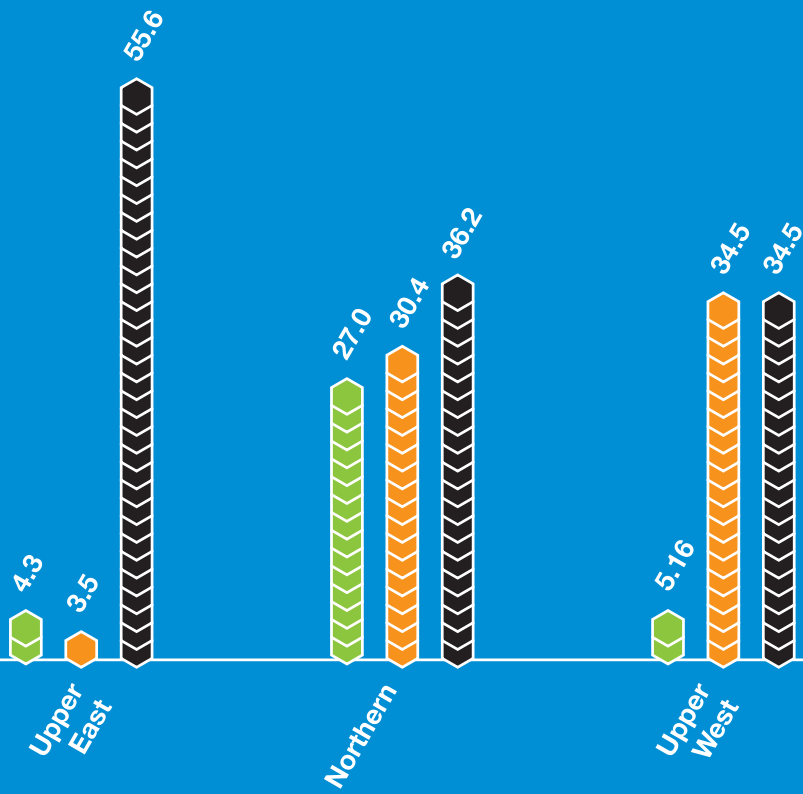
30

20

10

0

Aflatoxin conc. (ppb)



-  Pod
-  Kernel
-  Paste

Figure 6

Aflatoxin levels in products across regions.

Pupils of Binduri School (UER), northern Ghana, participating in a sensitization workshop on aflatoxin.

Photo 12

Credit: Paul Tanzubli,

ICRISAT



Photo 13

Healthy (right) and aflatoxin-contaminated (left) cooked groundnuts on sale in Tamale market, northern Ghana.

Credit: Paul Tanzubli, ICRISAT



Preliminary Impact of Upscaling Improved Groundnut Varieties into Selected States of Northern Nigeria

Pathways to increased productivity and cash incomes from groundnut production in Nigeria are becoming apparent from examining the impact of varietal development of improved varieties.

Though groundnut lost its strategic position in West Africa at the beginning of this decade, it remains a vital crop for smallholder farmers in the region where it is a reliable source of protein, fats and vitamins for children. Its grain and products are commonly consumed together with cereal and tuber-based food staples, milk and fruits. Groundnut cake, leaves and stems (fodder or haulms) are used as feed for livestock and poultry and its shells are used as fuel (1 kg shell = 1 kW of energy). Groundnut also enhances the sustainability of farming systems by fixing up to 60 kg of nitrogen per hectare into the soil, and has the capacity to reduce soil erosion and control weeds.

These reasons inspire the need to pursue actions to enhance the productivity of the crop in order to make it more competitive with other legumes and oilseed crops. The identification and promotion of groundnut varieties resistant to drought, less susceptible to aflatoxin contamination, foliar diseases, rosette virus, and development of quality seeds are all strategies for increasing productivity and competitiveness. In the light of this, the Institute for Agricultural Research (IAR) and national and international partners (including ICRISAT) have been actively engaged in varietal development in Nigeria over the past decade.

Apart from their high yield, many of the released varieties are resistant to major biotic and abiotic stresses. In 2012 and 2014, three high-yielding, early-maturing and rosette-resistant varieties – Samnut 24, Samnut 25 and Samnut 26 – were released. These three varieties were targeted for wide-scale promotion due to these intrinsic traits by the Nigerian component of the USAID-funded Groundnut Upscaling Project being implemented by ICRISAT in Ghana, Mali and Nigeria.

Against the background of the promotion of these varieties, a preliminary impact survey was conducted in 224 local government areas (LGAs) – split between targeted and non-targeted LGAs – in Kano, Katsina and Jigawa States, three out of five States where the Upscaling Project is being implemented. A combination of purposive and multi-stage random sampling procedures was used in the selection of respondents, who turned up in sufficient numbers to demonstrate their willingness to contribute to the revival of groundnut production in northern Nigeria.

