ICRISAT
West and Central Africa

2014 Highlights

Repossessing landscapes, bringing more food and hope
ICRISAT-WEST AND CENTRAL AFRICA LOCATIONS

ICRISAT-Mali (Regional Hub)
BP 320, Bamako, Mali
Phone: + 223 20 70 92 00
Fax: + 223 20 70 92 01
Email: icrisat@icrisatml.org

ICRISAT-Niger
BP 12404, Niamey, Niger (via Paris)
Phone: + 227 20 72 25 29
Fax: + 227 20 73 43 29
Email: icrisatcs@cgiar.org

ICRISAT-Nigeria
PMB 3491, Sabo Bakin Zuwo Road, Tarauni, Kano, Nigeria
Phone: +234 70 34 88 98 36
Email: icrisat-kano@cgiar.org

Citation

Contributors

Concept and editorial coordination
Agathe Diama, ICRISAT (a.diama@cgiar.org)

Editing and Proofreading
Textpolish (www.textpolish.com)

Design and layout
Quadrigraph sarl

Cover page
Agathe Diama, ICRISAT

2015 ICRISAT WCA. All rights reserved

www.icrisat.org
ICRISAT's scientific information :
http://EXPLOREit.icrisat.org

This is a draft version for limited circulation only.
Repossessing landscapes, bringing more food and hope

ICRISAT West and Central Africa 2014 Highlights

Repossessing landscapes, bringing more food and hope
CONTENTS

• Message from Director General 6
• Message from Director West and Central Africa 8

CGIAR RESEARCH PROGRAM ON POLICIES INSTITUTIONS AND MARKETS 12
Market studies and analysis
• Farmers hold the key to Mali’s sorghum market 12
• Good home-produced quality seed puts Malian farmers ahead of the game 14
• Imagery for Smallholders: Activating Business Entry points and Leveraging Agriculture (ISABELA) 16

CGIAR RESEARCH PROGRAM ON DRYLAND CEREALS 18
Technology diffusion and uptake
• Improved sorghum and pearl millet varieties flourish under the HOPE project 18
• Large-scale diffusion of technologies for sorghum and millet systems in Mali 22
  → Success stories from the Africa Rising large-scale Diffusion of Technologies of Sorghum and Millet Systems project 24
• Dual-purpose sweet sorghum, a new option for farmers to increase their income 28
• Sorghum landraces for development of diversified adaptable sorghum hybrids in Nigeria 29
• Parasitoid wasps for biological control to become a new Sahel cottage industry 31

CGIAR RESEARCH PROGRAM ON GRAIN LEGUMES 32
• Improving Nigeria’s groundnut landraces for resistance to multiple biotic and abiotic stresses 32
• Positive income impact for women groundnut farmers: from PVS to seed production and marketing 34

CGIAR RESEARCH PROGRAM ON DRYLAND SYSTEMS 38
• System intensification as an adaptive mechanism to climate change 38
• Watershed Management involves the community beyond farm level 40
• Friendly fungi are enrolled to offset soil nutrient mining 45
• Investment in Niger to meet the challenges posed by hunger and poverty 48
• Sorghum in poultry feed brings extra value to the crop-livestock system 50
• Sharing new ideas for baking and fueling cookers with sorghum 53
It is my pleasure to share with you the West and Central Africa (WCA) 2014 Highlights which summarizes our work over the year to improve the lives of smallholder farmers in the region.

During my visits to WCA, I was impressed by the support, dedication and spirit of engagement of all our stakeholders, including farmers and producers’ organizations, non-government organizations, scientists, National Agricultural Research System partners and the private sector. I value the meetings I had with leaders of the region which helped me get acquainted with the agricultural priorities in each of the countries. Meetings like these emphasize the importance of the country strategies we are working on to align with national priorities and to work along the crop value chain.

In Mali, I met the President, His Excellency Ibrahim Boubacar Kéita, and learnt that a substantial part of the government’s budget is allocated to agriculture and that investing in the agricultural sector is considered important not only for food security but also as a source of income by the government.

For many countries in WCA, food sovereignty is a top priority. ICRISAT’s family farming initiatives to help households improve their productivity, nutrition and livelihoods is crucial. In Niger, we are part of the 3N (Les Nigériens nourrissent les Nigériens) initiative to strengthen its engagement in the country. We are also engaged in collaborative projects which have been very successful in demonstrating new varieties of millet, cowpea, and groundnut and cultivation of dry-season vegetables through bio-reclamation of degraded lands.

Climate change is also a major concern. We will work on translating our experience in watershed management in India to address the challenges of water and land management in WCA. We will also work towards introducing varieties that are more drought resistant.

In Niger we are investing in new infrastructure for phenotyping for crop adaptation to abiotic stress.

For ICRISAT nutrition of farming households, especially of women and children, is a key driver as we follow the Inclusive Market-Oriented Development approach that enables better inclusion of youth and women in the agricultural sector. We are also committed to exploring ways to leverage the potential of digital technologies to support market integration, financial services and knowledge exchange among smallholder farmers.
In Nigeria I have seen what has been achieved through our partnerships, especially with the Federal Ministry of Agriculture and Rural Development, in providing improved varieties of sorghum, pearl millet and groundnut along with agronomic practices to increase farm profitability. I also see the challenges in setting up infrastructure like laboratories and modernizing agriculture and we are working to overcome these challenges.

Researchers in Nigeria and Mali are beginning to use tablets for electronic data capture for trial plots using software from the Breeding Management System and in Niger we are creating awareness on using climate-smart technologies and Integrated Soil Fertility Management. Also, these new technologies are part of a broad strategy of attracting youth to agriculture as we explore ways to provide year-round rural employment and reduce migration to cities.

Our vision is a prosperous, food-secure and resilient dryland tropics. We have a mission to serve the poorest of the poor, and through demand-driven innovation and strategic partnerships, we shall increase the pace of delivering science-backed technologies to the farmers.

David Bergvinson
It has been extraordinarily rewarding to work with members of this organization and partners in the region since I joined as Director for West and Central Africa in April 2014. However, as a scientist I have had the opportunity to collaborate with many colleagues who have been with ICRISAT over the decades. As in the past, I am always inspired by your commitment and by our shared belief that the critical work we do has a positive impact on our communities and our natural landscape in the Semi-Arid tropics in West and Central Africa.

Before outlining the content of this Research Highlights, I would like to pay tribute to my predecessor as ICRISAT Director, West and Central Africa, Dr Farid Waliyar, who led the region with great distinction until mid-2014. Under his leadership the institute built upon his reputation for very high quality work addressing the needs of the small-scale farmers in this region.

I must say that this collection of research highlights offers an opportunity to update and further engage our partners within the region as we implement the CGIAR Research Programs in which ICRISAT has a leading role or other involvement, namely: CGIAR Research Programs on Dryland Cereals, Grain Legumes, Dryland Systems, Policies, Institutions and Markets, Climate Change, Agriculture and Food Security, and Agriculture for Nutrition and Health.

The research highlights bring you to the heart of the interesting issues of crop diversification and resilient systems in improving productivity, yields, market access, revenues and livelihoods of the small-scale farmers who struggle with harsh climatic conditions in the semi-arid tropics.

Under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), an article highlights the role and importance of agricultural information for the mitigation of climate change through the value and benefits of using seasonal climate forecasts in agriculture, with some evidence from the cowpea and sesame sectors in northern Burkina Faso; this reinforces earlier indications from a CCAFS West Africa program on pilot sites in Burkina Faso, Ghana, Mali, Niger and Senegal.

Also, the report leads you through new steps that are being taken to cement the willingness and efforts of climate change stakeholders in five semi-arid countries to build capacity of local stakeholders to help influence policy changes related to climate change and thereby overcome the fragmentation and lack of coordination that has bedeviled previous attempts to implement major shifts in cropping and livestock management to offset climate change impact.

Sorghum is among the top crops produced by farmers in the region, and it is these self-same farmers who underpin the cereals marketing system. As part of the CGIAR Research Program on Policies, Institutions and Markets, the results of studies and analysis on sorghum marketing in Mali are being screened.

Furthermore, we introduce you to yet more major findings relating to sorghum, millet and groundnut within the region: for example, in Nigeria where promising steps have been taken to develop high-yielding and disease-resistant sorghum hybrids suitable for the dry northern zones in that country; in Mali, dual-purpose sweet sorghum varieties are offering farmers expanded opportunities for income from
selling fodder and sweet juices and syrup as well as grain; in Niger, we are pleased to unveil the successful experience with efforts towards the development of a cottage parasitoid industry for biological control of the millet head miner in the Sahel.

As part of the CGIAR Research Program on Grain Legumes, you will learn more about Nigeria’s groundnut landraces for resistance to multiple biotic and abiotic stresses, and how impact is made through participatory selection of improved groundnut varieties with women’s groups in Mali.

Evidence from the CGIAR Research Program on Dryland Systems will guide you to system intensification as an adaptive mechanism to climate change in Nigeria, and to watershed management efforts beyond farm level in the Sudanian Zone of Mali. Then, discover some results of studies of the impact of planting density of four legume crops and one cereal crop on the mycorrhizogenic capacity of sandy soil, and new facilities for phenotyping drought and low nutrients across seasons in Niger.

The use of sorghum in poultry feed in crop-livestock systems is another important focus in Niger and Nigeria where positive experiences are ongoing. Potent and early testimony to the power of digital agriculture is also evident through field research with remote sensing applications.

Last but far from least, as part of our Smart Foods campaign, we present the results of a farmer participatory food tasting experience as a crucial step to adoption of improved varieties, using the example of sorghum tô, a very popular food in Mali. Please, feel free to reach out to us at any time; we are happy to hear from you. Thanks to all our colleagues and partners for your efforts on our shared goals.

Ramadjita Tabo
HIGHLIGHTS

2014

Repossessing landscapes, bringing more food and hope
Farmers hold the key to Mali’s sorghum market

Sorghum is among the top three crops produced by Malian farmers, and it is these self-same farmers who underpin the country’s sorghum marketing system.

A study by ICRISAT West and Central Africa shows that, on average, about 27% (8 to 36% of individual harvests) of sorghum produced is sold into spot markets, indicating that sorghum grain is only sold to buyers once farmers have determined the quantity necessary to cover their own household consumption. However, some farmers invariably find they are short of grain in the lean period and have to buy sorghum from local markets. Figure 2 shows the sorghum commercialization system after harvest. Most farmers sell their product between November and February. Limited quantities of sorghum are traded in the lean period from July to October. The price of sorghum varies with the sale period, with a price ranging from FCFA 75/kg to FCFA 160/kg from November to May.

The sorghum marketing system consists of five categories of actors: farmers, collectors, wholesalers, retailers and consumers.

Farmers – The first major players in the sorghum value-chain. Although more than 70% of production is for their own consumption, they are largely responsible for ensuring national sorghum supply meets local demand. They are in direct contact with collectors in the production areas to whom they sell crop, which all farmers store at home in granaries (Figure 1).

After about three to five months of storage, the sorghum grains are often attacked by insects, but very few farmers use pesticide to control insect damage. Most farmers sell their surplus grain at home to keep down transport costs. It is important to note that the vast majority of sorghum producers also cultivate other cereals such as maize and rice, which increasingly compete with sorghum in terms of area cultivated.
Nowadays, there is a strong swing to producing these alternative cereal crops, especially maize for which farmers benefit from mineral fertilizer subsidies from the Malian Company for Textile Development (CMDT) in cotton areas and from the national government.

**Collectors** – There are two types of collectors: producer-collectors and specialized collectors (Figure 2). Both types generally live in the production areas and buy sorghum grains on a weekly basis for sale to wholesalers on the spot local market. Collectors travel to neighboring villages to collect grain from farmers, with some collectors having sufficient financial capital to buy large quantities of sorghum during harvest periods to store for a maximum of six months. This stock is then sold in the local markets or to wholesalers in urban and regional markets. Producer-collectors are farmers both producing sorghum and also collecting it from other farmers. This type of collector is usually a member of such cooperatives as the Union Locale des Producteurs de Céréales (ULPC) or the Association des Organisations Professionnelles Paysannes (AOPP). Both farmers’ organizations collect and sell sorghum and other crops to development aid organizations, including the World Food Program (WFP) and Oxfam Quebec.

During the 2014/2015 agricultural campaign, WFP alone bought 6,424 tons of sorghum in Mali, indicating the important role WFP plays in cereal commercialization. Collectors are highly knowledgeable on the supply and market conditions, and are major players in setting the price of sorghum because of the central role they play between farmers and wholesalers.

**Wholesalers** – As with collectors, there are two types of wholesaler: local wholesalers and external wholesalers. Local wholesalers often buy from collectors or, sometimes, from producers in local markets, and then deliver their stock to the external wholesalers who primarily operate from Mali’s major urban centers (Bamako, Mopti, Sikasso, Segou, etc). Local wholesalers contract verbally with collectors and also finance their farming activities. During shortage periods (about four to six months after harvest), local wholesalers also collect sorghum directly from farmers. Unlike the collectors, local wholesalers pack sorghum and other cereal grains in bags of 100 kg for storage in their own warehouses while they build up large stocks for sale to the external wholesalers who usually buy their product from local wholesalers. Trucks are used to deliver purchased sorghum grain to urban centers.

**Retailers** – In urban areas, retailers usually buy sorghum from wholesalers but their role in the marketing of sorghum is very limited. Indeed, the majority of household consumers and processors buy large quantities from wholesalers. Retailers do not have a strong influence in determining selling and buying prices. Some are mobile retailers going from market to market, while others have fixed sale points. They usually buy small quantities on a daily basis for immediate sale to consumers. The vast majority of players in the marketing of sorghum are men, along with a few female mobile retailers.

---

<table>
<thead>
<tr>
<th>Sorghum Producers</th>
<th>Small Producers</th>
</tr>
</thead>
</table>

**Collectors** | **Wholesalers** | **Retailers** | **Consumers** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Producers-collectors</td>
<td>Local wholesalers</td>
<td>Villages Retailers</td>
<td>Households</td>
</tr>
<tr>
<td>Specialized Collectors</td>
<td>External Wholesalers</td>
<td>Retailers</td>
<td>Processors</td>
</tr>
</tbody>
</table>

---

**Figure 2: Sorghum commercialization after harvest (normal period)**

---

Repossessing landscapes, bringing more food and hope
A 62-year-old farmer, head of a 25-member household and president of the local farmer cooperative Jigi Seme, Souleymane knows how important good seeds are for the farmer’s wealth. The cooperative, made up of 65 families, produces sorghum and maize, and legumes like cowpea. They have recently secured a contract from the World Food Programme’s Purchase for Progress scheme to sell sorghum grain. They are also engaged in producing quality seeds including new sorghum hybrids.

Eighty percent of Malians rely on low-yielding agriculture for their livelihood, often jeopardized by unpredictable rains, poor soils and limited access to productivity enhancing inputs. Most farmers have daily incomes of less than $2, so access to better seeds is often the most promising first step to boost harvests and food security in sub-Saharan Africa.

Agricultural researchers at ICRISAT and the Malian Institut d’Économie Rurale (IER) have developed many improved varieties of sorghum and millet, with some remarkable yield gains. For instance, new sorghum hybrids based on well-adapted local varieties, are giving yields 40% higher than the farmers’ best local variety. Souleymane even reports record yields over three tons per hectare in the best fields when most farmers harvest one ton or less.

Exceptional grain yield results from farmer-managed seed systems are boosting food security in Mali thanks to ICRISAT and its partners. “If you have good seeds, you will be ahead of the game”, says Souleymane Ballo, a respected elder from Mpessoba, a village between Segou and Kouïtiala, in South Mali where he is among the first farmers to benefit from research funded by the McKnight Foundation.

This yield increase is life-changing as sorghum is vital for food and income. Ensuring these improved varieties and hybrids are available to, and adopted by farmers, is the next task. Strengthening the capacity of farmer-managed seed enterprises like Jigi Seme is a promising way to do this.
Malian farmers are not in the habit of buying seeds. “A good farmer produces his or her own seeds”, as Souleymane puts it. This does not mean farmers do not try new seeds. In fact, they regularly test new varieties by obtaining seed through informal means, especially from family and close neighbors. It is a question of trust, which is understandable as varietal adaptation is critical for the farmer and his family’s survival in this highly variable environment.

Supporting decentralized seed production and marketing by local farmer seed cooperatives therefore suits farming communities in Mali. Where cooperatives operate, there is an impressive rate of adoption of improved cultivars. A recent study by ICRISAT, the IER and the McKnight Foundation showed that adoption was 25 to 50% in the villages where the seeds were produced, compared to the national average around 10%. Souleymane says that Jigi Seme produced one ton of sorghum hybrid seeds in 2014 and sold it all in 1 to 5 kg bags (enough seeds to sow up to one hectare). He expects even greater success in 2015.

Yet, recent seed policies do not adequately recognize the contribution of such farmer organizations. Constraints such as rigid and expensive seed certification procedures exclude smallholder farmers. Hopefully, when law-makers hear about the success of Jigi Seme, procedures will be modified so that Malian smallholder farmers will indeed be able to produce and market their own high quality seeds as Souleymane and his cooperative aspire to do, and by so doing help their neighbors achieve a better life.

ICRISAT and IER collaborated in 2013 and 2014 with a total of 28 farmer seed cooperatives in Mopti, Sikasso and Koulikoro regions. They have produced certified seed of sorghum, millet or cowpea varieties adapted to their specific localities and demanded by their clients: eight different sorghum hybrids and their parental lines, 10 different sorghum varieties, as well as different cowpea and millet varieties. For many of them, 2014 was the first season for marketing seed to their fellow farmers: the seeds were sold primarily in packets of 500 g or 1 kg, and total sales are estimated at about 35 t of certified sorghum and pearl millet seed by this type of sale to farmers who had never bought a packet of seed before. Overall, probably some 35,000 families bought seed of a new sorghum or pearl millet variety in 2014.

The seed sellers themselves were curious about their seed buyers’ successes; they called each other and even visited each other’s fields, creating a lot of excitement and a doubling of the area under seed production. Even with that increase, the seed cooperatives expect that their seed production from sowing season June 2015 may not be sufficient to meet all their buyers’ demands.
Imagery for Smallholders: activating Business Entry points and Leveraging Agriculture (ISABELA)

“We're thinking of replacing cotton with peanut. What do you think?”

This is the kind of question popping up in discussions between farmers and scientists in the heart of West Africa's cotton belt as they work together in STARS participatory fertility trials –originally to develop imagery value chains for smallholders.

Modern remote sensing technology, such as satellites, aircrafts and the information they collect, provide data to readily improve agricultural management systems in high-income countries but the application of similar benefits to the small, often indeterminate farming plots in sub-Saharan Africa (SSA) or southern Asia has always seemed much more problematic.

Out of the vast amount of data collected in high-income countries, advice can be provided to farmers on the ground to help inform their decisions about farming methods. This leads to better crop yields, higher quality produce and possibly more sustainable practices for the farming communities. This data can also inform higher-level decisions to manage national food supply needs more effectively.

The significant spatial and technical challenges present in SSA and southern Asia have prevented the use of remote sensing technology in many areas. For example, smallholder farmers, who produce two-thirds of the world's food, often have small plots with variable boundaries, they frequently grow multiple crops on the same plot and there is significant variation in the farm practices they use. These conditions make it difficult to distinguish farming practices from the skies and therefore capture and collate accurate and potentially actionable information, brought to farmer groups, agribusiness and public agencies.

Challenges, such as unproductive soil, plant diseases, pests and drought, mean that many farmers struggle to produce crops consistently and sustainably year-by-year. At a national level, these challenges can also present difficulties in understanding the condition of crops and pastures, seasonal outlooks, access to markets and likely production levels. Decisions such as whether additional food needs to be imported to supplement that season’s harvest, have been misjudged in the past due to a lack of information. There have been examples where produce was imported erroneously before what turned out to be a bumper crop, leading to an oversupply of food and financial difficulties for smallholder farmers as food prices plummeted.

