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

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

ICRISAT is headquartered near Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. ICRISAT is a member of the CGIAR Consortium.

ICRISAT-Bamako (Regional Hub West and Central Africa)
BP 320, Bamako, Mali
Phone: + 223 20 70 92 02
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-Kano
PMB 3491, Sabo Bakin Zuwo Road, Tarauni, Kano, Nigeria
Phone: + 234 70 34 88 98 36
Email: icrisat-kano@cgiar.org

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

Editing, design and proofreading
Textpolish
(www.textpolish.com)

www.icrisat.org

ICRISAT’s scientific information:
exploreit.icrisat.org

2016 ICRISAT WCA.
All rights reserved.

Contributors
Baloua Nebie¹, Eva Weltzien¹, Fred H Rattunde¹, Sabine Togola¹, Angarawai, II², Hakeem Ajeigbe³, Babu N Motagi³, Michael B Vabi³, Falalou Hamidou³, Fatondji Dougbedji³, Malick Ba¹, Alphonse Singbo³, Edmond Totin³, Krista Isaacs³, Chiaka Diallo³, John Nzungu³, Felix Badolo³, Hippolyte Affognon³, Birhanu Zemadim Birhanu³, Mathieu Ouédraogo³, Samuel T Partey³, Robert Zougmore³, Saratjith MC³, Ramadjita Tabo³, Aboubacar Toure³, Sapna Jarial³; JF Rami³, Denis Bastianeli³, Myriam Adam³, Fabrice Davrieux³, Kirsten vom Brocke³, Abdoulaye Gaoussou Diallo³, Fily Dembele³, Abocar Touré³, Samba Traoré³, Niaba Temé³, DA Aba³, Mary Yeye³, and Michael Blummel³.

Citation
Letter from Director General and Director, West and Central Africa

CROP IMPROVEMENT
8 Sweet ways to sorghum success in integrating crops and livestock thanks to high grain yield and stover quality
10 Climate-smart sorhums gain Nigerian farmers’ backing to reverse the crop’s production decline
12 Development of near-infrared reflectance spectroscopic calibrations for sorghum stem quality
14 Designing effective groundnut breeding strategies through farmer-breeder interaction in northern Nigeria
16 Groundnuts show new traits of tolerance to drought stress conditions under lysimeter system in Niger

INTEGRATED CROP MANAGEMENT
20 Effect of Acacia species husbandry on millet and cowpea grown in pure stands or strip cropping
22 Tillage practice and nitrogen application can boost soil health and productivity of sorghum-based systems in the dry savanna
24 Resistance genes retain a vital role in the face of climate change

SYSTEMS ANALYSIS AND POLICY AND IMPACT
28 Stable future for millet and sorghum as improved varieties penetrate Niger and Nigeria
30 Seed certification and marketing policies in Mali: do farmers actually benefit?
32 Opportunities and barriers in the purchase of sorghum hybrid seeds in Mali: a qualitative assessment
34 Research-development partnerships for large-scale use of priority proven technologies of millet and sorghum in Mali
36 Integrated management of soil fertility and the Striga parasitic weed gives a 60% boost to sorghum and pearl millet yields
38 Making improved varieties seed available to boost groundnut productivity in West Africa
40 Farmers in Mali adopt soil and water conservation measures to offset climate change

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY
44 Developing Climate-Smart village models through integrated participatory action research at West Africa sites

VISITS AND ACTIVITIES
48 WHO WE ARE
Letter from Director General and Director, West and Central Africa

We are pleased to present the ICRISAT—West and Central Africa annual research highlights for 2015. This report contains articles covering the major advancements that we experienced during the year with regards to crop improvement, integrated crop management and systems analysis, policy and impact.

To start this report, we will introduce you to the first multi-purpose sweet sorghum varieties with high grain yield and stover quality for integrating crop and livestock systems in West and Central Africa (WCA). Also for the first time, we present the results of our preliminary experiences with the development of near-infrared reflectance spectroscopic (NIRS) calibrations for assessing sorghum stem quality as a determinant of fodder and feed quality for livestock.

Our participatory variety selection by farmers at multiple locations has provided interesting results that are highlighted in the report. You will learn more about efforts of scientists and producers in designing effective groundnut breeding strategies through farmer-breeder interactions in Northern Nigeria. Also, read more about drought phenotyping of a groundnut reference collection sub-set in lysimetric conditions for new traits of tolerance in Niger.

With regard to integrated crop management, this report highlights the effects of some crop management practices on the productivity of crops and soil:

• the effect on millet and cowpea grown in pure stands or in strip cropping with managed Acacia species
• the effect of tillage practice and nitrogen application on soil health and productivity of sorghum-based systems in the dry savanna of West Africa
• the effect of water and nutrient stress on groundnut varieties.