It should be recalled that studying the ‘impacts’ of introduced agricultural technologies encompasses at least three aspects i) beneficiaries ii) effectiveness of delivery, and iii) institutions (*Anderson and Herdt, 1990; Anandajayasekeram et al., 1996; Moshi et al., 1998*). Beneficiary level impacts consist of socio-economic impacts (efficiency analysis), socio-cultural impacts, and environmental impacts (*Anandajayasekeram et al., 1996*). This initial study is a start-up attempt to assess beneficiary level impact of the USAID Groundnut Upscaling Project in targeted and non-targeted LGAs.

Appropriate control measures were carried out on the filled-out questionnaires. Frequency counts were used to summarize the data collected. Returns on variable costs or Gross Profit Margin were then computed to serve as a proxy of the profitability of groundnut production. This is simply represented as: $GM = \sum p_i q_i - \sum r_j x_j$; where GM is the Gross Margin; p_i is the unit price of groundnut output, q_i is the quantity of groundnut output, r_j is the unit cost of inputs used and x_j is the quantity of the inputs.

Table 3

Incorporation of different groundnut varieties into farm fields.

Socio-demographic profile of respondents

Of the respondents 98% were male in the project LGAs as against 93% in non-participating LGAs indicating that men dominate groundnut production. The mean age of respondents in the project area was 48 years while the mean age in non-project areas was 41 years. Respondents in both project and non-project areas reported farming experience of 28 years. Farm sizes were generally less than 5 ha.

Project LGAs

Improved varieties	Frequency	Respondents (%)	Local varieties	Frequency	Respondents (%)
Samnut 23	11	9.8	Jargyada	38	33.9
Samnut 24	40	35.7	Ex-Dakar	33	29.5
Samnut 26	2	1.8	Maibargo	18	16.1
Samnut 21 & 26	1	0.9	Kwankwaso	1	9
Samnut 23 & 24	22	19.6	Yarkosoma	11	9.8
Samnut 23, 24 & 25	3	2.7	Badankama	4	3.6
Samnut 24 & 25	13	11.6			
Samnut 22 & 24	1	0.9			
Samnut 24 & 26	1	0.9			
Samnut 24, 25 & 26	12	10.7			
Samnut 25&26	6	5.4			

Non-Project LGAs

Local varieties	Frequency	Respondents (%)	Improved varieties	Frequency	Respondents (%)
Jargyada	10	8.1	Samnut 23	5	4.5
Ex-Dakar	35	28.2	Samnut 24	61	54.5
Maibargo	27	21.8	Samnut 25	8	7.1
Kwankwaso	7	5.6			
Yarkosoma	7	5.6			
Badankama	7	5.6			
Mai Atampa	8	6.5			
Maizabuwa	4	3.2			
Ayaya	5	4.0			
Maikwarwa	2	1.6			

Improved varieties adopted

Table 3 confirms that both improved and local groundnut varieties are being used in all LGAs. The improved varieties being promoted by the project were used by 36% of those interviewed, with most respondents using more than one of the improved groundnut varieties. Eighty-two per cent of those interviewed expressed their preference for Samnut 24. Of the local varieties, Jargyada and Ex-Dakar (Samnut 14) were the

most popular in project LGAs, as reported by 34% and 30% of respondents, respectively.

In non-project LGAs, respondents reported using a wide range of local varieties and other improved varieties with Ex-Dakar being the most popular (28% of respondents), followed by Maibargo (22% of respondents). Samnut 24 was reported being used by over half (55%) of respondents in non-project LGAs.

While ICRISAT was cited as the main source of improved groundnut varieties in project LGAs and 83% of respondents in non-project LGAs reported sourcing local varieties from open markets, private seed companies were not cited as a source of improved groundnut seeds. Almost the same proportion of respondents in both project LGAs (94%) and non-project LGAs (92%) reported using saved seeds for subsequent seasons. This recycling of both local and improved groundnut varieties limits the yield potential of the crop in conjunction with inadequate use of accompanying crop management practices. It is known that developed seed markets tend to provide quality seeds needed to sustain crop performance. This underlines the fact that smallholders must remain key actors in the development of seed systems across the project area.

Table 4

Costs of and revenues from producing groundnut in the survey area.

Cost items	Project LGAs (Naira/kg)	%	Non-project LGAs (Naira/kg)	%
Seeds	11,084	16.71	9,035	18.29
Fertilizers	16,890	25.47	5,935	12.02
Pesticides	790	1.19	615	1.25
Farmyard manure	2,655	4.00	1,657	3.35
Land rental	893	1.35	778	1.58
Bags for storage	1,842	2.78	1,476	2.99
Sub-total	34,154		19,496	
Labor (man days)	30,268	51.50	28,876	39.47
Transportation	1,894	2.86	1,020	2.07
Total costs	66,316		49,392	

Profitability of farm operations

Average output (kg/ha)	1,109.23		448	
Average price (N/kg)	114		151	
Gross farm revenue (N/ha)	126,452.22		67,648	
Gross profit margin	60,136.22		18,256	

Gross margin

Table 4 summarizes the operational costs and revenues from producing groundnuts in project and non-project LGAs. The cost items comprise seeds, fertilizers and pesticides, seasonal rents for farmland, farm labor and transportation of produce from the farms to home. The cost of farm labor was the most important cost item in the production process, accounting for 52% in project LGAs and 40% in non-project LGAs. It should be noted that the cost of seed certification and extension services by appropriate public and private services were not included in the estimation of gross margins.