In West Africa like elsewhere, clearly identifying and understanding target customer segments is the first step towards a sound business model. It is a truism that farmers themselves don't need to know which crops stand in their fields - they know it already. However, they may indirectly benefit from input suppliers knowing better the land production potential and investment risk profile for a given community, based on timely, remote sensing estimates of the unfolding season’s potential for each individual farmer field – a knowledge at a granularity level hitherto unthinkable. Furthermore, local government tax recovery (currently levied, inter alia, on livestock and other assets) may expand to include land to help decentralize the equitable management of natural and financial resources. The STARS regional project in West Africa, dubbed ‘Imagery for Smallholders: Activating Business Entry points and Leveraging Agriculture’ (ISABELA) takes on these challenges with concurrent remote sensing of land tenure in 20+ communities, and crop production in 150 individual farmer fields to explore ways in which data can lead to the emergence of smallholder-friendly advisory services.

Astonishing results are emerging from two unprecedented measurement campaigns in Mali and Nigeria, where coordinated data acquisitions by satellites, unmanned aerial vehicle (UAV) and ground crew are not only unveiling fertility treatment effects, but more importantly uncovering enormous variability in smallholder operating conditions – both biophysical and socio-economic. For example, fortnightly satellite and UAV imagery reveal that fertilization effects on any single crop’s canopy cover and height are dwarfed by differences in crop type, which themselves are significantly smaller than the range of variability encountered in management and environment for any single species.

While this presents a tougher than expected challenge for the problem of automated crop recognition, it also demonstrates the power of remote sensing in monitoring crop conditions at a resolution relevant to the smallholder farmer. Assuming the crop is known, eg, from mobile crowdsourcing, then spectral indices, such as NDVI, and derivative variables, such as plant height can monitor degradation of a given field (or fractions thereof) vis-à-vis the neighborhood average, triggering discussion and emulation of best practices amongst farmers. Likewise, long-term monitoring of a given field and crop modeling can build yield probability distributions over a 30-year normal climate and provide, with fertility trials, unique information for land productivity assessments: a fertilizer and pesticide
A retailer or a farmer cooperative could subscribe yearly to an information service providing, for any community of interest, the probable returns on investment for different input levels applied to selected field typologies (combinations of farm endowment and biophysical constraint classes) and genotypes.

In Mali and Nigeria, STARS-ISABELA works with boundary partners (MANOBI S.A., agro-dealers, local government, farmer cooperatives) to develop viable business models for remote-sensed and crowd-sourced land tenure and agricultural information services, into which several thousands of farms are being subscribed following a 3-tier segmentation of the customer base.

The 2015 opening by partner NGO AMEDD of a remote sensing applications laboratory in Koutiala (Mali) demonstrates that STARS already generates outcomes within its own lifetime and provides a potent and early testimony to the power of digital agriculture. Because soon, we’ll also be able to tell Mr Berthe, farmer in Sukumba, what we think replacing cotton by peanut might uncover for him.

**Figure 3.** Plant height estimates from remote sensing (Sukumba, Koutiala district, Mali).

Conceived to explore the use of remote sensing technology in improving agricultural productivity and rural livelihoods in sub-Saharan Africa and South Asia, the STARS project (Spurring a Transformation for Agriculture with Remote Sensing) is literally unraveling the multi-dimensional problem of smallholder agricultural intensification, and shedding unprecedented light into the kaleidoscope of options in West Africa. What was firstly an ambition to use imagery for automatically quantifying the extent of cropland (and individual crops) to give improved agricultural statistics is rapidly turning into something much more profound; a transformative change in the nature, accessibility, frequency and relevance of information needed to address production constraints and opportunities in smallholder agriculture.

**STARS** is a project funded by the Bill & Melinda Gates Foundation and involving:

- **ITC** - The Faculty of Geo-Information Science and Earth Observation at University of Twente, the Netherlands (overall project lead);
- **ICRISAT** - The International Crops Research Institute for the Semi-Arid Tropics, Mali, Nigeria (lead, West Africa component);
- **UCL** - Université Catholique de Louvain, Belgium;
- **WUR** - Wageningen University and Research Centre, the Netherlands;
- **UDES** - Université de Sherbrooke, Canada;
- **MANOBI S.A.**, Senegal;
- **AMEDD** - Association Malienne d’Éveil au Développement Durable, Mali;
- **CDA/BUK** - Center for Dryland Agriculture, Bayero University Kano, Nigeria;
- **NASRDA** - National Space Research and Development Agency, Nigeria.
Introducing Malian farmers to improved varieties of both sorghum and pearl millet has boosted both yields and overall grain production in target villages and spilled over to their non-targeted neighbors.

Pearl millet and sorghum play a critical role in production and supply systems in Mali. These two staple crops account for about 80% of the country’s planted crop area, and for about 49% of cereal production over the period 2009–2010, an increase of 17% compared to the 2008–2009 period. Despite this extra production, yields of pearl millet and sorghum remained low at between 700 kg/ha and 800 kg/ha, according to the survey on production systems of millet and sorghum conducted by ICRISAT in 2010 (baseline data, HOPE project).

A combination of several factors account for these low yields. Lack of seed production systems is a major constraint to sector development. There is almost no structured market for certified seeds as there is for irrigated rice for which the private sector plays a crucial role in both seed production and marketing. Indeed, pearl millet and sorghum farmers use their own seeds (see article on page 14), which are often in poor condition. Fewer than 50% of farmers cultivate improved varieties on their plots.

Before the implementation of the HOPE project, it is estimated that about 31% and 45% of pearl millet and sorghum farmers, respectively, were using at least one improved variety in their plot (baseline survey data, 2009/2010). This highlights the low adoption rate for improved varieties, leading in turn to low levels of production that limit the ability of either sectors to meet national demand, particularly in urban areas, with implications for the other stakeholders.

In response, ICRISAT implemented the HOPE research project to make high yielding varieties of pearl millet and sorghum available to farmers. Based around a project partnership including the country’s Institute of Rural Economy, farmer managed seed cooperatives and non-government organizations, the HOPE project’s main objective is to increase productivity in both sorghum and pearl millet production systems, and thereby increase household income and food
security. A strong project research component is to target opportunities for technology development and delivery to maximize adoption and impacts of innovations on livelihoods. An increase of farmer yields by 30% or more was targeted in the project's first four years, while the overarching hypothesis is to combine improved technologies with institutional innovations that increase market access and demand to drive adoption and increase production of sorghum and millets.

Farmer adoption rates of improved pearl millet and sorghum varieties were assessed following the project's first four years (2009–2013), using the same sampling methods as in the original baseline survey in project villages and non-project villages selected for their proximity to project villages. Villages located around 10 km to 20 km from project villages are termed diffusion villages, i.e., villages where technologies and innovations will easily spill-over, while control villages are those located 40 to 60 km from project villages where it is assumed that technologies being developed in project villages cannot easily spill-over into such far-flung villages.

**Yields and production of pearl millet and sorghum growing under the HOPE project**

For study purposes, all diffusion and control villages in the sample are classed as non-project villages for not benefiting directly from intervention by HOPE project activities. Survey results in Table 1 show that pearl millet production increased during the first four years of implementation of the HOPE project both in project villages and non-project villages in Mali. On the intervention sites, pearl millet production increased by 26% against 16% in the non-project villages. Regarding yields, they increased from 692 kg/ha in 2009 to 874 kg/ha in 2013 in the project villages (21%) against 757 kg/ha in 2009 to 839 kg/ha in 2013 in the non-project villages (10%).

The results obtained for sorghum showed an increase in production by 25% in the project villages against 16% in the non-project villages. Yields of sorghum increased in the same proportions to those of pearl millet (21% for the project villages and 10% for the non-project villages between 2009 and 2013).

**Exposure and farmers going on to plant improved pearl millet and sorghum varieties**

Table 2 shows that during the first four years of implementation of the HOPE project, the proportion of farmers exposed in the project villages to improved varieties increased by 44% and 47% for pearl millet and sorghum, respectively.

The proportion of pearl millet farmers from project villages planting at least one improved variety is estimated at 52% in 2013 against 34% in 2009. The most adopted varieties in project villages were ToroniouC1 (25%), Sanioba (21%), and Sanioteli (7%). About 70% of the sorghum farmers at intervention sites are estimated to have planted at least one improved variety under the HOPE project in 2013 against 40% in 2009. The most adopted sorghum varieties at the intervention sites in 2013 were Seguetana (17%), Kenikedje (15%), Jakumbe (15%) and Tiemarifing (10%).

Table 1: Pearl millet and sorghum production and yields by type of village in Mali.

<table>
<thead>
<tr>
<th></th>
<th>Baseline survey</th>
<th>Early adoption survey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Project village</td>
<td>Non-project village</td>
</tr>
<tr>
<td>Pearl millet producers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production (kg)</td>
<td>1533.42</td>
<td>1069.03</td>
</tr>
<tr>
<td>Yields (kg/ha)</td>
<td>692.46</td>
<td>757.06</td>
</tr>
<tr>
<td>Sorghum producers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production (kg)</td>
<td>1653.89</td>
<td>1611.96</td>
</tr>
<tr>
<td>Yields (kg/ha)</td>
<td>729.07</td>
<td>731.96</td>
</tr>
</tbody>
</table>

Source: constructed using baseline survey and early adoption survey carried out in Mali in 2009–2011 and 2014
Table 2: Pearl millet and sorghum farmers exposed to and having planted improved varieties.

<table>
<thead>
<tr>
<th></th>
<th>Baseline survey</th>
<th>Early adoption survey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Project village</td>
<td>Non-project village</td>
</tr>
<tr>
<td><strong>Pearl millet producers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to improved varieties (%)</td>
<td>45.00</td>
<td>55.00</td>
</tr>
<tr>
<td>Planted at least one improved variety (%)</td>
<td>34.00</td>
<td>53.32</td>
</tr>
<tr>
<td>Most adopted varieties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ToronionouC1</td>
<td>3.94</td>
<td>0.00</td>
</tr>
<tr>
<td>Sanioba</td>
<td>22.83</td>
<td>26.44</td>
</tr>
<tr>
<td>Sanioteli</td>
<td>5.51</td>
<td>9.20</td>
</tr>
<tr>
<td>Guefoue16</td>
<td>7.09</td>
<td>11.49</td>
</tr>
<tr>
<td><strong>Sorghum producers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to improved varieties (%)</td>
<td>48.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Planted at least one improved variety</td>
<td>40.00</td>
<td>32.00</td>
</tr>
<tr>
<td>Most adopted varieties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seguetana</td>
<td>15.44</td>
<td>14.17</td>
</tr>
<tr>
<td>Kenikedje</td>
<td>14.71</td>
<td>14.17</td>
</tr>
<tr>
<td>Jakumbe</td>
<td>6.62</td>
<td>1.57</td>
</tr>
<tr>
<td>Tiemanifing</td>
<td>3.68</td>
<td>2.36</td>
</tr>
<tr>
<td>Tieble</td>
<td>1.47</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Source: constructed using baseline survey and early adoption survey carried out in Mali in 2009–2011 and 2014

*Increase in the area under improved pearl millet and sorghum varieties*

Intensity of adoption of improved pearl millet and sorghum varieties under the HOPE project is evaluated using a Difference-in-Difference method, which has become an increasingly popular way to evaluate causal relationships. The intensity of adoption is defined as the share of total area of pearl millet or sorghum under improved varieties. It entails identifying the effect of a specific intervention like the HOPE project by comparing the difference in the rates of adoption after and before a project for farmers exposed to improved varieties to the equivalent difference for unexposed farmers. The intensity of adoption of improved sorghum varieties before the HOPE project was about 32% and 31%, respectively, in the project and non-project villages.

After the first four years of project, the intensity of adoption is about 48% in the project villages and 40% in the non-project villages. This means that area under improved sorghum varieties increased by 16% from 2009 to 2013 in the intervention sites of the HOPE project. The average project effect on adoption rates is given by the Difference-in-Difference value (9.48). Table 3 shows that the proportion of the millet area under improved pearl millet before project implementation was 29% and 53% in the project and non-project villages, respectively.

The HOPE project therefore led to a 40% increase in area under improved pearl millet varieties at the project intervention sites, giving an estimated net impact of about 15% from the project on the adoption rates of improved pearl millet.

*Removing constraints to large-scale adoption*

Although the HOPE project has contributed to improving the rates of adoption of improved varieties, there are the major constraints that prevent large-scale adoption. For instance, there are the lack of information about management of new varieties, the unavailability of seeds and the low yields and late maturity of certain varieties.

Efforts should be made in the framework of the project’s second phase to include collaboration with the National Agricultural Research Systems, seed companies, and non-governmental organizations to develop seed production companies, and to encourage the proliferation and diversity of dissemination mechanisms for information about management of new varieties.

Research on varieties should be oriented towards high-yielding varieties with a time to maturity acceptable to farmers and easily available seed.
Table 3: Intensity of adoption of improved sorghum and pearl millet varieties under the HOPE project.

<table>
<thead>
<tr>
<th>Intensity of Adoption</th>
<th>Non-project village</th>
<th>Project village</th>
<th>Difference before project</th>
<th>Non-project village</th>
<th>Project village</th>
<th>Difference after project</th>
<th>Difference in Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved sorghum varieties</td>
<td>32.17</td>
<td>31.38</td>
<td>-0.79</td>
<td>39.56</td>
<td>48.25</td>
<td>8.69</td>
<td>9.48</td>
</tr>
<tr>
<td>Improved pearl millet varieties</td>
<td>53.11</td>
<td>29.43</td>
<td>-23.68</td>
<td>58.04</td>
<td>49.28</td>
<td>-8.75</td>
<td>14.92</td>
</tr>
</tbody>
</table>

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009–2011 and 2014
LARGE-SCALE DIFFUSION OF TECHNOLOGIES FOR SORGHUM AND MILLET SYSTEMS IN MALI

Potential success with new crop varieties, seed treatment, pest and weed control is being strengthened by giving sorghum and millet growers proven ways and means to better harvests.

A multi-stakeholder project consortium, including ICRISAT-WCA, is geared to improving sorghum- and pearl millet-based production systems in the Mopti and Sikasso regions of Mali through strengthened research-development partnerships for large-scale use of priority proven technologies. These selected technologies also improve nutrition, benefit women and children and enhance the sustainability of smallholder agriculture.

The project’s innovative approach is to make use of the consortium expertise to enhance the value chain from the production end, produce marketing and end uses. At the farm level, the focus has been to improve production by stepping up access to the identified new technologies and by increasing awareness and ‘know-how’ for the use of existing technologies that enhance sorghum and millet production.

One route is by enabling farmers to see the new technologies at the field level under their own conditions. These ‘marketing plots’, whether as demonstration plots or as part of farmer field school activities, which involve training of trainers, and publicity and awareness dissemination through organized village level visits, involve a hundred or more people per village, and local and regional radio programs that reach thousands. In Mopti region, the major technologies targeted for dissemination to enhance pearl millet production are the following: a) the use of seed treatment such as Apron Star 42WS; b) seed of improved varieties of pearl millet, groundnut and cowpea adapted to the Sahelian environmental conditions; c) integrated *Striga* and soil-fertility management practices; and d) biological control of the pearl millet head-miner.

Enhancing sorghum production is targeted by technology dissemination in the Sikasso region: a) seed treatment with Apron Star 42WS; b) seed of improved cultivars of sorghum (both hybrid and open pollinated varieties), together with groundnut adapted to the Sudanian and northern Guinea agro-ecologies; and c) integrated *Striga* and soil-fertility management practices.

Farmers have shown a preference for the 1/1 fertilizer/seed application rate among those proposed for sorghum because it does not require extra labor. On top of that, the yield has been increased by around 39% compared to standard farmers’ practices. Treatment of millet seed with Apron Star significantly reduced the incidence and severity of diseases in all Training of Trainers (ToT) plots compared to the untreated crops. Grain yield was 20% higher in the treated than the untreated plots (control).
Among the millet varieties, Toroniou is the most appreciated by the producers because of its earliness, its high yield and its large grains compared to G16, which is described by producers as a late seeded variety.

In terms of the sorghum varieties, all producers from Koutiala appreciated Pablo and Fadda hybrids for their high yielding characteristic, their tolerance to drought and for being easy to process into local dishes, unlike the Sewa variety which suffers from high losses during processing and is thus less appreciated for household use. Korobalen is the most popular of the cowpea varieties because of its high yield and adaptability to the Mopti region when compared to Wulibaly, which producers found to be low yielding; however, Wulibaly is highly appreciated in the Sikasso region. Farmers were also convinced of the merits of investment in Integrated Striga Management when it was demonstrated on every ToT site that greater benefit (FCFA 250,000/ha) was generated over the results from following the usual farmers’ practice (FCFA 110,000/ha).

By applying this technology growers can harvest two commodities on the same plot each year and also sell cowpea hay. Because farmers are very happy with the proposed technologies, demand for seeds of the new varieties is high, and the project is organizing direct links between growers and local seed producers to reduce transport costs.

In addition, a Public-Private Partnership is being set up between two institutions – one providing seed treatment chemical (Apron Star) and the other specialized in micro financing systems. This collaboration will create a mechanism that allows farmers to obtain a loan for chemical purchases and substantially increase the number of farmers using seed treatment.

Collaborators: Aga Khan Foundation, Association des organisations professionnelles paysannes (AOPP), Compagnie malienne pour le développement des textiles (CMDT), Catholic Relief Services (CRS), European Cooperative for Rural Development (EUCORD), the Institute of Rural Economy (IER), Mali Agricultural Market Development Trust (MALIMARK), Office de radiodiffusion télévision du Mali (ORTM)
Malian farmer Amadou Togo’s verdict on using seed treatment

On 28 June 2014, I went to my field with my kids to sow the Toroniou variety of millet for seed production. Upon arrival I found my neighbor Mr Souleymane Guindo had already sown his field more than a month before me, and was pleased with the result. He told me that I was too late for sowing and he thought it unlikely I could harvest anything in my field.

Because I had participated in a training organized in Ban- kass by ICRISAT and its partners, during which the trainers presented the product Apron Star and its benefits, I did not think I was too late in sowing and that the plants would catch hold because my seeds were treated with Apron Star. About 24 days later on July 22, my plants had overtaken those of my neighbor despite his plants being sown more than 50 days earlier, and the vigor of my plants was much better. Throughout the month of September, those who did not know the planting dates of the two fields were saying that my field must have been sown one month before Mr Guindo’s field.

I have just harvested my crop and am waiting for weighing to quantify my seeds but the difference from what I got from my plot and what my neighbor got from his field is very significant if you look at the ears of my millets. Millet head miners have attacked the neighbor’s field while my field is free of damage. I do not know exactly how to explain this, but the ears from my field look better than those in my neighbor’s field. My neighbor is now convinced of the effectiveness of Apron Star in promoting vigorous young plants. I win twice over compared to him, because I gain in time and efficiency.

In the same week, I sowed another field with seed treated with Apron Star, but this time using the local millet variety. Unfortunately, there was no rain until 10 days after sowing. After two more days of rain I sent my children to re-sow this field of seeds that had not germinated because of the drought. Once in the field, three of my kids decided to dig up some seed holes to see if there were still some seeds left, and had a pleasant surprise.

The children told me that the seeds treated with Apron Star were still fine after 10 days without rain following sowing. This time it was my children who tried to convince me, because for me the seeds would have lost their ability to germinate after spending 10 days in the soil without moisture. However, the children said: “No, Dad, do not bother wasting time on re-sowing because the seeds from the first planting are viable and they will germinate.” After reluctantly accepting their suggestion, I went to see all the seed holes three days later and realized that all of them had germinated.
In conclusion, it is clear to me that Apron Star is what we need to treat our seeds because it protects the seeds and seedlings, increases plant development and protects plants from disease. As the local farmers’ union president, Mr Togo is now actively involved in selling Apron.