The last section of this report shows the importance given to systems analysis in our research work; this year highlighting sorghum and millet productivity in WCA, seed certification and marketing policies, opportunities and barriers in the purchase of seeds in Mali through a qualitative assessment to ensure that farmers actually benefit from the results of the research. This also involves research-development partnerships being developed for large-scale utilization of priority proven technologies of millet, sorghum and groundnut.

The value of in-depth and thorough research in today’s agricultural environment impacted by the consequences of a changing climate cannot be overestimated as the impacts of global climate change – combined with rapid socioeconomic changes – are likely to increase uncertainty in water availability and water security. In this context, we are carrying out research on current and future water availability and on the demand scenarios.

Our research is geared towards improving water resources management and addressing water-related problems in the region. We are committed to generating and exchanging knowledge in order to strengthen cooperation, and we hope that our combined efforts will improve water management and help address the problems of water shortages and water-related hazards. ICRISAT in West and Central Africa is engaged in providing scientific and analytical background as a foundation for expansion and also in strengthening the capacities of our agrarian pilot communities, which should also serve as a catalyst for scaling.

To conclude, we would like to acknowledge the significant contribution of partners, and by ICRISAT as a whole, who have made it possible to provide our beneficiaries with a wide range of relevant services through a variety of channels in response to diverse needs.

To our political commitment, partnerships, adequate financing and complementary actions in all aspects of agricultural research for development are essential to reducing hunger and poverty. We always value the professionalism, efficiency, equity, integrity, accountability, transparency and assistance available to us from partners.

Through all such links it is our duty and obligation to improve the quality of life of the smallholder farmers population through our service deliveries. By continuing to work together we will achieve our goal of increasing agricultural productivity to improve the nutrition of many agricultural households and thus reduce hunger and poverty.
New multi-purpose varieties developed and identified by ICRISAT and its partners are providing higher grain and stover yield, together with greater stem palatability for cattle and a highly desirable sweet sorghum paste. Sweet sorghum has long been grown on a small scale in many countries of West and Central Africa (WCA) where its stems have been used as treats, especially by children, courtesy of a high content of juice and sugar for energy sourcing. Grain has been regarded as useless for food because of its flouriness, very small size and usual attack by grain mold. However, dwindling pasture area and increasing cattle numbers mean that farmers are increasingly using crop residues to feed animals, especially during dry seasons, and they have started to request varieties combining grain and stover qualities.

ICRISAT and partners responded by crossing local sweet sorghum with adapted grain sorghum to develop a set of varieties combining grain yield and quality, sugar/juice and stover yields. The objective of this work was to develop/identify adapted multi-purpose varieties for farmer uses and conditions. After developing and testing progenies on station, the first set was evaluated in 2015 under farmer conditions and some were placed at the top of rankings by farmers for their better food and stover yield and quality when compared to local checks.

Malian and Ethiopian sweet sorghum landraces (F60, F221 and IS23541) were crossed with grain sorghum landraces (Drongonikala) and improved varieties (Lata, Soumba, Soumalemba, Tieble) for their grain yield and quality. Two types of material were developed, including caudatum and guinea races. A total of 71 fixed progenies (29 caudatum and 42 guinea types), were evaluated on station during rainy season 2014, and the best lines combining grain yield and quality, stover, juice and sugar yields were selected for on-farm testing using a selection index (SI).

Sixteen varieties (including 1 hybrid and 1 local variety as checks) were evaluated on farm by 26 farmers from 13 villages in five zones (Kouilala, Koulikoro, Dioila, Beleko and Kita). Each variety was represented by six 5-m rows in two replications. Seventeen men and 10 women farmers carried out a participatory agronomic evaluation of the varieties in each village to select the four best varieties for food processing, combining grains and stover for culinary tests in which criteria such as percentage of decorticated grain, flour percentage, tô (thick sorghum paste) color, tô consistence, and tô taste, among others, were considered.

The dominant criterion chosen by farmers to evaluate a dual-purpose variety was the grain yield (100% of cases) and the second criterion was the number of green leaves per plant at the grain physiological maturity stage (80% of cases). High grain yields (around 2 t/ha) and high stover yield (20 t/ha) were recorded. Stover yield is important but not of the greatest importance in ensuring farmers accept a variety for animal feed. Sorghum landraces that are tall with substantial biomass weight are not appreciated by livestock eating leaves and the top of the stem because of the hardness (high lignin content) of these landraces and their leaves that dry before harvesting.