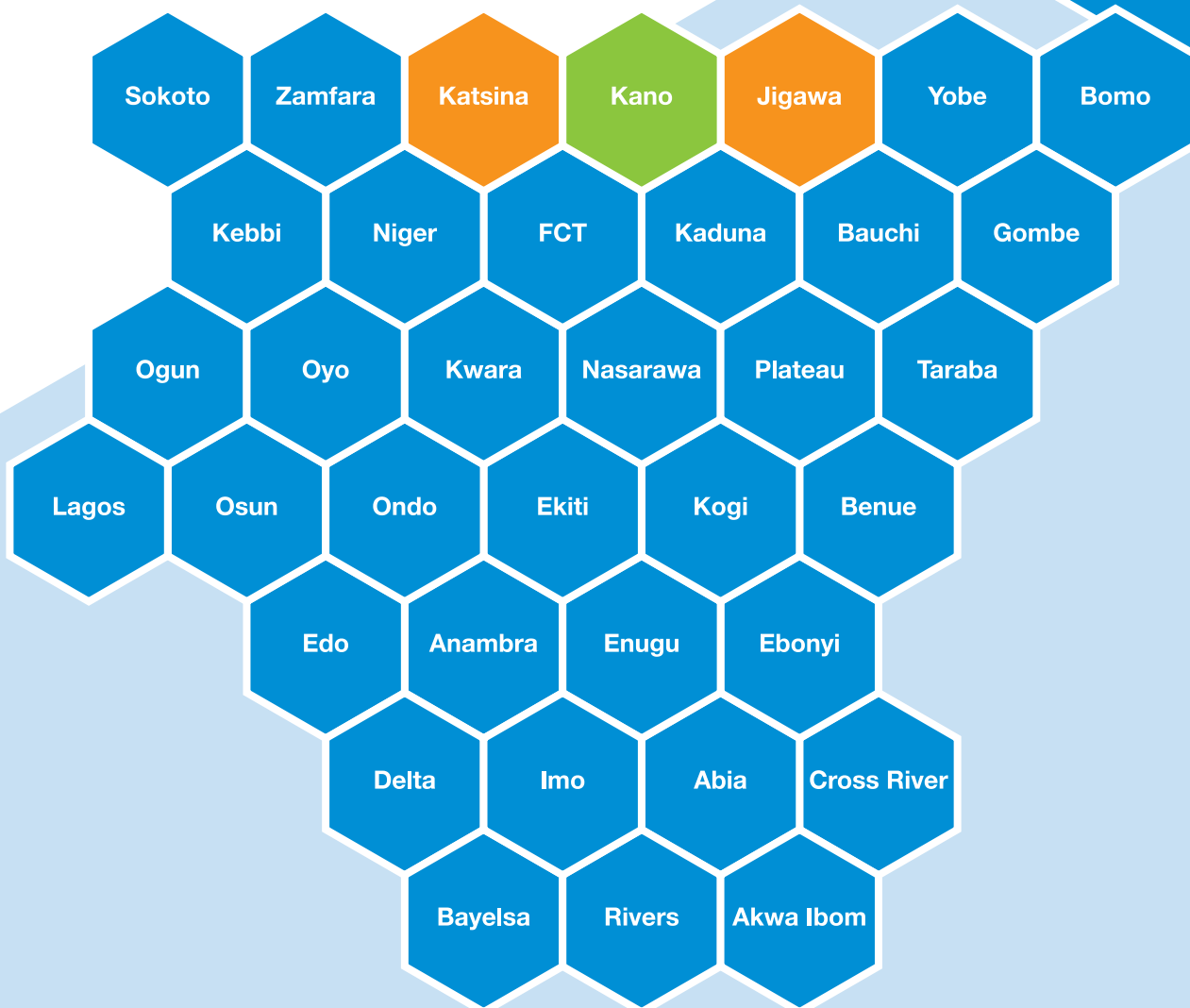
Mean prices/kg of seed were lower in project LGAs (Naira 14.00 or 37 UScents) than in non-project LGAs (Naira 151.00 (50 cents)). These mean prices were used to compute the total revenues, the outcomes of which constituted the basis for the calculation of gross profit margins. The gross profit margin in project LGAs and non-project LGAs were Naira 60,136 (or \$197) and Naira 18,256 (or \$6), respectively, indicating

potential for higher profitability in adopting the improved groundnut varieties being promoted by the USAID project. These translate into gross margin percentages of 48% for project LGAs and 27% for non-project LGAs.

The gross profit margins in project LGAs and non-project LGAs reveal that by adopting groundnut technologies (seeds and accompanying management practices) smallholder farmers could increase their productivity and cash incomes. It should be recognized that despite its limitations, the gross margin is a useful concept to track profitability. In both project and non-project LGAs, profitability can be improved either by tactfully manipulating wages and number of farm labor, and/or other inputs.