He develops sales strategies such as refundable credit, including payment in kind at harvest to allow even the poor and women producers to be able to get the product. Union members are impatiently awaiting 10 boxes of Apron Star ordered for the next planting season.

→ Farmer Issa Dembele’s account of his experience with the hybrid ‘Pablo’ at Yafola village, Koutiala in collaboration with CMDT

The seeds arrived late and I was dubious about them, so I chose a plot abandoned because of the poorly performing soil and was pleasantly surprised by the new variety.

It produces much better than our old variety, producing 230 sheaves against almost none from the old variety. Tassels are well filled to the point that I have decided not to tie them into the traditional bundles. Yet the areas are the same and all the work has been done in the same way. Our usual variety is too late to mature and needs to be sown early. But, even seeds I have sown earlier and in a good soil were not as good as the new variety on a poor soil.

There is no doubt that the new variety yields many more grains. Everyone visiting my fields has made the same observation. Next year, I will plant a larger field of this new variety if I can find the seeds.

→ Farmer experience with fertilizer micro-dosing techniques in Koutiala

My name is Bakary Dembele, a farmer trainer of Yognogo village, married to one woman and father of 2 girls and 4 boys. I am 54 years old and participated in the training in the previous agricultural campaign. I have 19.5 hectares (ha) of land divided between 2.5 ha of millet, 7 ha of sorghum, 4 ha of maize, 5 ha of cotton, and 1 ha of cowpeas. My main staple crop was maize.

As one of the project beneficiaries, I was able to cultivate 4 ha of millet, maize and sorghum with micro-dosing techniques. This technique allowed me to save on fertilizer costs. Previously, I was using five bags of fertilizer (125 kg DAP and 125 kg urea) on 1 ha of maize, but now fertilize the same area with 70 kg (35 kg DAP and 35 kg urea).

Using the micro-dosing technique has significantly reduced Striga on my plots. Compared to last season, this year I harvested 3 tons of millet compared with 1.5 tons in 2013, 2.5 tons of maize against 1.5 tons, and sorghum 7.5 tons against 3 tons. I will continue to apply these techniques and explain their advantages to other farmers.
Dual-purpose sweet sorghum varieties offer farmers expanded opportunities for income from selling fodder and sweet juices and syrup as well as grain. Although mainly grown for human consumption in the semi-arid tropics, where it constitutes a staple food for 500 million people in over 30 countries, sorghum stover or crop residue is one of the cereal’s by-products much used as animal feed by the majority of farmers, who also keep cattle strongly dependent on natural pastures and by-products from cereals and legumes.

Past research focused on grain yield and quality, and stover traits were rarely considered in variety development in West-African sorghum improvement. Farmers use stover from local landraces, especially off-season when other grasses are limiting, but this stover is highly lignified with low digestibility even for ruminants.

Sweet sorghum produces grains for human consumption and the stover is less lignified with a higher nutritional value than that from landraces. ICRISAT-Mali has developed and compared the performance of dual-purpose sweet sorghum varieties and developed sweet sorghum options that can be exploited by farmers.

Useful Malian sweet sorghum landraces and released varieties from Ethiopia were identified for their yield characteristics for grain, stover, juice and sugar, then crossed in various grain sorghum sets from 2009 onwards. The progenies – 29 caudatum and 42 guinea types – were evaluated on-station during the 2014 rainy season and the best lines combining grain quality, grain stover, juice and sugar yields were selected for on-farm testing using a selection index (SI).

Additionally, a survey was conducted with 112 sweet sorghum farmers in 33 villages in Mali’s Koulikoro region, where sweet sorghum improved varieties had been grown for the past three years, with the objective of identifying current and potential uses for sweet sorghum.

Among the caudatum-type sweet sorghum progenies evaluated, grain yield varied between 2.4 t/ha and 5.25 t/ha while the fresh stover yield was 14 t/ha to 39 t/ha compared to Soumba used in Mali as a dual-purpose control variety (grain yield = 2.85 t/ha and stover yield = 16.5 t/ha). The newly developed progenies maintained 40% to 61% of their leaves green until harvesting and 16 of them had higher selection indices compared to Soumba and other sweet sorghum checks (landraces and released varieties from Ethiopia).
The guinea sweet sorghum progeny grain yields varied from 1.2 t/ha to 4.2 t/ha, and the stover yield from 20 t/ha to 48.5 t/ha, while the improved grain sorghum Lata (grain yield = 2.5 t/ha, stover yield = 12.4 t/ha) and local grain variety Tieblé (grain yield = 1.6 t/ha, stover yield = 15 t/ha) recorded lower grain and stover yields. Eight progeny had higher selection indices compared to all of the checks (grain sorghum, Malian sweet sorghum landraces and sweet sorghum released varieties from Ethiopia), with panicle formation and grain quality similar to the grain sorghum landraces preferred by farmers in West Africa.

The sweet sorghum developed by ICRISAT-Mali and partners combine grain, stover and sweet juice well, and are considered as dual-purpose/multipurpose varieties. The caudatum sweet sorghum grains can be used industrially or in traditional cooking, especially couscous, often consumed with milk. Guinea sweet sorghum grains are more appropriate for tô (thick porridge) cooking and are well adapted for long storage.

Sweet sorghum stover adds high value to the crop because of its greenery, juice and sugar content. It is more digestible than landrace stover, which is hard because of its highly lignified structure. Direct use of sweet sorghum fodder as animal feed or its sale provides important income to farmers. After the 2014 harvest, some farmers in Koutiala, Mali sold sorghum green stover at 7500 FCFA (around US$15) per cart.

In many zones of Mali, farmers are organized into associations selling milk, so they buy sorghum, groundnut or cowpea stover for their dairy cows during the off-season when animal feed is very limited. In addition to these existing uses, sorghum syrup from the stem juice can enhance the crop's total value. Syrup is much appreciated by consumers and is made on-station on a small scale using butane gas or a solar condenser. Given the periodic availability of honey, sorghum syrup could be a substitute for honey and source of income for farmers.

According to the survey done in the Koulikoro region, farmers would like to use sorghum syrup as sweetener in foods such as bread, porridge, tea and in other food where sugar is used. The price of a liter of sorghum syrup is estimated at FCFA 1000 (US$2). Final selection of the best dual-purpose sweet sorghum with higher grain and stover yield will be based on the on-farm results and laboratory analysis of fodder quality, including Near infrared spectroscopy (NIRS) analysis.
This ICRISAT-Mali work offers new options to diversify sorghum uses and to make animal feed available even during the dry season. By expanding the crop’s value chain with sorghum syrup, farmers’ incomes will be enhanced, provided NGOs and all development organizations work together to apply these new technologies at the farm level.
SORGHUM LANDRACES FOR DEVELOPMENT OF DIVERSIFIED ADAPTABLE SORGHUM HYBRIDS IN NIGERIA

The first steps have been taken to develop high-yielding and disease-resistant sorghum hybrids suitable for the dry northern zones of Nigeria. Commercially viable sorghum hybrids are already available for West and Central Africa (WCA) but suit only a single maturity band (100 km from north–south) for the guinea-race zone of Senegal, Mali and Burkina Faso. There are no hybrids available for the drier, more northern zones of Nigeria, which is the largest sorghum producing area in the region, growing mostly the caudatum- or durra-types.

Sorghum, a predominantly self-pollinated crop, relies exclusively on the cytoplasmic genetic male sterility system for hybrid seed production. The system of hybrid development requires sorghum breeding programs to develop two breeding groups: a male-parent group (R-line/fertility-restorer) and a female-parent group (an A/B line, lacking the fertility-restoring gene of the A1 male-sterility system), which serve as heterotic groups in sorghum breeding programs. To use male-sterility-inducing cytoplasm effectively, it is necessary to identify restorers and lines that are suitable for conversion to male sterility.

Progressive research has been done on sorghum landraces in Nigeria, ranging from breeding for resistance to diseases to the development of open pollinated varieties, but little work has been done to determine heterotic groups and identification of good parental lines among sorghum landraces.

Based on this experience, the BMZ Project ‘Bringing the benefits of heterosis to smallholder sorghum and pearl millet farmers in West Africa’, conducted an exploratory collection of sorghum landraces across Kaduna, Kano and Jigawa States of Nigeria in early 2014 in conjunction with NARS (IAR Samaru) partners (Figure 5). The objective was to determine the existence of potential B and R lines for use as seed-parents for hybrid sorghum development. A total of 175 sorghum landraces were collected based on local names before being desegregated and grouped under 26 local names, of which Fara-Fara and Kaura were the most common generic names, accounting for 30% and 40%, respectively, of the landrace varieties.

Preliminary characterization showed that most of the sorghum landraces grown in the Sudan Savannah have white or yellow grain, with compact elliptic panicle forms (caudatum-type) accounting for 46% (Figure 4), as compared to those in the Guinea Savannah that produce white or red grains with loose dropping panicle forms (guinea-type).

This could be attributed to the fact that crops in those parts of the Sudan zone with relatively low rains avoid grain mould and insect damage and have fewer insect pest problems compared to those in the Guinea zone with high rains; the pests preferring loose panicles.

This implies that sorghum hybrid parent development should now target high yielding white or yellow grains with compact elliptic panicle forms, medium height (2 m) and medium maturity (100 days), since most of the end uses are currently for food consumption while we explore malting industry traits.

During the 2014 wet season, 89 test crosses of ICSA CK60 x Nigeria landraces were obtained to assess fertility restoration reactions or sterility maintenance for use in hybrid parent development. These are being further evaluated in 2015.
Figure 4: Histogram showing percentage variability in landrace sorghum panicle forms.

Figure 5: Exploratory sorghum landrace collection across Kano and Jigawa states.
Parasitoid wasps may soon join the range of ‘crops’ grown in millet-producing villages across the Sahel. If trials in Niger in 2015 and 2016 are successful in demonstrating the willingness of villages to purchase parasitoid wasps for pest control in their millet crops then local biocontrol will become a commercial reality for community-based producers.

The prime target is the millet head miner (MHM) *Heliochellus albipunctella* (de Joannis) (Lepidoptera: Noctuidae), which is a major chronic insect pest of millet in the Sahel, inflicting significant yield losses ranging from 40% to 85%.

Scientists in the Sahel have demonstrated over recent decades the potential of *H. hebetor* for biological control of the MHM. Augmentative releases of the parasitoid wasp Habrobracon (=Bracon) hebetor Say (Hymenoptera: Braconidae) led to up to 80% parasitism of the MHM larvae and resulted in yield increases of at least 30%. Achieving good control of head miner with releases of *H. hebetor* does not, however, guarantee an end to outbreaks of the MHM in subsequent years. Because of scarcity of alternate hosts for parasitoid survival during the off-season, fresh releases of parasitoids are needed every growing season to make the biological control program sustainable.

Because of the strong interest and acceptance of the technology by farmers and local NGOs, there is a growing demand for releases of biological control agents in West Africa, raising the question of how sufficient numbers of parasitoids can be produced to meet the demand.

Cottage industries have been the basis for commercialization of parasitoids for augmentative biocontrol in other settings. Therefore, scaling-up parasitoid production needs to be optimized to make such a cottage industry viable and ensure it meets farmers’ needs. Various experiments have been carried out since 2013 to fine-tune and standardize rearing techniques for *H. hebetor* and optimize mass production of parasitoids for industrial use. In addition, releases of different densities of parasitoid are being tested for identification of the optimum numbers needed for effective control of the MHM. Farmers’ organizations have been brought into discussions to identify the best model for parasitoid commercialization.

ICRISAT-Niger findings indicate that greatest production of parasitoids is achieved when *H. hebetor* are given the later larval stage of the rice moth *Corcyra cephalonica* to parasitize. In addition, results suggest that a honey and sugar solution is the best medium to support the longest parasitoid lifespan (up to one month) so the wasps can be used for graduated timely release. It was also found that the optimal time for mating, egg fertilization and highest progeny production is achieved when females are confined with males for 24 h in a 30 ml capacity vial. Furthermore the number of parasitoid wasps produced can be increased by 50% by adding a small proportion of cowpea flour to the millet-based diet of *C. cephalonica* larvae. Regarding the number of parasitoids needed for a given area of millet, releases of the parasitoids significantly increased the parasitism of MHM as compared to control villages not receiving parasitoids. The greatest incidence of parasitism was recorded in villages where 1,600 parasitoids were released. This experiment will continue in 2015 and will also involve identification of better timing for parasitoid releases with regard to pearl millet phenology.

Discussion with farmers in villages on the business model for commercialization of biocontrol agents has established the ‘public good’ nature of distributing the parasitoids. In other words, if one farmer adopts, his/her neighbors benefit, which affects willingness to adopt the technology. It appears that the solution is to establish community-based businesses that sell to farmers’ groups in multiple villages.

This model is being tested in 2015 in two Niger districts. Parasitoids will be produced at the local farmers’ union headquarters and a group of union members from surrounding villages will purchase supplies of parasitoids for the whole community while attending the weekly market. In the meantime, an analysis of the economic benefits – yield and cost effects and economic surplus – of the *H. hebetor* releases is being carried out to assess market-level impacts.

This work has been undertaken as part of the CGIAR research program on Dryland Cereals, and has been funded by the Sorghum and Millet Innovation Lab (SMIL) and the McKnight Foundation.
The gap between low groundnut yields in Nigeria and those achieved in other major groundnut-producing countries is set to reduce thanks to new elite lines with multiple resistance to biotic and abiotic stresses.

Several promising lines have already been identified by ICRISAT-Nigeria after evaluating more than 500 advanced breeding/elite lines over the wet and dry seasons in 2014. The next step over the coming seasons in collaboration with its NARS partners – the Institute for Agricultural Research (IAR) and the Bayero University of Kano (BUK) - is to confirm the superiority of the most promising lines in trials.

The West and Central Africa (WCA) region accounts for more than 70% of Africa’s groundnut production, with Nigeria accounting for 51% of regional production with 3.07 million tons of groundnut production annually. Groundnut plays a very important economic role for the region’s smallholder farmers as a major cash crop for many households, and a nutritious and safe food, thereby contributing to improved health in the rural population. Recent surveys indicate that groundnut is planted on 34% of the cultivated area and contributing to 54% of household cash revenue in Nigeria.

Despite Nigeria being one of the largest groundnut producing countries, crop productivity is very low (1 t/ha) compared with a global average of 1.5 t/ha and over 3 t/ha in the USA and China. This low groundnut yield is attributed to many factors, including biotic and abiotic constraints. Variable rainfall, drought, groundnut rosette disease, foliar (early/late leaf spots and rust) diseases and aflatoxin contamination are important constraints affecting the groundnut productivity and quality, especially under the present day climate-change scenario.

Colossal pyramids of groundnut were once a common sight in northern Nigeria, and the piles – some higher than surrounding buildings – were a symbol of the abundance of the region’s most important cash crop. The state of Kano was an important trading hub sending the legume to European markets.
Today, the dusty yards lie mostly empty. Two major causes for the failure of groundnut in Nigeria were drought and rosette virus disease. Changing rainfall patterns over the last 30 years have shortened the growing season from four to three months. Groundnut, which needs more than four months to reach maturity, was badly hit. Obsolete varieties such as Kampala, Sabiya, Kwankaswo, Olomometa, etc, which are mostly late maturing (120 days) and susceptible to pests and diseases, are still being grown.

Early-maturing varieties like Exdakar remain popular but highly susceptible to groundnut rosette disease, rendering them risky in case of rosette epidemics. Since most of the currently grown local landraces cannot escape drought and are susceptible to the rosette virus, research focused on the development of early-maturing virus tolerant/resistant varieties. Recently, early maturing (90 days) varieties that can escape drought and have resistance to rosette disease and high yield potential, viz., Samnut-24, Samnut-25 and Samnut-26, were developed and released for cultivation in Nigeria during 2011/13.

However, these varieties are still moderately susceptible to foliar diseases. There are also opportunities for introducing/dual-purpose and dual-season groundnut varieties for both haulm and grain yields, since the market for haulms remains high, especially in the dry season. Present-day breeding efforts at ICRISAT-Nigeria emphasize on developing new breeding material under a wider adoptive background and on identifying elite lines having resistance to multiple biotic and abiotic stresses with farmer- and market-preferred traits.

**Groundnut breeding highlights at ICRISAT-Nigeria during 2014**

- Generation of new breeding material: a groundnut hybridization block using cement rings was established at Kano station. Crosses involving three local landraces (Kampala, Kwankaswo and Sabiya) and two improved varieties (Samnut-24 and Samnut-26), with identified sources of resistance to rosette, foliar diseases, aflatoxin, drought tolerance and early maturity with good agronomic features, were made to develop new breeding material having these desirable traits under an adoptive background.

- Evaluation of advanced breeding/elite lines: a total of 541 advanced breeding/elite lines were evaluated over two seasons (wet and dry seasons of 2014/15) and locations (BUK and Minjibir), along with local landraces and improved/released varieties as checks for their reaction to drought, rosette and foliar diseases, as well as for productivity parameters. The resultant promising lines are being evaluated for their nutritional quality and to confirm their superiority in multi-location (MLT) and participatory varietal selection (PVS) trials in collaboration with the NARS partners during coming seasons for their possible release in Nigeria.

Repossessing landscapes, bringing more food and hope
Successful introductions of improved groundnut varieties and disease management through partnership with women’s groups have not only increased individual farmer incomes but also produced surplus cash for further investment in farming. And, male farmers spurred on by the results of the women’s involvement in participatory varietal selection (PVS) and aflatoxin management have also adopted similar approaches to improving their returns from groundnuts.

The breakthrough in Mali is the result of cooperation between ICRISAT and Plan Mali, who have been partnering since 2009 in Koulikoro to promote improved groundnut varieties through TL II fund support to enhance groundnut production and productivity in target villages. The women’s groups in the villages of Bougoula and Sanambélé in Kati district, Koulikoro Region were the focus of the PVS and training activities. Plan Mali, operated by the international children’s charity Plan, selected three women’s groups organized under its Saving for Change (Epargne pour le changement) approach, and partnered with ICRISAT-Mali for the training and research input. Two women’s groups in Bougoula and one group in Sanambélé, each with 25 members, were trained in improved groundnut production technologies and aflatoxin management practices.

Mother trials were used as the main participatory tool in the evaluation and selection of varieties. These are single-replication designs used to assess the relative performance of varieties. Each mother trial contained five improved varieties (for drought and foliar disease resistance) to compare to a local farmers’ variety (check). The trials on 1000 m² (50 m x 20 m) plots of each variety were managed by each women’s group over two years of testing after which the best varieties were chosen for seed production.

**PVS Trials**

Women farmers evaluated the new varieties in PVS alongside the local variety they have been cultivating for many years. Table 4 shows the yield performance of the varieties in Bougoula and Sanambélé across three years. In Bougoula, the variety ICGV 86124 had the highest average pod yield with 1380 kg/ha, followed by ICGV 86024 with 1160 kg/ha. All the improved varieties had better pod yield than the check. In Sanambélé, the improved variety ICGV 86015 had the highest yield of 907 kg/ha but it was not significantly better than the local check with its pod yield of 893 kg/ha.
Farmers were asked to rank the varieties based on preference. In Bougoula, ICGV 86024 was preferred for its good pod filling, early maturity, pod yield and drought resistance. Similarly, farmers preferred Fleur 11 for early maturity, taste and high pod yield plus its adaptability/suitability to all types of soil. In Sanambélé, farmers favored ICGV 86124 and ICGV 86015 for their high pod yield, good pod filling, early maturity and their resistance to drought as well as adaptability. ICG 7878 was appreciated in both Bougoula and Sanambélé for its big grain size, high fodder yield and foliar disease resistance but not for its pod yield and maturity duration.

Training for members took place both at the start and end of the crop season. At the start of the crop season training for members of the women’s groups involved in the PVS activities focused on better groundnut production techniques, including improved varieties and good cultural practices (planting time, seed rate, planting techniques, fertility management, weed management, etc).