Feedback from farmers highlighted that the multipurpose sweet sorghums are well appreciated by animals as they consume the whole stem with over 60% of leaves remaining green until harvest and due to stem lignin being low.

Furthermore, the tô paste from multipurpose sweet sorghum went down well with farmers and in some villages outranked the local checks (i.e., Tiankoré/Koutalé, Kenieroba/Kita, Mafejya/Koulikoro). Gender was strongly associated in some villages (Fig. 1) with the overall appreciation of the tô, demonstrating that both men and women should be included at each step of variety evaluation to increase the probability of acceptance and adoption.

Based on farmer appreciation and variety performance, five multi-purpose varieties well adapted to 800–1000 mm rainfall areas were proposed for registration in the national and regional catalogues.
Climate-smart sorghums gain Nigerian farmers’ backing to reverse a production decline

A reversal in Nigeria’s decline in sorghum production is on track after a joint program of developing and evaluating new improved ‘climate-smart’ varieties with farmer help.

Despite an annual consumption among smallholder farmers of more than 75 kg/person and its consequent important role in the diets and economies of the people of Nigeria, sorghum production in terms of area harvested and yields began to decline in 2009 (FAOSTAT, 2012) because of the unavailability and non-dissemination of improved varieties and hybrids adapted to the Sudan and Sahel ecologies with low rainfall and Striga infestation.

ICRISAT, in collaboration with the Institute for Agricultural Research at Ahmadu Bello University (IAR/ABU) of Zaria, Nigeria, developed and evaluated sorghum varieties with farmer participatory evaluation across major sorghum growing ecologies during the 2015 rainy season. Early maturity and high grain yields adapted to the dry savanna agro-ecology were targeted. Four sorghum varieties were evaluated on-farm across nine locations (Bakori, Gambawa, Wajeri, Gumel, Ikara, Kofa, Ningi, Zango and Zaria) with five farmers at each location tending the replications for farmer participatory selection against local checks.

On a plot size of 10 m², hills were spaced at 30 cm inter-row and 75 cm intra-row spacings for the on-farm trials. Recommended fertilizer rates were applied at three and six weeks after planting and data for days to 50% flowering and grain yield recorded and analyzed from the individual locations. Participatory appraisals at each location were based on the major farmer-preferred sorghum variety traits, including days to maturity (earliness), grain size (bold), plant height (medium) and grain color (white or yellow).

ICRISAT in collaboration with the Institute for Agricultural Research at Ahmadu Bello University (IAR/ABU) of Zaria, Nigeria, developed and evaluated sorghum varieties with farmer participatory evaluation across major sorghum growing ecologies during the 2015 rainy season. Early maturity and high grain yields adapted to the dry savanna agro-ecology were targeted. Four sorghum varieties were evaluated on-farm across nine locations (Bakori, Gambawa, Wajeri, Gumel, Ikara, Kofa, Ningi, Zango and Zaria) with five farmers at each location tending the replications for farmer participatory selection against local checks.

On a plot size of 10 m², hills were spaced at 30 cm inter-row and 75 cm intra-row spacings for the on-farm trials. Recommended fertilizer rates were applied at three and six weeks after planting and data for days to 50% flowering and grain yield recorded and analyzed from the individual locations. Participatory appraisals at each location were based on the major farmer-preferred sorghum variety traits, including days to maturity (earliness), grain size (bold), plant height (medium) and grain color (white or yellow).

Despite an annual consumption among smallholder farmers of more than 75 kg/person and its consequent important role in the diets and economies of the people of Nigeria, sorghum production in terms of area harvested and yields began to decline in 2009 (FAOSTAT, 2012) because of the unavailability and non-dissemination of improved varieties and hybrids adapted to the Sudan and Sahel ecologies with low rainfall and Striga infestation.

ICRISAT, in collaboration with the Institute for Agricultural Research at Ahmadu Bello University (IAR/ABU) of Zaria, Nigeria, developed and evaluated sorghum varieties with farmer participatory evaluation across major sorghum growing ecologies during the 2015 rainy season. Early maturity and high grain yields adapted to the dry savanna agro-ecology were targeted. Four sorghum varieties were evaluated on-farm across nine locations (Bakori, Gambawa, Wajeri, Gumel, Ikara, Kofa, Ningi, Zango and Zaria) with five farmers at each location tending the replications for farmer participatory selection against local checks.

On a plot size of 10 m², hills were spaced at 30 cm inter-row and 75 cm intra-row spacings for the on-farm trials. Recommended fertilizer rates were applied at three and six weeks after planting and data for days to 50% flowering and grain yield recorded and analyzed from the individual locations. Participatory appraisals at each location were based on the major farmer-preferred sorghum variety traits, including days to maturity (earliness), grain size (bold), plant height (medium) and grain color (white or yellow).