Figure 7

Map of Nigeria showing the States targeted for the study.



Constraints to the adoption of improved groundnut varieties

Table 5 summarizes the key constraints to the adoption of the improved groundnut varieties being promoted by the USAID Upscaling Project. Difficult access to improved groundnut seed emerged as the most important constraint (24%) while the late delivery of seeds was considered to be a major constraint in project LGAs (12%). Other constraints reported were the poor quality of seeds (4%) and the supply of varieties not preferred by farmers in project communities (2%). Previous studies reported difficult access to improved varieties (37.26%), low yields (20.82%), low market value (14.66%), lack of cash to purchase seeds (11.10%), and

pests and disease (6.30%) as key constraints to adoption in Kano, Katsina and Jigawa States.

Though the cost of seed certification and extension services by appropriate services were not included in this survey, it provides insights into i) the cost of producing groundnut in the States where the project is being implemented; ii) the gross margin as a guide to improving the profitability of groundnut farm operations; and iii) possible spillover pathways of introducing improved groundnut technologies. Within and between LGAs, spillovers of this nature could save resources for awareness raising and related enhancement of farmers' capacities on technology use. 🍌

Description of constraint	Project LGAs		Non-project LGAs	
	Frequency	%	Frequency	%
Difficult access improved seeds	27	24.1	55	49.1
Late arrival of improved seeds	13	11.6	13	11.6
Poor quality of seeds supplied	4	3.6	7	6.3
Undesirable variety supplied	2	1.8	37	33.0

Table 5

Constraints to the adoption of improved groundnut varieties.

Acknowledgments

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Moves to Establish *Just, Fair and Affordable* Prices for Certified Groundnut Seed in Northern Nigeria

Three words
– **fair, just and affordable** –
are key to ensuring that farmers in
Northern Nigeria continue to profit
from the right to exchange
farm-saved seeds.



Some 80% to 90% of the world's seed stocks are provided through systems primarily managed by farmers. In such systems, farmers procure seeds from other farmers with excess plantable materials to share and/or sell to other farmers. Denying farmers the right to exchange seeds could mean a substantial loss of rural cash income and quality seeds.

In the five States where the USAID-funded Groundnut Upscaling project is being implemented, ICRISAT facilitated five Focused Group Discussions (FGDs) to demonstrate that community-based seed producers can make quality seeds available to farming communities with realistic profit margins, thereby making farmer-to-farmer seed exchanges a regular and reliable source of cash incomes and quality seeds.

Photo 14

A bountiful
harvest.

Indeed, the Nigerian seed policy fully recognizes farmers' rights to seed exchanges as it stipulates that "farmers will maintain their right to use, exchange, share or sell their farm-saved seeds among themselves without any restriction and will have the right to continue using any varieties of their choice without being hampered by the system of compulsory registration provided they do not commercialize production emanating from proprietary varieties" (Point 4.6, National Seed Policy, 2014).

A core activity of the USAID Project is the *Enhancement of the Production and Availability*

of Different Classes of Improved Seed Varieties to Farmers. The promotion of community-based seed production is one of the core elements of this support. From the 2015 cropping season onwards, ICRISAT, in collaboration with project partners, identified and trained a total of 93 community-based seed producers to produce and facilitate access of farmers to certified seeds within their respective communities.

In total, the FGDs brought together 174 value-chain actors, comprising 66 community-based seed producers, 58 extension agents, 37 agro-input dealers/service providers and 13 other

Description of inputs / farm operations	Jigawa State		Katsina State		Kano State		Kebbi State		Sokoto State	
	Mean Cost	%	Mean Cost	%	Mean Cost	%	Mean Cost	%	Mean Cost	%
1. Land rental (rate /ha) ¹	9,000	5.72	8,500	6.31	9,600	6.43	7,000	5.37	8,100	6.99
2. Seeds (70 kg/ha) ²	24,600	15.61	19,200	14.25	20,000	13.41	20,833	15.99	11,960	10.33
3. Fertilizers (NPK and SSP) (1 bag of NPK to 3 bags of SSP per ha) ³	22,500	14.50	30,000	22.27	22,900	15.35	23,000	17.65	23,000	19.86
4. Pesticides (all categories) ³	8,850	5.61	3,200	2.37	2,750	1.84	3,742	2.88	4,920	4.25
5. Labor for different farm operations ^{4, 5}	74,100	47.08	58,750	43.6	83,800	56.17	43,149	33.11	53,460	46.16
Total cost of farm operations	139,050	NA	119,650	NA	139,050	NA	97,724	NA	101,440	NA
Imputed cost of farmer's time ⁶	18,000	11.43	15,000	11.14	10,000	6.70	32,500	24.94	14,300	12.34
Desired profit margin per kilogram of seeds produced by community-based seed producers	92.83	0.06	108.77	0.08	113.51	0.07	84.26	0.06	75.58	0.07
Total costs per hectare (N)	157,144	100	134,732	100	149,195	100	130,310	100	115,816	100
Average yield per hectare (kg)	1,000	NA	954	NA	800	NA	960	NA	750	NA
Unit price per kg of seeds produced (N)	157.14	NA	141.23	NA	186.49	NA	135.74	NA	154.42	NA
Agreed market price per kg (N)	250.00	NA	250.00	NA	300.00	NA	220.00	NA	230.00	NA
Expected total revenue per hectare (N)	250,000	NA	239,600	NA	240,000	NA	211,200	NA	172,500	NA
Gross Profit Margin (N)	92,856 (37%)	NA	103,268 (43%)	NA	94,805 (40%)	NA	80,890 (38%)	NA	56,684 (32%)	NA