End-of-season training then focused on aflatoxin management, including both pre- and post-harvest aflatoxin management techniques to minimize infestation.

Table 4: Yield performance (kg/ha) of the improved varieties compared to the local check conducted by women’s groups in Bougoula and Sanambélé.

<table>
<thead>
<tr>
<th>N°</th>
<th>Variety</th>
<th>Bougoula</th>
<th>Sanambélé</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICGV 86124</td>
<td>770</td>
<td>2100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1270</td>
<td>1380</td>
</tr>
<tr>
<td>2</td>
<td>ICGV 86024</td>
<td>680</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1300</td>
<td>1160</td>
</tr>
<tr>
<td>3</td>
<td>ICGV 86015</td>
<td>600</td>
<td>1700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>1100</td>
</tr>
<tr>
<td>4</td>
<td>ICG 7878</td>
<td>535</td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>817</td>
</tr>
<tr>
<td>5</td>
<td>Fleur 11</td>
<td>770</td>
<td>1600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>750</td>
<td>1040</td>
</tr>
<tr>
<td>6</td>
<td>Local Check</td>
<td>590</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>550</td>
<td>780</td>
</tr>
</tbody>
</table>

Table 5: Number of female/male farmers trained, crop season 2010/2011.

<table>
<thead>
<tr>
<th>N°</th>
<th>Village</th>
<th>Number of farmers trained</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bougoula</td>
<td>50 (2)</td>
<td>52</td>
</tr>
<tr>
<td>2</td>
<td>Sanambélé</td>
<td>27 (2)</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>77 (4)</td>
<td>81</td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate number of male farmers trained.
Seed production and marketing

After selecting their preferred varieties, the women’s groups from Bougoula and Sanambélé decided to multiply seed of the best two varieties they had each selected during the 2012/2013 crop season. Plan Mali and ICRISAT supported the farmer groups and individual farmers to produce and market seed of the preferred varieties.

Table 6 shows the results of seed multiplication during the 2012/2013 crop season. Poor results during the crop season 2014/15 followed a late start to the rains with consequent late planting and very poor pod filling.

Women’s group members were trained on small business management in 2013. A business development/market management specialist trained a total of 23 farmers, including 11 farmers from Bougoula (nine women and two men) and 12 farmers from Sanambélé (10 women and two men). The training modules included small business management, marketing, bookkeeping, entrepreneurship and related skills.

The women’s groups and individual farmers benefited from the production and marketing of seed for the improved varieties. They were able to enhance their income, with some farmers selling groundnut to pay for clothes, school fees, food (in time of shortage), medication, furniture and other expenses. The women’s groups at Bougoula built a savings reserve of around 1,500,000 FCFA, and the group at Sanambélé around 800,000 FCFA. They have started using this to provide micro-credit for group members. The group structure enables the women to act together and speak with one voice, and the groups plan to become seed companies or cooperatives eventually.

Awareness of the benefit of the improved varieties has been created in the two village communities as well as neighboring villages. Consequently, individual farmers (both men and women) have started producing and marketing seed of the improved varieties.

Table 6: Results of seed multiplication by women’s groups in Bougoula and Sanambélé villages, crop season 2012/2014.

<table>
<thead>
<tr>
<th>Villages</th>
<th>Variety</th>
<th>Dry pods weight (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanambélé</td>
<td>ICGV 86015</td>
<td>272</td>
</tr>
<tr>
<td></td>
<td>ICGV 86124</td>
<td>217</td>
</tr>
<tr>
<td>Bougoula</td>
<td>Fleur11</td>
<td>582</td>
</tr>
<tr>
<td></td>
<td>ICGV 86024</td>
<td>399</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1470</td>
</tr>
</tbody>
</table>
Repossessing landscapes, bringing more food and hope
SYSTEM INTENSIFICATION AS AN ADAPTIVE MECHANISM TO CLIMATE CHANGE

Food security in the dryland systems of the Sudan savanna of West Africa faces serious challenges driven by global climate change that can only be met by adaptation responses that embrace sustainable development and increases in area productivity.

As the main source of livelihood for the poor in West Africa and most developing countries, agriculture must change and adapt to feed an expanding population. Improvement of agricultural productivity is critical to achieving this food security in the face of long-term changes in average temperatures, precipitation and in climate variability. Current extensive agriculture in which any increase in production arises primarily from expanding the land area brought under cultivation will have to give way to an increase in productivity per unit area. Changes in agriculture systems are essential to meet these challenges.

ICRISAT-WCA is conducting and demonstrating different sustainable intensification options to increase productivities per unit area, to increase food security and job availability in rural communities. The promoted options with encouraging results include integrated soil fertility management, use of seeds of improved varieties (early-maturing, drought resistant etc), promotion of legume cultivation under irrigation for food, feed and seed as well as soil fertility management, conservation tillage, residue management and planting dates, and simple mechanization of agronomic and post-harvest activities. By using improved varieties (Table 7), grain yields of millet can be increased by 19 to 30% and stover yield by 10 to 23%.

The use of different fertilizer inputs can increase grain yields by 21 to 53% and stover yields by 21 to 59% (Table 7). Improved varieties of groundnut increase pod yields (Table 8) by more than 100% though haulm yields can reduce about 6%, while changing the hill population from an extensive planting population of about 44,444 hills/ha to 166,667 hills/ha leads to pod, haulm and profit increases of about 54%, 21% and 27%, respectively.

Threshing capacity and quality of produce is greatly increased by employing a multi-crop thresher. With the availability of early maturing rosette-resistant groundnut varieties, farmers can now cultivate groundnut in the dry season for grain, seeds and feed. This not only increases crop diversity during the dry season but also breaks the cereal-cereal cycle to increase sustainability.
Table 7: Effect of variety and fertilizer input on the grain and stover yields (kg/ha) of millet in the Sudan and Sahel regions of Nigeria

<table>
<thead>
<tr>
<th>Treatments Variety</th>
<th>Minjibir (Sudan)</th>
<th>Gumel (Sahel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td>Stover</td>
</tr>
<tr>
<td>GB8765</td>
<td>1447</td>
<td>3849</td>
</tr>
<tr>
<td>Sosat</td>
<td>2529</td>
<td>6515</td>
</tr>
<tr>
<td>Local</td>
<td>1954</td>
<td>5278</td>
</tr>
<tr>
<td>LSD</td>
<td>336.5</td>
<td>644.8</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MicNPK</td>
<td>1722</td>
<td>5013</td>
</tr>
<tr>
<td>MicNPK+OM</td>
<td>1951</td>
<td>5091</td>
</tr>
<tr>
<td>NPK 60-30-30</td>
<td>2563</td>
<td>6605</td>
</tr>
<tr>
<td>Control</td>
<td>1671</td>
<td>4148</td>
</tr>
</tbody>
</table>

Table 8: Mean pod and haulm yields (kg/ha) and Total profit (US$/ha) of groundnut production under different intensification treatments in Sudan Savanna, Nigeria

<table>
<thead>
<tr>
<th>Treatments Variety</th>
<th>Pod</th>
<th>Fodder</th>
<th>Total profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>742</td>
<td>1982</td>
<td>255,568</td>
</tr>
<tr>
<td>Samnut 24</td>
<td>1652</td>
<td>1869</td>
<td>352,500</td>
</tr>
<tr>
<td>P of F</td>
<td>&lt;.001</td>
<td>0.210</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LSD</td>
<td>114.2</td>
<td>178.1</td>
<td>27,289.3</td>
</tr>
<tr>
<td>Plant Population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13,333 hills/ha</td>
<td>1533</td>
<td>2098</td>
<td>347,185</td>
</tr>
<tr>
<td>66,667 hills/ha</td>
<td>1064</td>
<td>1954</td>
<td>292,008</td>
</tr>
<tr>
<td>44,444 hills/ha</td>
<td>994</td>
<td>1726</td>
<td>272,909</td>
</tr>
<tr>
<td>P of F</td>
<td>&lt;.001</td>
<td>0.004</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LSD</td>
<td>139.8</td>
<td>218.2</td>
<td>27,289.3</td>
</tr>
</tbody>
</table>
Climate data suggests that up to 1,000 mm of annual rainfall at Kani village in the Koutiala region is good enough to support crops and livestock, but potential evapotranspiration is high, rainfall is erratic, erosion is widespread and there is little storage of water. Scientists and farmers are now testing fresh ideas.

Most agronomic research in support of development has emphasized farm-level productivity issues, with limited efforts for managing interactions among components and actors beyond the level of the farm. In recent years however, there has been a strong push from governments and international academics and donors to move towards broader units of analysis and intervention, including landscape, catchment and watershed (German et al., 2005). While trees, crops, livestock and soil are present at both plot/farm and watershed levels, there are additional components largely absent from farm-level analysis that are yet central to the watershed-level analysis. These include hydrological processes (encompassing groundwater recharge springs, streams, and irrigation systems) and other common property resources (land uses, communal forests or grazing areas). Mali is no different to other semi-arid regions of the world, where land and water resources are increasingly scarce commodities. Worldwide, these two resources are extensively used in agricultural systems, both rainfed and irrigated, but the required demand in the semi-arid regions is not being delivered due to rainfall variability, extreme weather events and loss of important nutrients due to erosion. Ecosystem services, being the benefits that people obtain from ecosystems, also rely on the quantity and quality of water, and safety of the land to function (Garg et al., 2012). This calls for an integrated approach beyond efforts at farm/plot level.

A community-managed watershed-learning site was established at Kani watershed village in the Sudanian zone of southern Mali for research and capacity building for local NGOs, farmers and research organizations. Rainfall ranges from 800 to 1,000 mm, with the production system mainly focusing on cotton and sorghum (Birhanu et al., 2014). Biophysical characterization was conducted using data collected from climate and available intervention measures such as contour bunds and shallow wells.

Spatially explicit information on adoption of shallow wells and contour bunding provided a new dimension to the changes in agricultural practices. New sets of hydro-meteorological monitoring stations, including a weather station, ordinary rain gauges, soil moisture and groundwater monitoring equipment, were established to bridge the gap between on-site monitoring stations.
Community consultation programs were conducted to identify major agricultural constraints and possible technological intervention options. The prime objectives of the study were:

- Identification of a community-managed watershed for integration of system-level components and understanding biophysical components.
- Identifying priority constraints through a stakeholder consultation program.
- Identification of possible technological options for integrated watershed management.

Climate data (1980-2010) was collected from Koutiala weather station and seasonal variations are presented in Figure 6. Rainfall is mono-modal with a mean annual rainfall of 845 mm. Other climate values are maximum temperature (34 °C), minimum temperature (22 °C), solar radiation (20 MJ/m²), wind speed (2.3 m/s) and relative humidity (31%). The historical maximum rainfall recorded was 97 mm (2 August 1998) and the long-term average number of rainy days in a year was 193. Similarly, the historical maximum and minimum temperatures recorded were 43 °C and 8 °C respectively, and values for relative humidity and wind speed were 86% and 5.4 m/s respectively.

The seasonal pattern of PET along with rainfall is shown in Figure 7. The computed mean annual rainfall and PET, respectively, were 845 mm and 1752 mm. According to the seasonal rainfall pattern, rainfall starts in May, peaks in August and ends in October. PET was higher than rainfall for nine months of the year (October to June).

During the 31 years (1980-2010) a slight but statistically insignificant increase in rainfall was observed (Figure 7).
Stakeholder consultation

A stakeholders’ consultation program was conducted from April to June 2014 during which the four identified constraints that hinder agricultural productivity in the study area in the order of importance were: water scarcity, soil erosion, health issues as a result of improper agricultural use and lack of animal fodder and traction. Table 9 shows the summary results of stakeholders’ consultation in Kani watershed village on challenges and constraints to agricultural productivity.

Table 9: Summary results of stakeholders consultation in Kani village on challenges and constraints to agricultural productivity

<table>
<thead>
<tr>
<th>Challenges/Constraints</th>
<th>Actions taken</th>
<th>Efficiency of interventions since application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion and excessive runoff</td>
<td>Rock bunds</td>
<td>Rock bunds were slightly changed to be farm boundary demarcation and lost usefulness as a means of reducing erosion and water runoff.</td>
</tr>
<tr>
<td>Nutrient loss from farm fields</td>
<td>Contour Bunds</td>
<td>The practice was perceived to be useful by local communities and better suited to reduce erosion than rock bunds. However, it still lacks wider implementation because of absence of awareness in method of construction and its usefulness.</td>
</tr>
<tr>
<td></td>
<td>Composting</td>
<td>This practice is widely applied to improve soil fertility. However, its application is threatened by nutrient washing away during rainfall in the absence of protective measures to reduce erosion from fields.</td>
</tr>
<tr>
<td>Agroforestry options are decreasing over time</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Shortage of fodder and animal traction</td>
<td>Communities practicing feeding livestock with cowpea residues and integration of more legume crops, eg, groundnut</td>
<td>Lack of animal traction was solved by sharing labor. However, farmers without animal traction plow their land after those with oxen. This resulted in late sowing and reduction of ensuing crop productivity.</td>
</tr>
<tr>
<td>Lack of awareness on correct use of agricultural inputs</td>
<td>Advice on fertilizer application given by a local cotton agency (CMDT)</td>
<td>Advice was mainly related to the cash crop (cotton) as there was limited or no supply of fertilizer and other inputs for other staple crops. There was also lack of awareness on health concerns of improper use of fertilizers, pesticides and herbicides.</td>
</tr>
<tr>
<td>Drought, lack of enough rain and scarcity of both surface and groundwater</td>
<td>Dam/barrage constructed to store water for domestic and livestock water needs</td>
<td>The dam/barrage only holds water for four months after the end of rain season (November–February), thereafter drying completely from March to June.</td>
</tr>
<tr>
<td></td>
<td>Shallow wells constructed</td>
<td>The water levels in most shallow wells reach a depth of 3 to 4 m during rainy seasons and goes beyond 20 m during the dry season. Access during dry season is a major concern.</td>
</tr>
</tbody>
</table>
Technological options for integrated watershed management

The stakeholders’ consultation program revealed that farmers have a positive attitude towards the use of improved land and water management practices in their fields. Contour bunds were better suited to reduce erosion and help to increase the moisture content of the soil and hence avoid the dry spells. Research results (Traoré et al. 2004; Gigou et al. 2006) revealed that contour bunding is a well-known method for reducing water run-off and for controlling soil erosion in the southern parts of Mali.

The application involves creation of permanent contour ridges, covered with perennial grasses, whereby farmers follow the ridges to prepare the farm plot for crop production. While the biophysical and socio-economic benefits of contour bunding in Kani watershed village is yet to be tested, nearly 50 farmers have applied the technology in their fields since 2014. Figure 8 shows a farmer in a cotton field both with and without a constructed contour bund.

![Figure 8: Farmer fields: (a) and (b) Cotton fields with and without constructed contour bund; (c) and (d) Sorghum fields with and without constructed contour bund](image)

Shallow wells are also used for water management. In an effort to study the long-term water retention capacity of community-managed wells, a total of 259 shallow wells (Figure 9) were geo-referenced and studied within Kani watershed village. The minimum recorded well depth was 3 m and the maximum recorded depth was 33 m. Most wells (71%) range in depth from 8.5 to 18.5 m, with only one well to a depth of 33 m. Qualitative and quantitative data was obtained on depth level fluctuation and qualitative analysis showed that in 90% of shallow wells water levels drop during the dry season.

Quantitatively, 36% of shallow wells decrease in water level within the range of 6.5 to 9.5 m. This is followed by a decrease of water level in the range of 3.5 to 6.5 m (30%) and from the range of 9.5 to 12.5 m (18%). Three percent of the wells reduce in water level in the range of 15.5 to 18.5 m.

The same analysis was done for the rainy season, and in 52% of the wells increase in water level to a depth range of 0 to 4 meters to the surface, and 72% of wells are accessed at a depth of 8 m from the ground surface.

![Figure 9: Frequency distribution of depths of water level variations in shallow wells during dry season and rain season](image)
Conclusions, perspectives and the way forward

Kani watershed village receives a mean annual rainfall of 845 mm, which is considered to be good enough for agricultural production for both crops and livestock. However the major problem is the inter- and intra-annual variability of rainfall and lack of appropriate innovation to store the rainwater for dry season use. The reported potential evapotranspiration (PET) in the study area (1,752 mm/year) is more than twice that of the mean annual rainfall, rendering futile efforts to store surface water.

The aridity in the study area (low rainfall and high PET) and the low potential for surface runoff storage, demands an approach using in-situ rainwater conservation as an important intervention measure. For example, the reduction in water level in most shallow wells in the dry season (in 87% of wells the water level varies between 3.5 to 18.5 m) can be augmented with in-situ rainwater conservation practices. To achieve these two most common interventions, the options identified were management of water level in shallow wells and contour bunding on a scale ranging from farm fields to watershed.

There is evidence to show that fields treated with contour bunding gain two-fold benefits: increased recharging capacity for wells by slowing the runoff rate, and reducing the erosion and washing away of important nutrients from fields. To achieve better impact, application of contour bunds at the farm level needs to be practiced alongside other soil fertility management practices. These include but are not limited to fertilizers, composting, appropriate cropping systems, vegetation cover and development of fodder species.

Shallow wells were identified as the primary source of water for domestic, livestock and dry season farming practices in the study area. It was observed that even though there is depth level fluctuation in 87% of wells, water could be accessed at a reasonable depth during the dry season.

A little extra effort to treat the watershed with vegetation cover would guarantee improved recharging capacity of the wells. Presently, the increased cropland area in the watershed is at the expense of natural vegetation, and there are few studies that evaluate this tradeoff.

Taken together, these analyses highlight the need for integrated action to help improve agricultural productivity and natural resources management, with this integrated action based on various components, including water, crop, soil, trees, rivers, forests and degraded areas among others, within a defined hydrological unit. Activities in the watershed need to ensure wells are recharged and soil moisture and farm nutrients are maintained while erosion and runoff are minimized.

However, watershed development efforts are not always rosy. Strong institutional support is required at all levels. The Mali government has no current documented research evidence relating to watershed management although there is strong interest from the national agricultural research institution (IER), which, thanks to its important role in applied and adaptive research and its links via the extension service to local communities and farmers, makes it a potentially very important actor in the watershed development program. There are also lessons to be learned from watershed programs in India and East Africa.

Careful documentation and comparative analysis of the effectiveness, efficiency and sustainability of appropriate technologies is necessary to establishing a sustainable watershed program.

Promising activities need to be replicated by the inhabitants of the watershed, and the lessons learnt at the pilot learning site must be extrapolated to other areas with similar issues.

This program was undertaken as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE) and Dryland Systems (DS)
FRIENDLY FUNGI ENROLLED TO OFFSET SOIL NUTRIENT MINING

Naturally occurring soil fungi could form part of a strategy to offset soil nutrient mining if a balance can be found between the immediate needs of farmers and the benefits of long-term fertility management to improve crop productivity on sandy soils in Niger.

Cowpea, millet, dolic, voandzou, and sesbania are all associated with root-colonizing mycorrhiza fungi, which form symbiotic relationships with leguminous plants to fix soil solution dissolved nutrients such as phosphate, nitrogen and other nutrients that can be taken up by the host plant. The use of soil arbuscular mycorrhiza fungi is seen as an alternative to filling the gaps left by other soil fertility improvement techniques such as the use of organic and mineral fertilizers, crop rotation and soil management techniques.

Soil mining by agriculture has greatly contributed to poor crop productivity in sahelian zones (Bationo et al., 2004). At ICRISAT’s trials site at Sadoré in Niger the soil is sandy (90-93%), low in organic matter, phosphorus and nitrogen. The pH is between 4-4.59.

Extensive research has been carried out on using arbuscular mycorrhiza fungi in agriculture, horticulture and agro-forestry by inoculation of soil with outsourced fungi spores (Robson et al., 1994). Much less research has focused on naturally infested soil mycorrhizae, but it is still worth assessing the status and types of indigenous mycorrhizae in Sadoré’s sandy soil and the mycorrhizogenic ability of crop species that might have potential to impact positively on soil fertility and crop productivity through appropriate cropping systems (Robson et al., 1994).