¹ Imputed cost as farmers own most land, ² Foundation seeds provided, ³ Open market cost, ⁴ Farm operations requiring the use of labor include: land clearing, plowing/ridging, shelling, planting, weeding, fertilizer application, spraying for pesticides, stripping, harvesting, drying and transportation of inputs/pods and haulms from fields to homes, ⁵ Mostly done by women and children in all States, ⁶ Imputed cost

actors; 161 of the participants were men while 13 were women. After explaining the objective of the exercise and responding to a series of concerns, participants worked in clusters representing their Local Government Areas (LGAs) (Table 6). The outcomes of each cluster, representing participating LGAs were extensively discussed and consolidated into each of the five States where the project is being implemented. Imputed costs were later agreed upon and added as a separate cost items.

The outcomes of the FGD are summarized in table 6. The core elements of producing certified

seeds are: labor (44%), followed by fertilizers (17%) and then seeds (14%). Agreed market prices for certified seeds vary from a low of Naira 220 (72 US cents) in Kebbi to a high of Naira300 (98 cents) in the commercial city of Kano. These agreed market prices include the profit margins of community-based seed producers, which represent an insignificant proportion of agreed market prices across the five project States.

Recurrent farmer-to-farmer seed exchanges will continue to thrive alongside formal system distribution and marketing systems. In such circumstances, results presented here underline one of several entry points for linking agricultural sector policies and regulations to the realities of seed markets.

Regardless of attempts to ensure that fair, just and affordable prices are established for quality seeds, consistent awareness remains vital to ensure that farmers are conscious of differences in seed classes. The prices agreed upon during the FGDs are cheap enough to enable willing farmers to buy (**affordable**), are supported by facts (**just**), and are also free from speculative tendencies (**fair**). ●

Overall for the States			
Total	%	Mean	Standard deviations
42,200	6.14	8,440	± 981
96,593	14.06	19,318.6	± 4,604
121,400	17.66	24,280	± 3,204
23,462	3.41	4,692.4	± 2,461
313,259	45.59	66,651.8	± 16,695
596,914	NA	119,383	± 19,778
89,800	13.07	17,960	± 8,616
474.95	0.06	94.99	± 16.04
687,197	100	137,439	± 16,219
NA	NA	892.8	± 110
NA	NA	155	± 19.7
1250	NA	250	± 30.8
113,300	NA	222,660	± 31,553
428,503	NA	85,700	± 18,082