ICRISAT-Niger decided to study the impact of legumes and cereal cropping on soil mycorrhizogenic capacity through:

1. Assessing the types and levels of mycorrhizae in Sadoré sandy soils
2. Determining the link between crop species and rate of mycorrhization
3. Investigating the impact of crop planting densities on mycorrhization

A completely randomized bloc design (CRBD) was used for the 36-plot layout with five crop species – four legume species, one cereal and two check plots:

1. Cowpea (KVX 30-309-6-G), Voandzou (local Vigna subterranea L. Verdc.), Dolic (white seed), Sesbania pachycarpa, Millet (ICVM-IS89305 with 95-100 days)
2. Buffer plots and natural fallow plots.

Two planting densities used: the traditional farmers’ density (D1) and a recommended density (D2) were as follows:

<table>
<thead>
<tr>
<th>Crop</th>
<th>D1 Planting Density</th>
<th>D2 Planting Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolic (D)</td>
<td>1 × 0.75</td>
<td>0.5 × 0.75m</td>
</tr>
<tr>
<td>Sesbania (S)</td>
<td>0.40 × 0.50</td>
<td>0.75 × 0.75m</td>
</tr>
<tr>
<td>Cowpea (N)</td>
<td>1 × 0.75 × 0.75</td>
<td>0.50 × 0.50m</td>
</tr>
<tr>
<td>Voandzou (V)</td>
<td>0.20 × 0.20</td>
<td>0.15 × 0.15m</td>
</tr>
<tr>
<td>Millet (M)</td>
<td>1 × 1.5</td>
<td>1.00 × 1.00m</td>
</tr>
</tbody>
</table>
The method developed by Walker (1982) was used to extract the spores in the rooting zone and the identification carried out with binocular magnifying glasses, as was the assessment of roots mycorrhization using the method of Trouvelot et al., (1986). Mycocalc software was used to calculate mycorrhizae incidence.

The two types of fungus spore extracted from the soil samples belong to Glomus and Gigasporaceae genera with the Glomus genus accounting for 90.09% of mycorrhizae vs. 9.09% of Gigaspora. This does not line up with the findings of Trappe (1984), which state that soil with neutral pH is more favorable to Glomus spore germination while Gigaspora spores do better in pH between 4 and 6. However, Ambouta et al., (2009) stated that these two types are the most abundant in West African soils.

Planting density D2 had a greater number of spores than in D1 for both genera. A high significant difference was found in the interaction culture × density (at 1%) for Glomus with the three best rankings (per 100 g of soil) attributed to dolic D2 (1888), cowpea D1 (1138) and voandzou D2 (1095) for Glomus species and sesbania D2 (73), dolic D2 (52), cowpea D2 (36) for Gigaspora.

Root assessment indicated that the frequency of mycorrhization was 100% for all cultures except for sesbania with 99%. In terms of root cortex mycorrhization, significant difference was found only with cowpea at D2 for the intensity of mycorrhization (M%); however, the three best were ranked as dolic D1 (73.35%), Cowpea D2 (67.97%) and cowpea D1 (65.28%), with sesbania D2 (65.28%).

The rate of arbuscular colonization of the mycorrhized root (A%) was higher in D2 than in D1, except for voandzou and dolic. This is due to the low plant population. Cowpea D1 and D2, dolic D2 and voandzou D2 were the best mycorrhizogenic crops, while millet and sesbania were the poorest as they were the least infested species, despite their good performance in biomass production.

Plenchette et al., (2000) had similar results with millet. In terms of vegetal biomass production, sesbania, millet and cowpea produced the greatest quantities while voandzou and dolic produced the least; the main reasons being that voandzou was damaged by rodents at germination stage and dolic was not adapted to the sandy soil and the plants died during the growth stages.

The study showed that the sandy soil at Sadoré contains two indigenous genera of spores, ie, the genus Glomus and genus Gigaspora, and that the roots of legumes and millet were associated with mycorhizal symbiosis. Cowpea made the greatest contribution to the soil mycorrhizogenic capacity, followed by dolic and voandzou, while the root infestation with Arbuscular mycorrhizal fungi (AMF) was greatest with dolic D1 and cowpea at D1 and D2. Sesbania D2 and millet D2 produced the largest quantity of dry biomass (Table 10).

The planting density D2 overtook the D1 for all parameters, although occasionally no statistically significant difference was found. A strong interaction of culture × planting density was obtained for the spore density in the rooting zone.

Cowpea is a valuable market crop and low income and low input farmers in an agropastoral environment such as Sadoré will not be receptive to incorporation of its residue. Nevertheless, its high mycorrhizogenic ability in the dryland area makes it a worthy part of the cropping system. Sesbania, which is less valuable to the market, could be more acceptable for incorporation.

It should be associated with cowpea or dolic whose roots have a high rate of sporulation and AMF colonization. Such a strategy could help sustainably replenish the soil’s organic pool, while increasing its mycorrhizogenic capacity sufficiently to be an antidote to nutrient mining practices. Further research is needed to gather more information on other crops to widen the choice of crop species associated with mycorrhizae.
Diversity of AMF spores identified in Sadoré sandy soil

Table 10 : Summary of mean data

<table>
<thead>
<tr>
<th>Trait</th>
<th>Biomass (kg)</th>
<th>Glomus (per 100 g of soil)</th>
<th>Gigaspora (per 100 g of soil)</th>
<th>M%</th>
<th>A%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD1</td>
<td>21.23</td>
<td>430.6</td>
<td>73.33</td>
<td>52.11</td>
<td>20.03</td>
</tr>
<tr>
<td>SD2</td>
<td>56.73</td>
<td>725.8</td>
<td>15</td>
<td>63.78</td>
<td>24.25</td>
</tr>
<tr>
<td>ND1</td>
<td>11.17</td>
<td>1138.1</td>
<td>11.67</td>
<td>65.28</td>
<td>34.91</td>
</tr>
<tr>
<td>ND2</td>
<td>18.83</td>
<td>695.3</td>
<td>35.67</td>
<td>67.97</td>
<td>36.11</td>
</tr>
<tr>
<td>MD1</td>
<td>19.97</td>
<td>750.6</td>
<td>10</td>
<td>63.33</td>
<td>22.19</td>
</tr>
<tr>
<td>MD2</td>
<td>30.43</td>
<td>454.7</td>
<td>10</td>
<td>61.42</td>
<td>28.27</td>
</tr>
<tr>
<td>DD1</td>
<td>0.0087</td>
<td>183.6</td>
<td>12</td>
<td>73.35</td>
<td>39.58</td>
</tr>
<tr>
<td>DD2</td>
<td>0.023</td>
<td>1836.7</td>
<td>51.67</td>
<td>58.64</td>
<td>30.64</td>
</tr>
<tr>
<td>VD1</td>
<td>0.0045</td>
<td>561</td>
<td>35.04</td>
<td>63.25</td>
<td>31.29</td>
</tr>
<tr>
<td>VD2</td>
<td>0.0045</td>
<td>1094.8</td>
<td>2.41</td>
<td>62.9</td>
<td>23.81</td>
</tr>
<tr>
<td>CV %</td>
<td>63.87</td>
<td>44.31</td>
<td>146.63</td>
<td>13.78</td>
<td>33.63</td>
</tr>
</tbody>
</table>

S = Sesbania  
D = Dollic  
N = Natural fallow plot  
M = Millet  
D1 = Traditionnal Farmer Density  
D2 = Recommended Density  
V = Voandzou
Investment in Niger to meet the challenges posed by hunger and poverty

In the Sahelian zones of West and central Africa (WCA), drought, heat and low soil nutrients are the major abiotic constraints to crop productivity. The biggest challenge in this region is the identification and characterization of drought/heat/low-nutrient tolerant genitors to provide material to be used in genetic breeding programs for improving productivity. The improvement of tolerance to these constraints relies on the manipulation of the traits that limit yield, and their accurate phenotyping under control and field conditions. For genotypic evaluation of large numbers of groundnut, pearl millet and sorghum entries to select tolerant genitors and investigation of drought, heat and/or low phosphorus/nitrogen tolerance-related traits, new facilities have been developed at ICRISAT Sahelian Centre (ISC) in Sadoré, Niamey-Niger.

Phenotyping platform for crop adaptation to abiotic stress at ICRISAT-Niger

1 - Rainout Shelter (ROS) for imposing drought stress in rainy season
Drought stress imposition and measurement of physiological traits is challenging during the rainy season, so a rainout shelter (ROS) was developed at Sadoré to exclude rainfall. The ROS (20 m × 10 m) is movable for covering plants during rain and has a translucent roof allowing almost full plant insolation. In the March - May off-season, the ROS is also used for genotypic evaluation to heat stress.

Meeting the challenge of improving productivity to combat hunger and poverty calls for investment in providing new exciting material for use in genetic breeding programs. Crop improvement requires good phenotyping for selection of high-yielding varieties adapted/tolerant to environmental constraints.
2- **Lysimeter system for investigating root architecture, water and nutrients use**

The lysimetric system comprises trenches and lysimeter tubes (PVC cylinders). This facility, developed in Sadoré, has eight trenches (20 m × 2 m × 1 m) with the capacity to hold 1840 large (35 cm diameter) or 3200 medium diameter (25 cm) lysimeter tubes. The system allows investigation of root-related traits, water-use traits, nutrients (P, N) uptake and the dry-down technique to rigorously control the application of water stress.

Crop response to combined abiotic stress (eg, drought and low P) is also assessed. In addition to accurate measurement of traits, the lysimeter system mimics field conditions, especially for soil volume and depth for root development. The structure of lysimeter tubes (cylinder, collar, metal plate at the cylinder bottom, soil) associated with a block-chained pulley and inserted S-type load cell allows regular weighing to determine the total transpired water per plant and per day.

3- **Soil moisture tube access and TRIME-TDR probes for precise moisture measurement**

TECANAT access plastic tubes are installed in the soil-filled lysimeter tubes. From emergence to plant maturity, the water content profiles are measured regularly using the TRIME-PICO sensor (introduced in the access tubes) while PICO TALK software (with Bluetooth®) reads and displays the soil moisture/temperature based on the calibration.

In field or control conditions, the TRIME-PICO-64/32 sensor is used for non-destructive measurement of gravimetric soil moisture/temperature. Accurate, rapid, routine and non-destructive measurements of water content profiles are possible with this setup without the use of hazardous radioactive materials.

Other equipments available to the crop physiology program at ICRISAT-Niger includes an infra-red camera for thermal imaging and canopy temperature determination, an LAI 2200 plant canopy analyzer and leaf area meter for specific leaf area measurement, a Scholander pressure chamber for leaf water potential determination, and a SPAD chlorophyll meter for leaf nitrogen content estimation.

Besides phenotyping research activities, all of the equipment is used for hands-on training of partners on drought-related phenotyping, updating trainees on the state of the art of drought/low soil fertility research, and to enable them to acquire the skills and methods to measure specific traits.
SORGHUM IN POULTRY FEED BRINGS EXTRA VALUE TO THE CROP-LIVESTOCK SYSTEM

Poultry farmers’ concerns about using sorghum instead of maize in poultry feed have been overcome thanks to dietary trials by ICRISAT in Niger, Nigeria and India. A key problem facing poultry production in Niger and Nigeria is the inadequate supply and high cost of feed ingredients, for which maize is the main energy source. Alternative energy sources such as sorghum may help reduce the high cost of poultry feed.

By proving that tannin-free sorghum has a nutritional value comparable to that of maize, the ICRISAT researchers were able to show that locally produced non-tannin sorghum is a good alternative for poultry feeds in West Africa when grain prices are similar.

In experiments undertaken in India and Niger, sorghum varieties developed by ICRISAT and Niger’s National Institute for Agronomic Research (INRAN) were equal to maize in nutritional value for broilers and layers (Parthasarathy et al., 2005, Issa et al., 2007, Issa 2009).

Sorghum is the fifth most widely grown crop in the world, with the largest area of production in India, followed by Nigeria, Sudan and Niger. Fifty-three percent of the world’s production area is located in sub-Saharan Africa where sorghum comes second only to maize in crop area. Maize importation and its use as food contribute to the high production costs that are the main constraint to poultry production in Niger and Nigeria (Maizama et al., 2003, Issa et al., 2009, Kawari et al., 2011). In terms of chemical composition, sorghum grain contains 2650 kcal/kg metabolizable energy and 10% crude protein, slightly lower than maize’s 3300 kcal/kg metabolizable energy but higher than its 9% crude protein. Sorghum is close to maize in proximate composition, except for variation in protein, linoleic acid and mineral concentration, making it a candidate for poultry nutrition in some parts of the world. Also, Hancock et al., (2000) proposed that adequate processing improved the nutritive value of sorghum in poultry to levels similar to that of maize. Consequently, with selection of good varieties and proper processing, sorghum could play an important part in livestock (poultry and fish) feed in West Africa. The poor and the under-privileged are the main sorghum consumers, while brewing drives industrial demand for the crop in Nigeria.

The Nigeria Government Sorghum Transformation Value Chain project hopes to increase sorghum production by 4 million tons and increase industrial demand and utilization by the same amount. Industrial markets are expected to take up the additional sorghum grain production for fortified foods, malt and malt beverages and drinks, high quality sorghum flour and livestock feed.

Unlike maize, Nigeria currently imports no sorghum, the cost of which is about 80% that of maize at the grain marketing board. If poultry production is to be boosted in the semi-arid zones, which are characterized by recurrent drought and poor soil conditions, then the use of well-adapted cereal crops like sorghum needs to be explored, particularly given the present lack of adequate information.
on the chemical composition, anti-nutritional factors and the feeding value of different varieties of sorghum as an energy source for the broiler diet.

Nevertheless, poultry producers and extension personnel in the Sahel have concerns about using sorghum in feeds because of the perceived low nutritional value of domestically produced sorghum grain. Thus, a broilers experiment was initiated in Niger and Nigeria to determine the nutritional value of broiler diets formulated with either maize or sorghum grains. The goal was to demonstrate the merits of diets based on sorghums at 0, 25, 50, 75 and 100% levels of inclusion.

**Niger:** This project was implemented by ICRISAT-Niger and INRAN together with Guidan Gona Poultry Farm in Maradi a total of 240 1-day-old broiler chicks of the Early Bird strain were randomly allocated to 20 pens (12 birds per pen) with four pens per treatment and five treatments, from 6 June 2014 at the Maradi poultry farm in Niger for seven weeks. Birds were housed on deep litter in an open-sided building with 1.4 m²/pen. Ranges of temperature (29 to 37 °C), humidity (23.6 to 24.4%), and wind speed (1.40 to 1.5 m/s) were observed during the day. The vaccinations included were Newcastle HB1/Lasota (NVD-I2) and Gumboro (Nobilis gumboro 228E).

Birds were allowed to consume feed and water as they wished, with the control diet being maize-based with fish-meal and peanut meal used as the primary protein supplements. The diet was formulated to 1.2 and 1.1 Lys (dietary lysine) for day 0 to 21 and 21 to 49, respectively. Sorghum was used to replace maize on a wt/wt basis so that treatments were: 75% + 25% sorghum, 50% + 50% sorghum, 25% + 75% sorghum, and sorghum alone. The maize was imported from Nigeria and the Sepon 82 improved sorghum with white seed and no detectable tannins was used. Maize, sorghum and diet samples were collected and analyzed for proximate components (AOAC, 1990) and particle size. Bird body weights were recorded on days 0, 21 and 49. At the end of the experiment, five birds per pen were randomly chosen and killed for carcass analysis. Response criteria were live weight (at d 0, 21, and 49), average daily gain (ADG at d-21 and 49), average daily feed intake (ADFI at d-21 and 49), gain to feed ratio (G:F at d-21 and 49), and carcass weight and carcass yield.

All growth and carcass data were analyzed as a randomized complete block design using the SAS Proc Mixed procedure (Table 11). Live weight was used as a covariate during carcass data analysis.

Growth and carcass data from 240 broiler chicks were collected in a 49-day growth assay, and all data were tested normal (P > 0.15). At d-21, ADG was greater (14.5 g) in birds fed 50% Maize + 50% sorghum. Average daily gains were similar to those (31 to 37 g). The low ADG in the experiment was likely caused by extreme heat stress in the naturally ventilated building (26 to 40 °C).

In the trial conducted, d-1, d-21, and d-49 body weight (BW) were similar (P < 0.14) for birds fed Maize, 75% Maize + 25% sorghum, 50% maize + 50% sorghum, 25% Maize + 75% sorghum and sorghum alone.

Table 11: Growth performance and carcass measurements of broilers fed maize-and sorghum-based diets at Maradi, Niger

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Maize</th>
<th>75% Maize + 25% sorghum</th>
<th>50% Maize + 50% sorghum</th>
<th>25% Maize + 75% sorghum</th>
<th>Sorghum</th>
<th>Mean</th>
<th>Standard error deviation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>D-1 BW (gms)</td>
<td>41</td>
<td>40</td>
<td>41</td>
<td>41</td>
<td>42</td>
<td>41</td>
<td>2</td>
<td>P &gt; 0.92</td>
</tr>
<tr>
<td>D-21 BW (gms)</td>
<td>283</td>
<td>290</td>
<td>346</td>
<td>299</td>
<td>306</td>
<td>305</td>
<td>38</td>
<td>P &gt; 0.14</td>
</tr>
<tr>
<td>D-49 BW (gms)</td>
<td>1405</td>
<td>1418</td>
<td>1458</td>
<td>1474</td>
<td>1340</td>
<td>1419</td>
<td>83</td>
<td>P &gt; 0.17</td>
</tr>
<tr>
<td>D1-21 Feed intake (gms)</td>
<td>24</td>
<td>24</td>
<td>26</td>
<td>23</td>
<td>23</td>
<td>24</td>
<td>2</td>
<td>P &gt; 0.18</td>
</tr>
<tr>
<td>D21-49 Feed intake (gms)</td>
<td>72</td>
<td>72</td>
<td>77</td>
<td>77</td>
<td>70</td>
<td>74</td>
<td>5</td>
<td>P &gt; 0.11</td>
</tr>
<tr>
<td>D1-21 W gain (gms)</td>
<td>11.5</td>
<td>11.9</td>
<td>14.5</td>
<td>12.3</td>
<td>12.6</td>
<td>12.6</td>
<td>1.8</td>
<td>P &gt; 0.14</td>
</tr>
<tr>
<td>D21-49 W gain (gms)</td>
<td>40.1</td>
<td>40.3</td>
<td>39.7</td>
<td>41.9</td>
<td>36.9</td>
<td>39.8</td>
<td>3.0</td>
<td>P &gt; 0.22</td>
</tr>
<tr>
<td>D1-21-Feed/gain</td>
<td>489</td>
<td>497</td>
<td>556</td>
<td>535</td>
<td>554</td>
<td>527</td>
<td>26</td>
<td>P &gt; 0.27</td>
</tr>
<tr>
<td>D21-49-Feed/gain</td>
<td>558</td>
<td>550</td>
<td>520</td>
<td>544</td>
<td>528</td>
<td>540</td>
<td>23</td>
<td>P &gt; 0.70</td>
</tr>
<tr>
<td>Carcass weight (gms)</td>
<td>1013</td>
<td>1014</td>
<td>1015</td>
<td>1017</td>
<td>1061</td>
<td>1023</td>
<td>7</td>
<td>P &gt; 0.01</td>
</tr>
<tr>
<td>Carcass yield, %</td>
<td>71.40</td>
<td>71.37</td>
<td>71.42</td>
<td>71.45</td>
<td>70.75</td>
<td>71.29</td>
<td>0.21</td>
<td>P &gt; 0.70</td>
</tr>
</tbody>
</table>
With BW used as covariate, all birds had similar (P > 0.68) carcass weight and carcass yield. Indeed, carcass measurements were similar for all treatments, which favors substitution with sorghum in place of maize if priced more cheaply.