Table 6

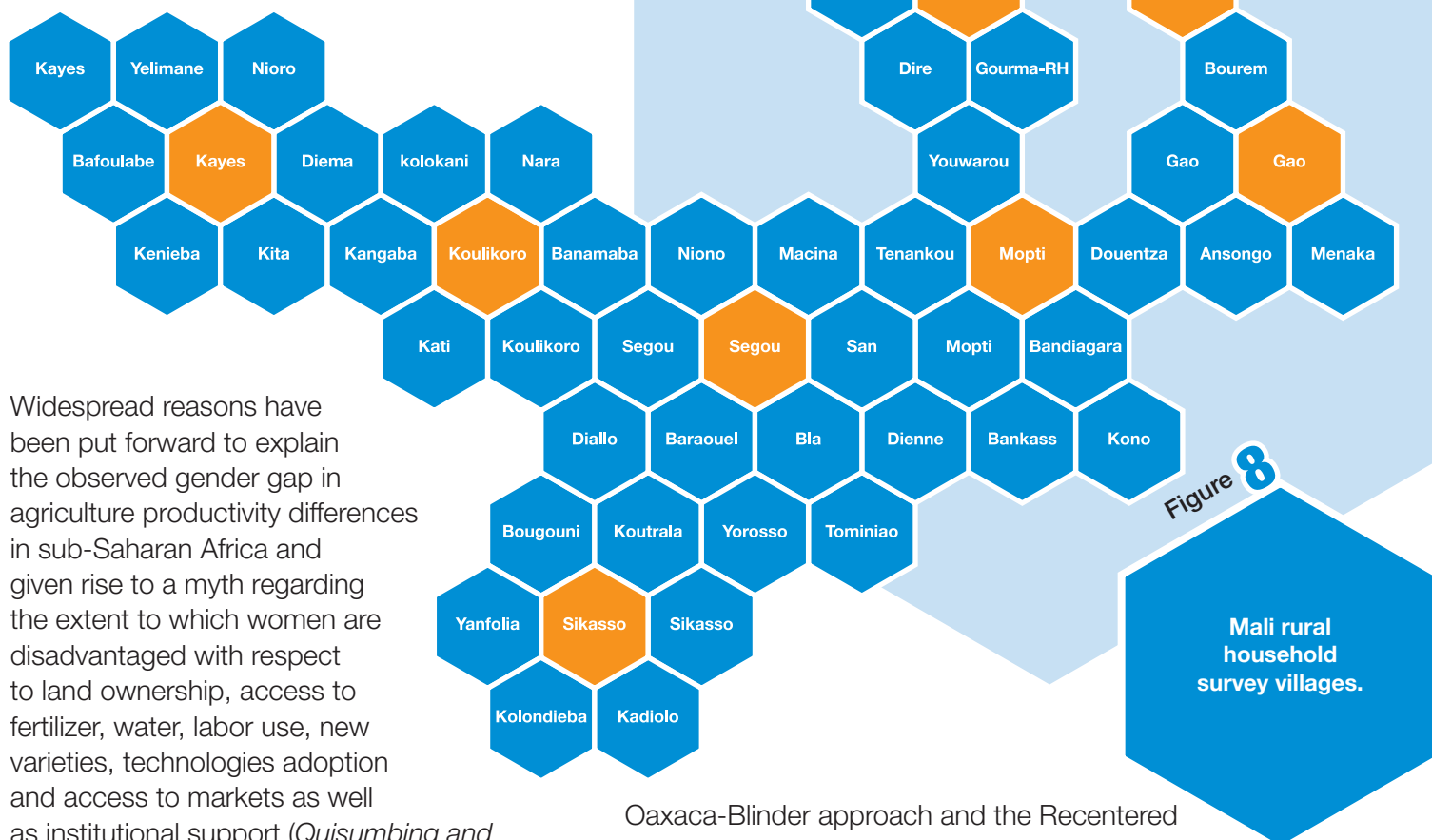
Per Hectare Costs (Naira) and Expected Returns of Producing Certified Groundnut Seeds in Selected States of Northern Nigeria

Photo 15

A scientific team visits seed plots in Nigeria during 2016 main season. This Samnut-24 plot highlights one of the groundnut varieties promoted in Increasing Groundnut Productivity of Smallholder Farmers.

Gender Agricultural Productivity Gap in Mali

Unravelling the underlying reasons for the gender disparity in farmer incomes is tackled in a new study undertaken in Mali by ICRISAT-WCA.



Widespread reasons have been put forward to explain the observed gender gap in agriculture productivity differences in sub-Saharan Africa and given rise to a myth regarding the extent to which women are disadvantaged with respect to land ownership, access to fertilizer, water, labor use, new varieties, technologies adoption and access to markets as well as institutional support (*Quisumbing and Pandolfelli, 2010; Doss et al., 2015*).

Mali is one of the West African countries located in dryland areas and has a population of 14.5 million people, 50.4% of whom are female. Out of the 77.46% of the population living in rural areas of Mali, about 50.58% are female. Of the 35% of active female population, more than 84% are rural women farmers (*FAO, 2017*). Although women play a major role in agriculture in Mali, little is known of the gender agricultural productivity differences. Recently, several empirical studies in other SSA countries have investigated the extent of this gender gap. The aim was to directly and explicitly address the underlying causes in the disparities of the observed gender gaps (*Kilic et al., 2015*).

The ICRISAT study investigates the decomposition of gender agricultural productivity gap and factors that underline the gender differences in Mali. It uses the

Oaxaca-Blinder approach and the Recentered influence function decomposition methodology to quantify farm income gap between male and female agricultural plot managers. The study makes use of the national representative World Bank data from the Living Standards Measurement Study and the Integrated Surveys on Agriculture (LSMS-ISA) for Mali of 2014. Released by the Planning and Statistics Unit of the Ministry of Rural Development with the assistance of the World Bank team, this data set is representative of the nation and covers all regions, excluding Kidal region (Figure 8).

On average, female plot managers have less agricultural income than male plot managers in the study area. The income from plots managed by a female manager (FCFA186,337.20 equivalent to US\$344) was significantly lower, at the 1% level, than that of a male manager due to a difference of FCFA56,971.13 (US\$105). The value of harvest per ha (i.e., productivity) is calculated by dividing the harvest value per

area of the plot. On average, the harvest value per ha for the full sample is FCFA536,407.20 (US\$990). The value number for plots managed by a female (FCFA429,587.20, equivalent to US\$792) is also significantly, at the 1% level, lower than those of a male, with FCFA200,184.50 (US\$369) difference. The mean values show that male plot managers achieve more output per ha compared to female plot managers.

Female plot managers are likely to have less area, more likely to live in households with a higher adult and child dependency than male managers on average. Female plot sizes average 6% smaller than male-held plots. The average size of female-managed plots is 0.78 ha while that of male managers is 0.83 ha, and the difference is significant at the level of 10%. Female-managed plots are located farther from the household compared to the male plots (Table 7). It can be explained by the fact that female plot managers are allocated new farms that are located on the outskirts of a village. These plots are sometimes abandoned by men. Female plots managers use more purchased seeds per ha than males, with a 2% difference on average.