In summary, birds fed maize-based, sorghum-based or maize-sorghum-based diets had similar growth performance and carcass characteristics. Thus, tannin free sorghum had nutritional value comparable to that of maize and in West Africa local sorghum is a good alternative for poultry feeds when grains price are similar. It is important to make sorghum grains available for poultry producers and other processors.

**Nigeria:** ICRISAT collaborated with the Sorghum Transformation Value Chain of the Nigeria Agricultural Transformation Agenda and Centre of Dryland Agriculture, Bayero University Kano (CDA) to carry out several stakeholders’ design studies to evaluate the replacement value of some sorghum varieties selected from the broad groups based on seed characteristics present in the country. Kaura represents the broad group with light yellow seed coat color, Farafara represents the group with bold bright white seed coat and Red sorghum represents the broad group of several landraces found in the Guinea savannas with a reddish brown seed coat.

ICSV400, an improved released variety with the typical light creamy color associated with most of the introduced varieties and the few hybrids available in Nigeria, was evaluated. The results were positive, especially in the first four weeks. Except for the red sorghum, the feed samples based on the other three sorghum varieties (Farafara, ICSV400 and Kaura) were better than or as good as maize-based feed (Figure 10). In the broiler finisher trial, there were no significant differences among the sorghum varieties and between the average sorghum values and the maize-based feed for final bodyweight gain.

Although the feed conversion ratio appears higher for maize, the sorghum-based diets had significantly lower feed to weight gain value (Table 12). This implies that farmers can replace maize in poultry feed at a 50% or 100% level with sorghum and, during the seven months of the year when the sorghum price is lower than maize, feed and poultry production costs can be significantly reduced by use of sorghum as the main energy source in poultry feeds.

To showcase to value-chain actors the performance of the birds fed to sorghum ration, a large field day was organized on 11 December 2014 at the research farm in Imawa, Kura LG Kano State in collaboration with the desk office of the Sorghum Value Chain and CDA. More than 100 participants, including poultry farmers, poultry feed millers, male and female sorghum farmers, traditional and political leaders graced the occasion. Feedback from the field day, which also helped forge links between actors, included a request by poultry farmers for the value chain to conduct similar demonstrations with layer birds. This challenge has been taken up in 2015 activities by ICRISAT, the Centre for Dry Land Agriculture at Bayero University, Kano and the Sorghum Value Chain.
Table 12: Main effects of sorghum inclusion level on the performance of broiler chicken finisher (4–8 weeks)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial body weight (gms)</td>
<td>1076.63</td>
<td>1074.18</td>
<td>1073.29</td>
</tr>
<tr>
<td>Final body weight (gms)</td>
<td>2271.53</td>
<td>2330.21</td>
<td>2267.70</td>
</tr>
<tr>
<td>Total weight gain (gms)</td>
<td>1194.90</td>
<td>1256.03</td>
<td>1194.41</td>
</tr>
<tr>
<td>Average daily weight (gms)</td>
<td>56.9</td>
<td>59.81</td>
<td>56.88</td>
</tr>
<tr>
<td>Total feed intake (gms)</td>
<td>3407.60</td>
<td>3091.90</td>
<td>3136.90</td>
</tr>
<tr>
<td>Average daily feed intake (gms)</td>
<td>121.70</td>
<td>110.30</td>
<td>112.00</td>
</tr>
<tr>
<td>Feed conversion ratio</td>
<td>2.28</td>
<td>2.00</td>
<td>1.91</td>
</tr>
<tr>
<td>Feed cost N/kg gain</td>
<td>297.77</td>
<td>223.21</td>
<td>232.47</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>5.33</td>
<td>4.00</td>
<td>4.33</td>
</tr>
</tbody>
</table>

SHARING NEW IDEAS FOR BAKING AND FUELING COOKERS WITH SORGHUM

New baking and bio-charcoal production techniques have been introduced to women farmers in Kano, Nigeria so they can benefit from technologies for enhancing the sorghum value chain. A training-of-trainers workshop primarily focused on the use of sorghum in making bakery products such as cakes, biscuits and bread, and on producing bio-charcoal. Twenty-one women extension agents and group leaders drawn from the Kano State Agricultural Development Project learned about the benefits of sorghum, food safety practices, hygiene, sanitation, and entrepreneurship during the two-day workshop organized by ICRISAT.

Participants in the workshop, aimed at building the capacity of rural women to actualize the objectives of the Nigeria Sorghum Transformation Value Chain (STVC) to reduce poverty, improve food security, nutrition and health of women and children, also expressed support for the formation of a ‘Women Sorghum Processors and Marketers Association’ and proposed to provide training to other women in their communities on new technologies. They have sought the support of STVC, ICRISAT and its partners to achieve these objectives. ICRISAT and STVC used the opportunity during the training held at Kura Local Government Area, Kano state to link up with the Africent Integrated Trade Microfinance Cooperative Society who provided training on carbonizing of agricultural waste product to make bio-charcoal. Large-scale adoption of this technology will help reduce deforestation in semi-arid regions since women could use bio-charcoal as an alternative source of energy for household use as well generate income. Africent also promises markets and credit linkages to women entrepreneurs who are interested in making bio-charcoal. The material for making bio-charcoal includes easily available material like crop residues, weeds, rice shaft and irrigation channel weeds that are abundant in the rural areas of northern Nigeria.

This research was undertaken under the CGIAR Research Programs on Dryland Cereals and on Dryland Systems.
Agroforestry offers triple wins in food security, adaptation and mitigation to smallholder farmers hit by declining soil fertility in the West African Sahel and dry savanna areas.

High hopes for farmer-managed natural regeneration of indigenous trees and its potential recognition as a Climate Smart Agricultural method depend however, on the hard scientific data being gathered by ICRISAT and its partners in the CGIAR Research Programs on Dryland Systems and Climate Change, Agriculture and Food Security (CCAFS). These scientific findings show that fruit, leafy vegetables and nuts associated with trees have a positive impact on nutrition, that trees can protect land against degradation, and that additional wood can be used in the household or provide extra income.

Declining soil fertility has become a major farming constraint. Huge tracts of farmland have become degraded to the point that they no longer produce enough for consumption and financial needs. Hence, households and their communities, which make up a large proportion of rural population that rely on subsistence farming, suffer from malnutrition and hunger, particularly during the lean period in years with the least favorable climate. Evidence across the region, and particularly from Niger, indicates that diversification of smallholder crop production is a crucial step in food and nutrition security strategies. For a number of farmers, raising crop trees on farmland or homesteads strengthens livelihood, buffering capacity and broadens sources of food in household diets.

These farmers have embraced an innovative practice known as farmer-managed natural regeneration (FMNR), which is a set of practices farmers use to foster the growth of indigenous trees on agricultural land. This agroforestry technology offers an alternative solution to resource-constrained smallholder farmers who, in the absence of inorganic fertilizers, would otherwise grow crops without addressing nutrient requirements and harvest little or nothing for storage. However, unless farmers widely adopt these technologies as part of their farming system, the potential benefits for livelihoods and the environment will not be realized.

FMNR is now being considered as a promising Climate Smart Agricultural method that represents an inexpensive means of enhancing rural livelihoods, and may contribute to climate change mitigation by sequestering large amounts of carbon in tree biomass and soil in addition to conserving biodiversity. Despite the potential relevance of FMNR as an efficient way to contribute to climate change mitigation and livelihood, there has been so far no attempt to substantiate anecdotal evidence with factual data provided by field-based evaluation.
The CRP-Dryland System, CCAFS, ICRISAT and national partners have assessed the status of tree biodiversity, the drivers of tree conservation on farmland, and the impacts on the livelihoods of rural communities. This evidence-based activity will prove the benefits from FMNR and establish a basis for further scaling-up initiatives. Data were collected using qualitative and quantitative methods. Focus group discussions and key informant interviews were held and households surveyed in two target areas (Maradi region and Fakara).

**Key results:**

- Trees on farms improve household food security as provision of fruit and leafy vegetables and nuts have a positive impact on nutrition. They are sources of micro-nutrients, providing dietary fiber, vegetable proteins and medicine.

- From various farmers’ testimony, integrating trees into agricultural systems is an effective strategy to protect land against land degradation through reduction of wind speed and wind erosion. Trees can be cropped or their fruits harvested, serve as fences and raise the income derived from market gardens.

- FMNR helps solve the household energy crisis by providing fuel wood, which alleviates the burden on women. “We are making various products such as hut roofs and tool handles that bring in additional income,” indicates an innovator-farmer and trainer from Dan Saga in the Maradi region where FMNR has been practiced for 20 years. “This was not possible before FMNR was introduced. Moreover, income from the sale of wood has risen to the extent that farmers are now organized in a cooperative serving the rural wood market. This provides extra income in addition to the fact that we get necessary wood supply for our households.”

- Maintaining tree cover on farmland rebuilds soil quality and fertility by depositing organic matter, attracting animals that deposit manure and urine, and trapping airborne topsoil.

- The adoption of FMNR increases tree biodiversity at the farm level and offers various opportunities.

**Lessons learned:**

- Conducive legal environment is needed with regards to tree and land tenure: farmers are willing to embrace the practice if they are sure they will not be dispossessed of the land.

- FMNR relies on local management of existing indigenous species; it is cheap to implement, and has the potential to quickly increase tree cover.

- FMNR benefits soils, crops, livestock, the environment and the welfare of local communities.
Large areas of degraded lateritic soils are being converted into productive land through an integrated approach, which combines water harvesting technologies, the application of organic residues and planting of fruit trees and vegetables. The strategy has also enabled increase in farmers' income as well as an active involvement of the country's largely marginalized women in food production through their gaining access to land.

Degrading environmental conditions in the Sahel have caused inexplicable human suffering for many decades and the situation is still far from over. The region suffered drought periods in the 20th century that caused an acute human and environmental crisis. The impacts of these changes in the climate have been very severe. Food production dropped drastically. Sorghum and millet yields decreased, and a majority of farming households suffered annual food deficits of 50% or more.

The loss of trees and soil degradation that increased the local population’s vulnerability to drought is induced by a complex scheme of historical and socio-economic factors. Demographic growth is putting untold pressure on the Sahel’s cropland. Population growth, combined with other factors such as an increase in extensive agriculture, covering larger areas of land, with a trend to cereal monocultures, led to reduced tree cover.

Fallow time decreased (or was even abandoned) and applying less manure per unit of surface area led to soil degradation and erosion. Useful tree species were lost and little natural regeneration occurred.

In the Maradi region of Niger for example, wind erosion left the soil completely barren and both ecosystem and human settlements became increasingly vulnerable to drought. Degraded lateritic soils occupy more than 50% of the land surface of Niger so it was vital to identify the best options or methods to help these communities to build resilience and improve their livelihoods.

Bio-reclamation of Degraded Lands (BDL) is an integrated system aiming at increasing food production and income of women through the utilization of degraded lands for production. Worthy to note is the fact that in the Sahel as in many parts of Africa, women are denied land ownership rights. And, it is these women who are responsible for feeding their families. Innovative technology for rainwater harvesting and for small-scale irrigation aimed at increasing both water availability and water productivity in the semi-arid zones has been tested with great success by ICRISAT in Africa.
Now, the innovative production system encourages the production of indigenous horticultural crops that provides solution to a range of critical constraints affecting thousands of households in the Sahel. The fact that the technology is easy to practice means there is a very high potential for mass adoption.

Best described as a multi-purpose strategy, the system helps to reduce further land degradation, increases water availability and productivity of the land while bringing economic benefits to farmers. The most significant is the fact that it helps to mitigate desertification and climate change. The system entails creating micro-catchments, often referred to as half-moons, that are stuffed with organic waste matter so they retain runoff when it rains. In-between the half-moons, are small pits of up to 20 cm deep called zaï in which women plant vegetable and other crops. These too are covered with organic waste.

To re-green the vegetation, improved cultivars of three multipurpose woody species are introduced: Ziziphus mauritiana (referred also to as the Sahelian apple or “juju-bier”), Tamarindus indica (sweet tamarind), Sclerocarya birrea (marula) and Moringa stenopetala. These species provide food, medicine and fodder. Added to these is Acacia senegal, a small thorny deciduous tree also known as Gum Arabic Tree, the source of the world's highest quality gum. It provides fuelwood and fodder. In addition, two Australian acacias (Acacia colei and Acacia tumida) can be planted as they provide firewood, mulch and nitrogen to the soil.

Their protein-rich seeds serve as poultry feed. These tree species can be intercropped with traditional leafy vegetables such as Senna obtusifolia, Cassia tora, Gynandropsis gynandra, Corchorus stridens, Ceratotheca sesamoides, Leptadenia hastata and Hibiscus sabdariffa. Such vegetables have very important roles in both human nutrition (food security) and income generation.

Medicinal crops such as Cassia acutifolia (senna), Cassia occidentalis and Abelmoschus esculentum (okra) are also planted. Earlier studies by ICRISAT in Niger have enabled the identification of best combinations of trees and leafy vegetable suitable for the different regions based on ecological conditions and farmers’ interests.

**Key results**

- BDL contributes to empowering women. They are denied the right to own cropland but village chiefs can allot them degraded lands, which they are able to make productive. The women form legally registered associations that lease each member a plot of land in the BDL, ranging from 100-300 m² in size.

- Smallholder women secure access to land where they can produce food high in micronutrients for consumption and income, and improve food quality for women and children.

- BDL contributes to diversification of smallholder production and consumption of nutritious crops. Furthermore, it increases production of high value crops for income generation.

The impact of the BDL has been multidimensional. Firstly, it is gradually increasing the available arable land area and making it possible to meet the growing demand for food that goes along with demographic increase. Secondly, the BDL system is giving vulnerable and marginalized women a voice and opportunity to help improve the livelihoods of their families. They are able to produce more food and vegetables and are generating income from their activities.

A study at ICRISAT shows that a 200 m² plot can yield an annual income of FCFA 50,000 (approximately 100 US$), equivalent to what men traditionally earned per hectare from millet production.

Increased availability of nutritious food, as well as income from extra millet production, benefited the women, their children and other members of their households. Livestock also have more fodder. As a result, the system is being adopted by many NGOs (eg, Catholic Relief Service) as a major means to empower women and to improve household livelihoods in various zones of intervention across Niger. Lastly, the system is gradually making way for re-greening.

The success of Bioreclamation of Degraded Lands has highlighted key lessons:

- BDL is an excellent intervention for areas with degraded land with a light laterite crust.

- BDL will cover all areas with annual rainfall above 400 mm. Its success depends on committed women organized in groups.

- Availability of seeds and trees that are proven to be locally ecologically adapted is important.

- BDL is an excellent resilience-enhancing land management practice but requires good integration of various scientific disciplines, the potential of nature and the culture of the targeted communities.
Farmers with access to seasonal and daily weather forecasting for growing cowpea and sesame in the northern region of Burkina Faso have responded by changing cropping strategies and task scheduling with resultant gains in crop yields and gross margins.

These findings reinforce earlier indications from a CCAFS West Africa program on pilot sites in Burkina Faso, Ghana, Mali, Niger and Senegal that some of the uncertainties of climate change could be smoothed out by informed decision-making at the farm level. The access to climate information may help farmers to take advantage of good years and minimize the losses during poor years. CCAFS implemented the communication of climate information in 2014 within the cowpea and sesame sectors in northern Burkina Faso to assess the effect of climate information use on farm productivity and determine the willingness to pay for climate information within these sectors in the target area.

The value of the use of climate information in agriculture is defined as the net benefit a user (farmer) incurs as a result of change in farm management practices in response to the availability of the climate information. Assuming that the use of climate information will lead to subsequent changes in key management decisions, including farm inputs allocation and planning of farming activities, this should in turn lead to outcomes that are different to those based on business-as-usual scenarios.

In this ICRISAT study, an ex-post assessment method (with an experimental and a control group) was used to evaluate the added-value of using seasonal forecasts. Farmers from the experimental group were exposed to climate information and agro-advisories through workshops, radio shows, while farmers from the control group were not exposed to climate information. Farmer willingness to pay for climate information was determined using the contingent valuation method. Data was collected through farm surveys on 170 farmers from 17 villages, including 11 experimental villages and six control villages.

Based on seasonal rainfall forecasts for West Africa from the Climate Outlook Forum known as PRESAO (Prévisions Saisonnieres pour l’Afrique de l’Ouest), the National Meteorological Agency (DMN) of Burkina Faso produced agro-met advisories, developed by a multidisciplinary team, including local extension workers from the agriculture Ministry, DMN climatologists and agronomists from the country’s Environmental and Agricultural Research Institute (INERA).
Three types of climate information were generated: seasonal forecasts, 10-day forecasts, and daily climate information. The seasonal forecasts were communicated to farmers through a one-day workshop at which communication of climate information was coupled with discussions on traditional forecasting practices.

The 10-day forecasts, as well as the daily climate information, were disseminated through radio shows. Each farmer from the experimental group (120 farmers) was issued and a rural radio station (La voix du paysan) contracted for climate information dissemination.

The study highlighted the potential role that predictive climate information can play in shaping farmers’ crop management strategies in situations of climate uncertainty. The survey showed that farmers exposed to climate information used this information to make decisions regarding their farm management.

They used the seasonal forecast, including onset information and length of the rainy season, mainly (i) to select crops and varieties to grow, (ii) to choose the location of growing sites (in terms of lowland or plain) and (iii) to define the size of cropping area. However, farmers used the daily climate information to make decisions on day-to-day management practices such as choosing the date of land preparation, plowing, sowing, planting, fertilizing, hoeing, weeding, pest control, harvesting, and threshing.

Table 13 shows the use of climate information for making decisions on farm practices within the study sample in the Yatenga region. These findings suggest that the type of information used depends on the type of decision to be made. The seasonal forecast affects strategic decisions (such as selection of crops and varieties) while the daily information influences current management practices.
Change in farm inputs use in response to climate forecasts

The study showed that farmers exposed to climate information used less seed than the non-exposed farmers. They used less local seed and more improved seed for cowpea and sesame cropping. They also used less organic manure and more fertilizers for sesame production. They used less labor than the non-exposed farmers.

This is not surprising because good use of climate information should lead to an optimal choice of the period for farm activities (sowing, fertilizing and pest control). This contributes to avoiding the waste of farm inputs, including seed, fertilizer and labor, that can follow bad planning of farm activities.

How climate information affects farm productivity?

Productivity is defined as the ability of a unit of input to produce a certain level of output. Under this definition, the use of climate information should definitely affect farm productivity through changes in agricultural inputs use (Table 14).

The study showed that cowpea producers exposed to climate information obtained higher yields. Savings in seed and pesticides led to lower inputs costs. Their gross margins were therefore higher compared to non-exposed farmers. For sesame, the effect of climate information on farm productivity was not statistically significant during 2014 (Table 15). Further investigations are needed to confirm these results.

Demand for climate information

About 68% of farmers exposed to climate information accepted to pay for the seasonal forecast and 69% for the daily climate information. The observed willingness to pay is about FCFA 7404 (12 US$) for seasonal forecasting and FCFA 3441 (8 US$) for the daily climate information.

Table 16 shows the observed willingness to accept (WTA) and pay (WTP) for climate information within the study sample. The results showed that there is a high demand for climate information.

The study showed that farmers exposed to climate information changed their farm practices based on the information they received, and that this translated into management of inputs to increase their farm productivity and improve their resilience to climate variability.

Further investigations are necessary in the sesame sector to confirm these results, but the study revealed significant gains vis-à-vis risk induced by climate variability may follow from scaling-up the use of seasonal forecasts to country level, especially for cowpea.