Another reason for differences in productivity may be the use of other inputs. In terms of

non-labor inputs, male plot managers are more likely than female plot managers to be using inorganic fertilizer, herbicide and pesticide, and using them in greater quantities. Labor inputs are categorized into family (men, women and children) and hired labor (men, women and children). Male plot managers are more likely to be able to use family labor than female-managed plots, with 2% difference on average. In addition, male plot managers get significantly (at the 5% level) more days of men labor on average, with 2.97 days difference of labor.

On the other hand, female-managed plots are also likely to use more women family labor compared to male managed plots, with 3% difference on average. Female-managed plots get more days of female family labor than male-managed plots. The degree of difference remains the same with normalization. In terms of labor from outside the household, female plot managers are less likely to use male hired labor compared to male plot managers, with 3% of significant difference at the 1% level. Once we normalize the number of days for family labor with plot size, male plot managers still use more male hired labor than female plot managers, but the difference is not statistically significant.

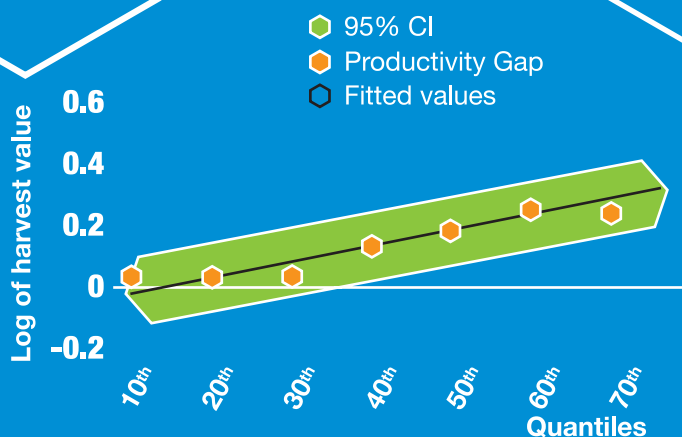
In summary, it can be noted that the essential part of 20.3% of gender productivity gap can be attributed to the female's structural and the endowment effect. The essential part of this gap (58.62%) remains unexplained after accounting for that part of the gap explained by gender differences in plot manager characteristics (endowment effect).

The structural effects are significant at full sample and at the level of all percentiles of agricultural productivity, except the first three percentiles. This suggests that above the first three percentiles (10th to 30th) of agricultural productivity, female managers obtain on average lower returns from the factors they apply on their plots compared to male managed plots.

The positive and significant coefficients of the female structural disadvantage at the full sample and from 40th to 80th percentiles across distributions of the aggregate decomposition suggest that unobservable factors work against the endowment effect widening the gender gap in agricultural productivity. But from 10th to 30th percentiles, the female structural disadvantage's coefficients are not important and are insignificant. The important information from the results is that the plot size is not a determinant in explaining the gender gap. The structural effects' magnitude suggest that equalizing access to the factors of production across managers is unlikely to close the gender gap in Mali.

Figure 9

Effect productivity gap across the quantile distribution.



Variables	All	Male	Female	Difference
Productivity measures				
Harvest value (FCFA ^a)	216,737.40	243,308.30	186,337.20	-56971.13***
Harvest value (FCFA ^a /ha)	536,407.20	629,771.70	429,587.20	-200,184.50***
Manager characteristics				
Age	41.38	42.76	39.79	-2.97***
Secondary educational level				
Basic educational level				
Household adult size (age 15–64)	6.78	6.72	6.85	0.13
Household male adult size (age 15–64)	3.20	3.26	3.14	-0.12**
Household female adult size (age 15–64)	3.58	3.46	3.71	0.25***
Children 0–14 years old	6.93	6.78	7.11	0.33**
Children under 5 years	3.09	3.02	3.16	0.14*
Children 6–14 years old	3.85	3.76	3.95	0.19**
Child dependency ratio	1.14	1.13	1.15	0.02
Main production				
Maize (=1 if yes)	0.16	0.17	0.06	-0.11***
Millet (=1 if yes)	0.26	0.26	0.07	-0.19***
Sorghum (=1 if yes)	0.20	0.20	0.08	-0.12***
Groundnut (=1 if yes)	0.16	0.42	0.15	-0.27***
Paddy (=1 if yes)	0.11	0.27	0.10	-0.17***
Cotton (=1 if yes)	0.01	0.01	0	-0.01
Plot characteristics				
Area (self-reported ha)	0.81	0.83	0.78	-0.05*
Plot distance to HH (km)	5.65	5.19	6.19	0.99**
Soil: loam (=1 if yes)	0.50	0.50	0.33	-0.17***
Soil: clay (=1 if yes)	0.38	0.51	0.37	-0.14***
Soil: red (=1 if yes)	0.05	0.05	0.06	-0.01
Soil: other (=1 if yes)	0.05	0.05	0.05	0.00
Plot slope: flat top (=1 if yes)	0.65	0.65	0.63	-0.02
Plot slope: slightly steep (=1 if yes)	0.13	0.13	0.14	0.01
Plot slope: very steep (=1 if yes)	0.01	0.00	0.01	0.01*
Plot slope: other (=1 if yes)	0.19	0.19	0.19	0.00
Erosion (=1 if yes)	0.98	0.98	0.98	0.00

^a The noted significance level for the difference in mean characteristics between sole female managed plots and all other plots is from running the corresponding least squares regression allowing for the errors to be clustered by enumeration area; ***P < 0.01. **P < 0.05, *P < 0.1. a US\$1 equals to FCFA542.07 in 31/12/2014.

Summary statistics and results from tests and mean differences by gender of the plot manager.

Table 7

Variables	All	Male	Female	Difference
Family labor				
Family labor	0.99	0.98	0.99	0.01
Male family labor (=1 if yes)	0.87	0.88	0.86	-0.02**
Male family labor (days)	19.16	20.54	17.57	-2.97**
Male family labor (days/ha)	50.37	58.12	41.50	-16.62***
Male family labor days/ha (conditional on use)	116.77	130.35	100.84	-29.51***
Female family labor (=1 if yes)	0.59	0.57	0.60	-0.03**
Female family labor (days)	8.46	8.89	7.97	-0.92
Female family labor (days/ha)	9.50	10.22	8.67	-1.55*
Female family labor days/ha (conditional on use)	87.60	89.77	85.28	-4.49
Used child family labor (=1 if yes)	0.65	0.65	0.65	0.00
Child family labor days	12.78	13.38	12.09	-1.29
Child family labor (days/ha)	49.20	50.95	47.20	-3.75
Child family labor days/ha (conditional on use)	123.93	113.58	135.96	22.37
Hired labor				
Hired labor (=1 if yes)	0.14	0.15	0.12	-0.03***
Male hired labor (=1 if yes)	0.12	0.13	0.11	-0.02***
Male hired labor (days)	18.33	18.33	18.34	0.01
Male hired labor (days/ha)	4.23	4.63	3.78	-0.86
Male hired labor days/ha (conditional on use)	83.31	98.19	61.35	-36.84
Female hired labor (=1 if yes)	0.40	0.50	0.30	-0.20***
Female hired labor (days)	0.71	0.82	0.57	-0.25
Female hired labor (days/ha)	32.6	30.85	35.68	4.82
Female hired labor days/ha (conditional on use)	50.93	52.48	48.06	-4.42
Used hired child labor (=1 if yes)	0.30	0.30	0.32	0.02*
Hired child labor days	27.6	37.17	13.46	-23.71
Hired child labor days/ha	147.33	227.31	29.21	-198.10
Child hired labor days/ha (conditional on use)	38.83	41.42	34.81	-6.61
Inputs				
Pesticide (=1 if yes)	0.24	0.23	0.23	0.00
Pesticide (kg)	2.7	2.79	2.59	-0.21
Pesticide (kg/ha)	5.00	5.18	4.79	-0.39
Organic fertilizer (=1 if yes)	0.99	0.99	0.99	0.00
Organic fertilizer (kg)	6,841.58	7,233.70	6,353.51	-880.17
Organic fertilizer (kg/ha)	17,757.31	20,065.14	14,884.83	-5,180.32**
Inorganic fertilizer (=1 if yes)	0.33	0.35	0.31	-0.04***
Inorganic fertilizer (kg)	2,601.34	3,151.54	1,890.09	-1,261.45
Inorganic fertilizer (kg/ha)	4,256.54	4,528.20	3,905.35	-622.85
Used purchased seed (=1 if yes)	0.87	0.86	0.88	-0.02*
Observations	5,341	2,850	2,491	5,341

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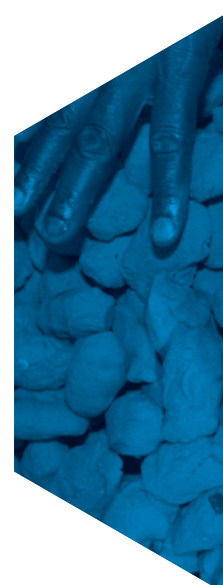
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About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, nonpolitical organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners from throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger, malnutrition and a degraded environment through better and more resilient agriculture. ICRISAT is headquartered near Hyderabad, Telangana state, India, with two regional hubs and eight country offices in sub-Saharan Africa. ICRISAT is a member of the CGIAR System Organization.

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We believe all people have a right to nutritious food and a better livelihood.

ICRISAT works in agricultural research for development across the drylands of Africa and Asia, making farming profitable for smallholder farmers while reducing malnutrition and environmental degradation.

We work across the entire value chain from developing new varieties to agribusiness and linking farmers to markets.

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ICRISAT appreciates the support of CGIAR investors to help overcome poverty, malnutrition and environmental degradation in the harshest dryland regions of the world. See <http://www.icrisat.org/icrisat-donors.htm> for full list of donors.



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