Table 13: Changes in farm practices in response to climate forecasts

<table>
<thead>
<tr>
<th>Type of use</th>
<th>Percentage</th>
<th>Type of information used and contribution (%) to decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selecting crop</td>
<td>36.45</td>
<td>Seasonal forecast (67.50)</td>
</tr>
<tr>
<td>Selecting variety</td>
<td>50.93</td>
<td>Seasonal forecast (44.23)</td>
</tr>
<tr>
<td>Selecting cropping site</td>
<td>38.89</td>
<td>Seasonal forecast (51.28)</td>
</tr>
<tr>
<td>Defining the size of cropping area</td>
<td>56.48</td>
<td>Seasonal forecast (87.93)</td>
</tr>
<tr>
<td>Date of land preparation</td>
<td>13.08</td>
<td>Daily information (42.86)</td>
</tr>
<tr>
<td>Date of plowing</td>
<td>35.19</td>
<td>Daily information (65.79)</td>
</tr>
<tr>
<td>Date of sowing</td>
<td>32.41</td>
<td>Daily information (71.43)</td>
</tr>
<tr>
<td>Date of application of organic manure</td>
<td>10.19</td>
<td>Daily information (72.73)</td>
</tr>
<tr>
<td>Date of application of organic manure NPK</td>
<td>29.63</td>
<td>Daily information (93.55)</td>
</tr>
<tr>
<td>Date of application of organic manure urea</td>
<td>12.15</td>
<td>Daily information (83.33)</td>
</tr>
<tr>
<td>Date of hoeing</td>
<td>55.56</td>
<td>Daily information (88.37)</td>
</tr>
<tr>
<td>Date of weeding</td>
<td>40.19</td>
<td>Daily information (91.67)</td>
</tr>
<tr>
<td>Date of controlling pests</td>
<td>19.44</td>
<td>Daily information (96.24)</td>
</tr>
<tr>
<td>Date of harvesting</td>
<td>21.30</td>
<td>Daily information (91.30)</td>
</tr>
<tr>
<td>Date of threshing</td>
<td>3.74</td>
<td>Daily information (75.00)</td>
</tr>
</tbody>
</table>

Number of farmers: 108
Table 14: How climate information affects inputs use

<table>
<thead>
<tr>
<th></th>
<th>Cowpea</th>
<th>Sesame</th>
<th>Difference</th>
<th>t-statistics</th>
<th></th>
<th>Cowpea</th>
<th>Sesame</th>
<th>Difference</th>
<th>t-statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>Exposed (n=49)</td>
<td>Not exposed (n=27)</td>
<td>0.23</td>
<td>0.20</td>
<td>0.03</td>
<td>Exposed (n=51)</td>
<td>Not exposed (n=22)</td>
<td>0.34</td>
<td>0.31</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Improvised seed (kg/ha)</td>
<td></td>
<td>8.0</td>
<td>12</td>
<td>6.80 **</td>
<td></td>
<td>8</td>
<td>8</td>
<td>1</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Local seed (kg/ha)</td>
<td></td>
<td>18</td>
<td>49</td>
<td>-31 **</td>
<td></td>
<td>5</td>
<td>8</td>
<td>-2</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Total seed (kg/ha)</td>
<td></td>
<td>26</td>
<td>50</td>
<td>-25 **</td>
<td></td>
<td>13</td>
<td>15</td>
<td>-2</td>
<td>-0.54</td>
</tr>
<tr>
<td></td>
<td>Manure (kg/ha)</td>
<td></td>
<td>15</td>
<td>26</td>
<td>-10</td>
<td></td>
<td>8</td>
<td>16</td>
<td>-8</td>
<td>-1.58</td>
</tr>
<tr>
<td></td>
<td>Fertilizers (kg/ha)</td>
<td></td>
<td>33</td>
<td>36</td>
<td>-3</td>
<td></td>
<td>23</td>
<td>1</td>
<td>23*</td>
<td>1.95</td>
</tr>
<tr>
<td></td>
<td>Insecticide (l/ha)</td>
<td></td>
<td>2.58</td>
<td>3.46</td>
<td>-0.88</td>
<td></td>
<td>1.1</td>
<td>0.5</td>
<td>0.55</td>
<td>1.11</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td>166</td>
<td>178</td>
<td>-11</td>
<td></td>
<td>104</td>
<td>111</td>
<td>-8</td>
<td>-0.28</td>
</tr>
</tbody>
</table>

*Significant at 10%; ** significant at 5% level.

Table 15: How climate information affects farm productivity

<table>
<thead>
<tr>
<th></th>
<th>Cowpea</th>
<th>Sesame</th>
<th>Difference</th>
<th>t-statistics</th>
<th></th>
<th>Cowpea</th>
<th>Sesame</th>
<th>Difference</th>
<th>t-statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>Exposed (n=49)</td>
<td>Not exposed (n=27)</td>
<td>0.23</td>
<td>0.20</td>
<td>0.03</td>
<td>Exposed (n=51)</td>
<td>Not exposed (n=22)</td>
<td>0.34</td>
<td>0.31</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Yield (kg/ha)</td>
<td></td>
<td>847</td>
<td>685</td>
<td>162*</td>
<td>550</td>
<td>605</td>
<td>-55</td>
<td>-1.46</td>
<td>-1.50</td>
</tr>
<tr>
<td></td>
<td>Gross product (CFA/ha)</td>
<td></td>
<td>43,706</td>
<td>63,128</td>
<td>-19,423*</td>
<td>33,435</td>
<td>392,786</td>
<td>-117,290</td>
<td>-1.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gross margin (CFA/ha)</td>
<td></td>
<td>56,170</td>
<td>33,797</td>
<td>22,373</td>
<td>538,087</td>
<td>510,075</td>
<td>-5,652</td>
<td>0.57</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 10%.

Table 16: WTA and WTP for climate information

<table>
<thead>
<tr>
<th>Type of information</th>
<th>WTA (%)</th>
<th>WTP observed (CFA)</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal forecast</td>
<td>68</td>
<td>7404</td>
<td>19,209</td>
<td></td>
</tr>
<tr>
<td>Decadal information</td>
<td>42</td>
<td>1776</td>
<td>6,240</td>
<td></td>
</tr>
<tr>
<td>Daily information</td>
<td>69</td>
<td>3441</td>
<td>11,260</td>
<td></td>
</tr>
<tr>
<td>Agro-met advisories</td>
<td>48</td>
<td>2884</td>
<td>10,606</td>
<td></td>
</tr>
</tbody>
</table>

# of valid farmers = 108
It is established that for countries in the semi-arid region of West Africa, changing climate conditions will affect major crops such as sorghum, maize, common beans and finger millet that are currently the staple food for many communities (O’Brien and Leichenko, 2000). Changes towards climate-adapted livestock management, and shift to more drought-tolerant and heat resistant varieties, or crops such as cassava, yam and sorghum will be needed, which requires long-term investments along with policy and institutional shifts (Ramirez-Villegas and Thornton, 2015).

Recent consultations within the pilot countries, including Mali, Ghana, Niger, Burkina Faso and Senegal, covered by the CGIAR Climate Change, Agriculture and Food Security (CCAFS) program, revealed that various governmental and research institutions have developed multiple initiatives aimed at reducing the negative effects of climate change, but these interventions yielded limited success because they were fragmented and uncoordinated. Therefore, the CCAFS projects committed to facilitating a deep engagement with end users, including state agencies, the private sector, scientists, farmers and extension agents, to get collaborative solutions to climate change problems. CCAFS builds on the so-called “platforms” approach as a way to facilitate effective interaction and create enabling conditions to support investment and inclusive climate policy development.

In each of the CCAFS countries, relevant stakeholders were engaged through national science-policy platforms to explore opportunities of convergence and to promote climate-smart technologies for sustainable agricultural intensification. The CCAFS Policies and Institutions Flagship project assumes that the gaps between the scientists and the policymakers can be reduced by decentralizing the multi-stakeholders platform process at a lower level (district-level) for wider coverage. A harmonized framework was then designed for setting the district-platforms across the intervention countries. The framework was meant to enable comparison across the countries and facilitate experience sharing and exchange of best practices.

The district platforms target mainly frontline stakeholders and work at the grassroots’ levels to identify the challenges and the opportunities of the district actors. In total, nine district-platforms were established with local policymakers, scientists, private sector representatives, farmer associations, and traditional and religious authorities.

The district-level alliances aim to complement the national platforms by providing insights and guidance from district levels, which can then help support the mainstreaming of climate change into relevant food security policies at both district and national levels. These multi-stakeholder platforms offer space for sharing perspectives on food and climate change related topics and for making joint decisions.

**Tackling future challenges by taking action now**

In each district platform, the Policies and Institutions Flagship team is making use of a tried and tested method to address the demanding climate challenges to which local communities are exposed. The method includes bringing the district-platform members together to jointly develop future climate and socio-economic scenarios. These scenarios were previously developed at the West Africa regional scale. At this stage, the Policies and Institutions Flagship project downscales the process to the district level, providing opportunity for district actors to collectively visualize the future development of their communities and contemplate the implications for their adaptability. The process lasts for three consecutive days per district to outline plausible future scenarios for the district in the next 30 years. This helped the district actors to identify the various factors that can influence future development in their communities and to reflect on the key actions that they can take to avoid envisioned catastrophic scenarios.

Outputs from these scenarios are used to inform policymakers and sensitize them on the need to establish an enabling context to steer districts towards a sustainable and prosperous future.
REPOSSESSING LANDSCAPES, BRINGING MORE FOOD AND HOPE

HIGHLIGHTS 2014

Increasing the power supply to mixed systems means that more tasks can be completed at the right time. Innovation in mechanization also means that new technologies can be employed more effectively to feed humans and animals by using less power.

Currently, many of the smallholder farms have limited access to production inputs, especially mechanization, and therefore achieve low levels of productivity. Given the current reliance on human muscle power in smallholder agriculture, the power limitation implications are grave as populations increase rapidly and consequent demand for food is driving agriculture towards greater intensification in West Africa, where livestock and crop production systems are highly integrated.

Crop residues have multiple uses: livestock feed, mulch, fuel and housing, as confirmed by studies in Katsina-Kano (Nigeria), Maradi (Niger) and Sikasso (Mali). The crop residues are often burnt, sometimes by accident, but they otherwise occupy a lot of storage space and consequently invite rodents. Not only that, inefficient feeding of crop residues to animals leads to considerable wastage, and competes with biomass for storage space.

Against this background, mobile choppers and grinders for processing fodder for animals were introduced at a training program organized by ICRISAT West and Central Africa along with the Centre for Dryland Agriculture, Bayero University at Kano, Nigeria from 26 October to 1 November 2014. The main objectives of the training were: a) to train participants on use of innovation platforms for better crop-livestock integration, b) to introduce different crop combinations and ways of making efficient use of crop-residues, c) to enhance participants’ knowledge and skills in better feeding practices by use of equipment, processing of feeds, feed formulation and case study and d) to train participants on soil fertility management in the context of crop-livestock integration.

Various training methodologies, including classroom lectures, discussions, practicals and visits to farms practicing crop-livestock integration, were used. Innovative machines such as a mobile chopper for cutting both green and dry fodder were introduced, along with a grinding machine that converts any plant material into powder for further processing as feed block. Training and use of these machines reduced the drudgery of farmers and facilitates efficient use and storage of crop residue.

Forty-one participants (73% men) took part: representing six universities from Benin, Niger, Mali, Burkina Faso and Nigeria; national and international institutes such as the Institute for Agrucultural Research, International Livestock Research Institute, Mercy Corps International, non-governmental organizations such as AMEDD Mali, SHARE-USAID Sokoto, Women Farmers Advancement Network; public departments like the Federal Ministry of Agriculture of Nigeria and Rural Development, Kano State Agricultural and Rural Development Authority and National Agricultural Extension Research and Liaison Services; and private farms like Rahama Integrated Farms, Kano.

There were no women participants from Benin, Burkina Faso and Mali, although three came from Niger and 11 from Nigeria. Most of the male respondents were from Nigeria, followed by Niger, Mali, Benin and Burkina Faso.

A knowledge, attitude and practice survey was conducted before and after the training to assess the current level of knowledge, beliefs and practices in relation to crop-livestock production and management.

Within the context of this study, knowledge refers to the partners’ understanding of crop-livestock production and management and barriers to service delivery. Attitudinal measures are pre-conceived ideas and perceptions that partners have about crop-livestock production and management in the villages. Most partners were able to make a self-assessment about their knowledge before and after the training, indicating a very good level of existing knowledge (Figure 11).

The assessment topics covered, related to cropping system, large ruminants, small ruminants, poultry, use of innovation platform and gender. Most of them had previous training on these topics.
Positive attitudes were reported before and after the training (Figure 12) regarding the potential to improve the degraded soils, access to services in crop-livestock systems in terms of basic inputs, favorable by-laws and policies for integrating gender, mechanisation and manure management.

The crop-livestock practices (Figure 13) were mainly performed by men, women or both together. In the case of crop residue management, chopping green fodder was not an activity practiced in the region.

The take-home messages as reported by the participants were: i) demand for poultry products is fairly inelastic; as such local production should be enhanced; ii) sorghum should be promoted as a maize-substitute energy source because of its availability, accessibility and reduced cost at some periods of the year; iii) crop residue storage and processing should be encouraged to address seasonality issues of feeds; iv) use of mobile choppers, grinders should be used to reduce drudgery and for efficient utilization of crop residues and forages; v) research findings should be disseminated through innovation platforms; and vi) need for training of extension agents and encouraging women to engage in extension activities in crop-livestock activities.

Some of the feedback given by participants:

“...I did not know that green fodder could also be chopped using a machine. We have seen it here for the first time! Even women farmers can use this machine as it is easy and mobile. It can be easily pulled using a donkey in our context here.” – Ms Victoria, trainee from National Agricultural Extension Research and Liaison services.

“ICRISAT has sent us a similar chopper machine. Upon return we will soon start to build awareness and train farmers of 21 farmer organizations in Koutiala involved in crop-livestock activities to cut the green and dry fodder for increasing productivity and reducing wastage.” – Mr Arouna Bayoko and Mr Ousmane Dembele of NGO AMEDD.

“I liked the grinder machine which grinds pods, straw, stover and salt into a fine powder, which can be made into blocks to feed animals.” – Pierre Gbènoukpo Tovihoudji, a trainee, from University of Parakou, Benin.

“In this training we learnt formulas for poultry feeding with sorghum. Normally, farmers feed maize. We never knew sorghum is a cheap substitute with comparable quality. Interestingly, poultry manure is equally important as it replenishes the soil.” – Trainee from Women Farmers Advancement Network.
Repossessing landscapes, bringing more food and hope
Food tasting has joined the list of activities in which farmer participation is a vital ingredient to producing and marketing the correct products. Farmer Participatory Varietal Selection (PVS) is now routinely used by ICRISAT-WCA to test the performance of new varieties under farmers’ management and field conditions. Besides their agronomic qualities, this useful tool has now embraced taste testing with a traditional sorghum porridge for which color and consistency are as important as actual taste.

Why culinary testing?
Over the years, agricultural crop research has developed many new varieties of sorghum and other essential staple crops. However, farmers’ access to these varieties is frequently low in many sub-Saharan African countries. It is estimated that over 90% of seeds are either farmer-saved or informally exchanged. Engaging farmers at an early stage in the variety development process is therefore important. Culinary testing of new varieties is one tool used in PVS to ensure that these varieties are not only adapted to the local agroecological conditions and farming systems, but also have the right grain quality to meet farmers’ grain quality expectations for home consumption and local market demand. For instance in Mali, the sorghum Tô (traditional porridge recipe) has to have the right color, consistency and taste. Culinary testing is also a valuable way to involve women in crop research.

The Culinary Test methodology comes into play after conventional PVS trials have been carried out. Farmers first discuss the yield performance and the evaluation scores they gave to the different sorghum varieties tested by their village in PVS trials. They choose four new test varieties and a well-known local variety to include in their culinary test. Grain of each chosen variety is split into three equal quantities, with three teams of women preparing Tô (traditional sorghum porridge) from each of these varieties. Observations are made throughout the grain processing of each variety, starting with the ease of decortication (pounding off the seed coat).

The yield of grits, bran and flour are measured. In the case of sorghum Tô preparation, the exact quantity of water added is measured so that the final quantity of Tô prepared for each grain sample can be compared (important criteria for men). Doing three replications is important as some aspects of grain processing may vary between women, such as the extent to which they decorticate the grain and the time they take.
Previous PVS testing found that decortication yields could vary from 61 to 87%. The nutritional value of flour is affected by the decortication yield. A large part of essential minerals like iron and zinc are lost with the bran, amounting to 56% loss on average. When the Tô is finally ready, the actual taste testing can begin, with each person tasting Tô from each of the five varieties, one at a time, and giving their appreciation scores for color, taste and consistency using a scale of one (problematic) to three (very good). Each person also gives a score for global appreciation based on his/her overall impression of the Tô of that variety. It is advised that the food tasting is started only after a shared meal, as a hungry taster may rank all food samples highly.

The science of making Tô
First, women pound the sorghum grain with a pestle and mortar, a tiring process often involving two women pounding in rhythm (one woman can only decorticate a maximum of 1.5 kg of grain per hour). The flour is sieved and winnowed to separate flour and bran (the fibrous outer layers of the grain). Sieving with different mesh widths produces the fine flour for Tô or the coarser flour for couscous. Water is boiled. Then some is taken in a bowl and mixed with fresh water (to make it lukewarm) and then mixed with homemade potash (used to improve Tô consistency) and some flour. This is then added to the boiling water. It is stirred regularly and the rest of the flour is slowly added while stirring. This is crucial to avoid the disgrace of producing a Tô with lumps! The pot is removed from the fire so that the flour finishes cooking in its steam (steaming, kawoussou in Bambara). Uncooked flour has a telltale odor if not well cooked. Each woman may cook slightly differently, which is why culinary testing should have at least three replications.

Tô color: finding the balance between taste and adaptation.
The color of the Tô depends on several grain characteristics as well as the way the grain is prepared. Sorghum grain colour is highly variable, from white to black, red or bronze. There are three “genetic colors” in sorghum: white, lemon-yellow and red. The flour and Tô appearance may also depend on other factors like the presence of a tannin rich red testa (subcoat between the pericarp and endosperm) and the presence or absence of pigments (anthocyanes) in the plant.

All local sorghum varieties in Mali are pigmented. This pigmentation was most likely selected for over thousands of years due to the protective advantages it provides against grain mold and disease, which is of particular benefit during germination. At maturity the protective glumes open revealing the grain. A Tô sorghum variety may become purple – rich in anthocyanes—-if purple glumes stay in contact with the grain and moisture from a late rain causes staining of the grain. In Mpessoba village in Mali, farmers are not used to purple or black Tô, most probably because they grow varieties selected over generations for producing “clean” colored grain. Crop selection is about finding the right combinations of many important traits.

Involving women in crop research through food tasting
Color, taste, consistency, ease of decortication and preparation...a new variety has to also perform well in the family kitchen to be adopted. Being responsible for household nutrition, women are leading the culinary testing. This provides a great entry point for gender and nutrition sensitive research.

For example, ease of decortication can significantly reduce women’s workloads, giving them valuable time for childcare and other livelihood options. Culinary testing suits the Malian culture well, as meals are generally shared collectively and the building of social links (maaya juru) is important.
Aminata Sanogo, mother of four children, has sparked a cookery revolution among women in her village, N’golobougou, in the Dioila circle in southern Mali. She cooks her Tô (a traditional staple dish in rural Mali) with whole grain sorghum. Normally, a woman will be praised if her sorghum grains are perfectly decorticated after half an hour of incessant pounding with the pestle and mortar to remove the outer seed coat. Finding bran in the Tô is not acceptable and results in bitter remarks about laziness. However Aminata’s husband finds the whole grain Tô delicious and often invites people to taste it, jokingly warning that they must “Be careful, this is the Tô with non decorticated grain.”

Malnutrition is widespread in Mali, especially among young children in rural areas. Anemia, of which iron deficiency is a major cause, is particularly severe, leading to poor child health and development.

The McKnight foundation-funded An Be Jigi project aims to prevent such malnutrition by increasing iron and zinc nutrition from locally grown sorghum and millets through biofortification, improved cooking and feeding practices and better nutrition education among women farmers, most of whom are illiterate. The focus of research has been on sorghum and millet, crucial staple crops in the rural Malian diet, providing three quarters of the total energy intake of mothers. While these cereals provide about 75% of children’s iron and zinc intake, the total intake of these essential minerals is far below international recommendations for child health and development.

About half the grain’s mineral content (44%) is lost through decortication. Using whole grain would improve the quantity of minerals ingested and also ease mothers’ workload so they could spend more time on childcare. However, bran and seeds are rich in phytates (which are essential for germination and the main form of phosphorus in grain), both inhibiting iron and zinc bioavailability.

Yet bioavailability can be increased by some types of food preparation like fermenting (soaking the grain before milling) and adding vitamin-C-rich ingredients like tamarind or baobab fruit, which significantly increase iron and zinc uptake. Data shows that these measures could help increase iron uptake in children by over 50%. “Akadi, akadi!” (good, good!), says Aminata as she sees how enthusiastically the women and children eat the Tô and nutritiously sweet millet and tamarind porridge she helped the mothers prepare. This supplies proof that women can change the way they cook even the most traditional dishes to improve nutrition and diet diversity once given the correct information.

So, how can An Be Jigi’s success be replicated elsewhere? Aminata has now joined forces with an equally energetic pioneer, Sitan Sidibe, a very active mother of 10 children and grandmother to six, to spread the word.

Convinced about the impact on children and women’s health, Animata and Sitan have become nutrition experts for their community and they are often asked by other villages to organize the same cookery sessions. Even though they are not paid, they see benefit for themselves in what Aminata calls maaya-juru, making more acquaintances in the local Bambara language, which is highly valued in the very sociable Bambara culture. Training more women like Aminata and Sitan could create a revolution.
MAINTAINING GENDER IN AGRICULTURAL RESEARCH FOR DEVELOPMENT: SCIENTISTS HAVE THEIR SAY!

Since its launch in May 2014, ICRISAT’s first ever ‘Gender Forum’ has become a monthly event, as exemplified by this summary from the September 2014 meeting in Niamey that highlighted work in Dryland Cereals and Grain Legumes.

C. Tom Hash, pearl millet breeder, describes ‘shibras’, a weedy intermediate between cultivated pearl millet and its wild progenitor. Shibras often have much lower grain yield than cultivated pearl millet plants. They are found in cultivated pearl millet fields where, as young plants, they are indistinguishable from cultivated pearl millet plants. At later growth stages when they can easily be identified, however, they are left to mature and contribute their progeny to the soil’s weed seed bank.

Shibras are labor-intensive to harvest because their grains are very small and shatter easily. Despite the arduousness of the harvest, it is uncommon for pearl millet producers (except producers of Certified Seed) to remove shibras from a pearl millet field in West Africa. For Dr Hash shibras are a chance to think through the question “For whom am I breeding?” If he is breeding for other breeders, shibras are a weed to be eliminated. Most of the improved landrace varieties of pearl millet that have been released for cultivation in West Africa are shibra-free landraces. Traditionally, shibras are classified by agricultural scientists as “weeds” because they consume soil water and nutrients that could be used by more productive plants growing in the field.

If the breeder is breeding for communities and considering the needs and experiences of men and women in the community, shibras fulfill an important community role. Unlike strict pearl millet that is harvested by men in Niger, shibras are harvested by women, who then control the processing as well as harvest of the shibras. They are the sole decision-makers and are free to use or sell the grain. The shibra harvest occurs earlier in the season than the grain from cultivated plants.

Thus, it is an important resource for food security during the ‘hungry period’, especially for nutritionally-vulnerable men and children. Even though it requires considerable harvesting effort by women, its arrival is very timely and contributes to a family’s food security. In addition the thin-stemmed shibras are seldom vulnerable to grain-feeding birds. Therefore, Dr Hash is aware of the challenges associated with replacing a shibra-infested seed stock with a ‘shibra-free improved version’ of the same variety.

The challenges include consideration of increases in the grain and biomass yield harvested and controlled by the men and the accompanying unintended consequences for those dependent on shibras for food security. In turn, this challenges Dr Hash to consider how improved varieties and shibras could complement each other to decrease the differences in the community in terms of access to food during the pre-harvest ‘hungry period’.

Dr Sapna Jarial, a crop-livestock scientist, spoke about the socio-economic and cultural impacts on farmers’ organizations from six Malian villages where research incorporated the question of how farmer organization membership influences everyday activities for men and women in regions dependent on dryland cereals and grain legumes. She used focus group discussions, stakeholder meetings and semi-structured interviews with the members of farmer organizations to highlight the different experiences for men and women on sustainable development in dryland cereal watersheds. By using same-gender focus groups Dr Jarial’s research confirmed the importance of having men and women members in the farmers’ organizations, and the need for capacity building for men and women to improve agricultural production.

Dr Jupiter Ndjeunga, a socio-economist asks “what differences are defining men and women farmers’ income generation?” By looking at the impact of processing equipment on the livelihoods of rural farmers in western Niger, Ndjeunga is identifying new linkages between women seed producers and seed markets. These linkages can be used as points of intervention for reducing women’s drudgery and increasing women’s income in regions growing grain legumes.

By including the experiences, expertise and perspective of both men and women farmers in breeding, farming and processing, we can enrich our science and help ensure that it is adopted and provides the intended consequences, he argued. It has to be understood that the questions guiding ICRISAT’s science are gendered: “Do we see shibras as undesirable weeds or as desirable sources of grain for human consumption and fodder for livestock?” Answering such questions shapes the science produced. By asking “who?”, “how?” and “what?” questions during the development or application of science, ICRISAT can contribute to decisions on technology adoption, and to food security, at the community level.

Repussing landscapes, bringing more food and hope
VISITS AND ACTIVITIES

In 2014 ICRISAT WCA hosted a wide range of events and welcomed several VIPs: highlights

Deputy Director of China’s Oil Crops Research Institute visits ICRISAT in Mali
Dr Liao Boshou (left), Deputy Director and Professor of the Oil Crops Research Institute, Chinese Academy of Agricultural Sciences (OCRI-CAAS), visited the ICRISAT office in Bamako, Mali on 8-14 January. During his visit, Dr Boshou presented a seminar on “Groundnut Improvement and Industry Development in China” attended by ICRISAT scientists and partners from the Institut d’Economie Rurale (IER). After the seminar, he met with Mr Cao Zhongming, Ambassador of China in Mali, to discuss opportunities for partnerships and bilateral funding.

Nigeria Minister of Agriculture named ICRISAT Ambassador of Goodwill
Dr Akinwumi Adesina, Minister of Agriculture and Rural Development of the Federal Republic of Nigeria, was named ICRISAT’s Ambassador of Goodwill for his vision and leadership in the agricultural transformation of Nigerian agriculture and his valuable achievements in the field of agricultural research for development in Africa.

The Ambassador of Goodwill plaque of recognition was presented to Minister Adesina by Dr William Dar, ICRISAT Director General, during the launch of the groundnut value chain project in Abuja, Nigeria on 24 February. The project is a partnership initiative between the Federal Government of Nigeria and ICRISAT aiming to rebuild Nigeria’s groundnut pyramids and to reclaim the country’s former prime position as the largest groundnut producing country in Africa. The groundnut value chain project will produce an additional 120,000 metric tons of groundnut grains valued at US$ 155 million, to be implemented directly in 16 states in Nigeria.

Africa RISING review and planning meeting held in Mali
On 3-4 February, The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project held its review and planning meeting in Bamako, Mali, to take stock of the activities and plan future course of action in West, East and southern Africa.

Harnessing the power of community radio in Mali
A total of 54 radio producers and hosts (including women) attended a 4-day capacity building session targeting community radio producers in Sikasso region of Mali. For wide dissemination of information on sorghum hybrid, micro-programs, large public shows, sketches, interviews and magazines were proposed.

42nd Annual Day Celebrations at ICRISAT West and Central Africa
Formal and informal recognition awards were presented to those who excelled in the areas of learning and training, contribution to partnership, rational utilization of resources, advance planning, flexibility, commitment, and contribution to strengthening good relationships in the working environment.
Improving the adaptive capacity of smallholder farmers in Mali

ICRISAT’s West and Central Africa (WCA) Regional Office based in Mali started two new initiatives in 2014: to enhance the sorghum and millet value chain; and to develop resilient-smart technologies to improve the adaptive capacity of smallholder farmers. Stakeholders of the initiatives met on 18 February to discuss best practices for increasing the productivity and production of sorghum and millet in the targeted areas at scale, and to link to ongoing activities that would enhance any part of the sorghum and millet value chain, including but not limited to seed multiplication and input access, enhancing agronomic practices, harvest and post-harvest practices, markets and nutrition. Following the meeting, concept notes were submitted to the United States Agency for International Development (USAID) – Accelerated Economic Growth Program by ICRISAT and partners.

Attracting youth back to agriculture in Africa

With the aim of attracting youth back into agriculture and nurture their curiosity and passion for science and research for development, ICRISAT along with the World Vegetable Center (AVRDC) organized a joint exhibition of their research results at the first ‘Sciences Day’ organized by the French school, Lycée Liberté, in Mali. Dr Ramadjita Tabo, incoming Director, ICRISAT West and Central Africa (WCA), was in attendance at a round-table session aiming to help students with professional orientation.

ICRISAT and partners in West and Central Africa bade farewell to Farid Waliyar and welcome new Regional Director

ICRISAT staff and partners in West and Central Africa (WCA) bade farewell to outgoing WCA Regional Director Dr Farid Waliyar at ceremonies organized in Mali and Niger. Dr Ramadjita Tabo, the incoming Regional Director was also extended a warm welcome into the ICRISAT family.

ICRISAT West and Central Africa new Director visits partners in Niger

Upon his nomination, Dr Ramadjita Tabo, ICRISAT Director for West and Central Africa, visited staff and partners in Niger from 11 - 17 May as part of his first regional tour. During his mission, Dr Tabo held high-level talks with officials and partners in Niger. Dr Tabo met the Prime Minister of Niger, His Excellency Brigi Rafini and Foreign Minister Mr Mohamed Bazoum. He also met Ms Martine Therer, Deputy Resident Representative and Programme Director, United Nations Development Programme (UNDP); Mr William Rastetter, Representative of the Catholic Relief Services; Mr Oumarou Malam Issa, Representative of the Institut de Recherche pour le Développement (IRD); and Mr Ahamadou B. Ndiaye, United States Agency for International Development (USAID) Food for Peace Officer.

Other meetings included senior staff of the African Centre of Meteorological Application for Development (ACMAD) and the Centre for Application in Agrometeorology and Operational Hydrology (AGRHYMET), and members of the Sadoré Village Women Association involved in market gardening activities. He also visited ICRISAT’s office in Nigeria and met with staff and partners.
### Mali

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramadjita Tabo</td>
<td>Director, West and Central Africa (since April 2014)</td>
<td>Chad</td>
</tr>
<tr>
<td>Eva W Rattunde</td>
<td>Principal Scientist - Sorghum Breeding &amp; Genetic Resources (Dryland Cereals)</td>
<td>Germany</td>
</tr>
<tr>
<td>HFW Rattunde</td>
<td>Principal Scientist - Sorghum Breeding &amp; Genetic Resources (Dryland Cereals)</td>
<td>France</td>
</tr>
<tr>
<td>Robert Zougmoré</td>
<td>Team leader (CCAFS West Africa Region)</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Birhanu Zemedim</td>
<td>Birhanu - Scientist - Land and Water Management</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Felix Badolo</td>
<td>Scientist - Agricultural Economics</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Agathe Diama</td>
<td>Regional information and communication officer</td>
<td>Mali</td>
</tr>
<tr>
<td>Alphonse Gbemayi Singho</td>
<td>Scientist - Market Economics (Markets, Institutions and Policies)</td>
<td>Benin</td>
</tr>
<tr>
<td>Moses Osiru</td>
<td>Scientist (groundnut pathology)</td>
<td>Uganda</td>
</tr>
<tr>
<td>Sarathjith, Madathiparambil</td>
<td>Post Doctoral Fellow (Dryland Cereals)</td>
<td>India</td>
</tr>
</tbody>
</table>

### France

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farid Waliyar</td>
<td>Principal Scientist - Director, West and Central Africa (until April 2014)</td>
<td>France</td>
</tr>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
<tr>
<td>Baloua Nebié</td>
<td>Junior Professional Officer Sorghum Breeding (Dryland Cereals) - Burkina Faso</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Monica Petri</td>
<td>Project Manager / Agronomist (Resilient Dryland Systems)</td>
<td>Italy</td>
</tr>
<tr>
<td>Myriam Adam</td>
<td>Scientist/ICRISAT-CIRAD</td>
<td>France</td>
</tr>
<tr>
<td>Baptiste Guitton</td>
<td>Post Doctoral Fellow (Dryland Cereals)</td>
<td>France</td>
</tr>
</tbody>
</table>

### Germany

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eva W Rattunde</td>
<td>Principal Scientist - Sorghum Breeding &amp; Genetic Resources (Dryland Cereals)</td>
<td>Germany</td>
</tr>
<tr>
<td>HFW Rattunde</td>
<td>Principal Scientist - Sorghum Breeding &amp; Genetic Resources (Dryland Cereals)</td>
<td>France</td>
</tr>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Kenya

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Australia

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Italy

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Benin

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### USA

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### India

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### USA

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Rwanda

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### Benin

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### India

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>

### India

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre CS Traoré</td>
<td>Scientist (Remote sensing scientist and head of geographic information systems) - Resilient Dryland Systems</td>
<td>France</td>
</tr>
<tr>
<td>Mathieu Ouedraogo</td>
<td>Scientist-Participatory Action Research, CCAFS West Africa</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Haile Michael Shewayrga</td>
<td>Scientist (groundnut breeding-Grain Legumes)</td>
<td>Australia</td>
</tr>
</tbody>
</table>
Repossessing landscapes, bringing more food and hope

Niger

Malick Niango Ba
Senior Scientist - Entomology (Grain Legumes / Dryland Cereals) and Country Representative (since dec. 2014) - Burkina Faso

Hamidou Falalou
Regional Scientist - Physiology (Grain Legumes) - Niger

Fatondji Dougbedji
Senior Scientist Agronomy (Resilient Dryland Systems) - Benin

Patrice Savadogo
ICRAF/ICRISAT Agroforestry systems scientist - Burkina Faso

Sapna Jarial
Scientist, Crop Livestock WCA (Resilient Dryland Systems) - India

Jupiter Ndeunga
Principal Scientist (Markets, Institutions and Policies) - Cameroon

Bakary Djaby
Senior scientist Resilient Dryland Systems Livelihood Diversification - Burkina Faso

Mensah Edouard Romeo
Associate professional officer (economics), markets, institutions and policies - Benin

Hassane Amadou
Manager - Finance - Niger

Gaston Sangaré
Senior Regional Farm Manager - Mali

Nigeria

Hakeem Ayinde Ajeigbe
Principal Scientist - Agronomy and Country Representative (Resilient Dryland Systems) - Nigeria

Babu Nagabhushan Motagi
Senior Scientist - Groundnut Breeding (Grain Legumes) - India

Ijantiku Ignatius Angarawai
Scientist - Sorghum Breeding (Dryland Cereals) - Nigeria

Prakash Gangashetty
Post Doctoral Fellow Pearl Millet Breeding - India

Buckner Akouete Koffi
Consultant- Seeds Systems - Niger

C. Tom Hash
Principal Scientist Breeding (Dryland Cereals) - USA

Mensah Edouard Romeo
Associate professional officer (economics), markets, institutions and policies - Benin

Fatondji Dougbedji
Senior Scientist Agronomy (Resilient Dryland Systems) - Benin

Jupiter Ndeunga
Principal Scientist (Markets, Institutions and Policies) - Cameroon

Bakary Djaby
Senior scientist Resilient Dryland Systems Livelihood Diversification - Burkina Faso

Mensah Edouard Romeo
Associate professional officer (economics), markets, institutions and policies - Benin

Hassane Amadou
Manager - Finance - Niger

Gaston Sangaré
Senior Regional Farm Manager - Mali
PHOTOS CREDITS

Cover Page: Agathe Diama, ICRISAT
Page 3: Agathe Diama, ICRISAT
Page 7: Agathe Diama, ICRISAT
Page 9: Agathe Diama, ICRISAT
Page 10-11: Agathe Diama, ICRISAT
Page 12: Ousmane Traoré, ICRISAT
Page 13: Alphonse Singbo, ICRISAT
Page 14 (Photo1 and 2): Agathe Diama, ICRISAT
Page 14 (Photo2): Jerome Bossuet, ICRISAT
Page 15: Ousmane Traoré, ICRISAT
Page 18: Agathe Diama, ICRISAT
Page 21: Emmanuel Daou, Malidjaw
Page 22: Agathe Diama, ICRISAT
Page 23: Agathe Diama, ICRISAT
Page 24: Samuel Guindo, ICRISAT
Page 25: Mamourou Sidibé, ICRISAT
Page 26: Ibrahima Sissoko, ICRISAT
Page 27: Baloua Nebie, ICRISAT
Page 28: Baloua Nebie, ICRISAT
Page 31: Malick Ba, ICRISAT
Page 32: Shiyambola Abiodun, ICRISAT
Page 33 (Photo 1): Jerome Jonah, ICRISAT
Page 33 (Photo 2): Benjamin Kurya, ICRISAT
Page 33 (Photo 3): Babu Motagi, ICRISAT
Page 34, 35: Moustapha Diallo, Macina Film
Page 36, 37: Agathe Diama, ICRISAT
Page 38: Photo ICRISAT
Page 40: Marc Traoré, ICRISAT
Page 43: Birhanu Zemadin Birhanu
Page 45: Oumarou Diofou, ICRISAT
Page 48: Hamidou Falalou, ICRISAT
Page 49: Agathe Diama, ICRISAT
Page 50: Sapna Jarial, ICRISAT
Page 53: Abubakar Inua, ICRISAT
Page 54, 55, 56: Patrice Savadogo
Page 58, 59: Mathieu Ouedraogo
Page 62: Edmond Totin, ICRISAT
Page 63: Sapna Jarial, ICRISAT
Page 65: Samuel Guindo, ICRISAT
Page 66 (photo1): Agathe Diama, ICRISAT
Page 66 (photo2): Hamidou Guindo, 3A-Sahel
Page 67, 68: Jerome Bossuet, ICRISAT
Page 69: ICRISAT, Niger
Page 70: Agathe Diama
Page 71 (Photo1, 2, 4): Agathe Diama, ICRISAT
Page 71 (Photo3): ICRISAT, Niger
Page 71 (Photo5): ICRISAT, Nigeria
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 agri-business and linking farmers to markets.

About ICRISAT: www.icrisat.org

ICRISAT-India (Headquarters)
Panchery, Telangana, India
icrisat@cgiar.org

ICRISAT-Liaison Office
New Delhi, India

ICRISAT-Mali (Regional hub WCA)
Bamako, Mali
icrisat-w-mali@cgiar.org

ICRISAT-Niger
Niamey, Niger
icrisatnc@cgiar.org

ICRISAT-Nigeria
Kano, Nigeria
icrisat-keno@cgiar.org

ICRISAT-Kenya (Regional hub ESA)
Nairobi, Kenya
icrisat-nairobi@cgiar.org

ICRISAT-Ethiopia
Addis Ababa, Ethiopia
icrisat-addis@cgiar.org

ICRISAT-Malawi
Lilongwe, Malawi
icrisat-malawi@cgiar.org

ICRISAT-Mozambique
Maputo, Mozambique
icrisatmoz@panintra.com

ICRISAT-Zimbabwe
Bulawayo, Zimbabwe
icrisatzw@cgiar.org

ICRISAT’s scientific information: EXPLOREit.icrisat.org

ICRISAT is a member of the CGIAR Consortium