A reversal in Nigeria’s decline in sorghum production is on track after a joint program of developing and evaluating new improved ‘climate-smart’ varieties with farmer help.

This farmer participatory rating across the various agro-ecologies selected 12KNICSV-188 and 12KNICSV-22 as first and second, respectively, in the Sudan and Sahel zones.

Mean performance for yield and other agronomic characters from the combined nine locations indicated that 12KNICSV-188 and 12KNICSV-22 were the earliest to attain days to 50% flowering in 67 and 68 days, respectively. Combined average yield for the nine locations showed that 12KNICSV-188 and 12KNICSV-22 had high grain yield of 2818 kg/ha and 2356 kg/ha, respectively (Table 1). On-station genotype-by-environment data (GxE biplot) analysis underlined that the clustering of Ikara and Birninkudu sites located in the Sudan savanna ecology, and that of Sokoto and Zangon Daura located in the Sahel favors the performances of 12KNICSV-188 and 12KNICSV-22 as robust farmers’ choices.

This was reinforced by Mallam Isa Ahmed, Ward Head of Ikara Local Government in Nigeria’s Kaduna state, who called on behalf of participating farmers for ICRISAT, the Institute for Agricultural Research (IAR) Samau and the Government of Nigeria to facilitate new releases and ensure seed availability for smallholder farmers to buy the improved varieties as a matter of urgency.

“We are very happy with improved Deko because of its uniformity, bold white grain, panicle shape and size, and earliness to maturity,” he said. “This variety has the potential to give food even in the years of low rainfall, as in the coincidental case of 2015 when the rain ceased mid-September. On the other hand it will allow early harvest before the Fulani herdsmen can do damage to late crop varieties.”

<table>
<thead>
<tr>
<th>Entry No.</th>
<th>Variety designation</th>
<th>Days to 50% flowering</th>
<th>Plant height (cm)</th>
<th>Panicle length (cm)</th>
<th>Grain yield (kg/ha)</th>
<th>Smut disease score (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12KNICSV-188 (DEKO)</td>
<td>67</td>
<td>177</td>
<td>31</td>
<td>2818</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>ZAUNA-INUWA</td>
<td>81</td>
<td>156</td>
<td>42</td>
<td>2409</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>12KNICSV-22 (ZABUWA)</td>
<td>68</td>
<td>167</td>
<td>28</td>
<td>2356</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>DAYYANA</td>
<td>80</td>
<td>213</td>
<td>36</td>
<td>1719</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Farmers’ local</td>
<td>86</td>
<td>222</td>
<td>36</td>
<td>1631</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>76</td>
<td>187</td>
<td>35</td>
<td>2187</td>
<td>1.6</td>
</tr>
<tr>
<td>SE±</td>
<td></td>
<td>14.3</td>
<td>69.7</td>
<td>6.7</td>
<td>288.7</td>
<td></td>
</tr>
</tbody>
</table>

Note: On-farm trials were carried out at Bakori, Gambawa, Wajeri, Gumel, Ikara, Kofa, Ningi, Zango and Zaria during the 2015 cropping season.

Despite an annual consumption among smallholder farmers of more than 75 kg/person and its consequent important role in the diets and economies of the people of Nigeria, sorghum production in terms of area harvested and yields began to decline in 2009 (FAOSTAT, 2012) because of the unavailability and non-dissemination of improved varieties and hybrids adapted to the Sudan and Sahel ecologies with low rainfall and Striga infestation.

ICRISAT, in collaboration with the Institute for Agricultural Research at Ahmadu Bello University (IAR/ABU) of Zaria, Nigeria, developed and evaluated sorghum varieties with farmer participatory evaluation across major sorghum growing ecologies during the 2015 rainy season. Early maturity and high grain yields adapted to the dry savanna agro-ecology were targeted. Four sorghum varieties were evaluated on-farm across nine locations (Bakori, Gambawa, Wajeri, Gumel, Ikara, Kofa, Ningi, Zango and Zaria) with five farmers at each location tending the replications for farmer participatory selection against local checks.

On a plot size of 10 m², hills were spaced at 30 cm inter-row and 75 cm intra-row spacings for the on-farm trials. Recommended fertilizer rates were applied at three and six weeks after planting and data for days to 50% flowering and grain yield recorded and analyzed from the individual locations. Participatory appraisals at each location were based on the major farmer-preferred sorghum variety traits, including days to maturity (earliness), grain size (bold), plant height (medium) and grain color (white or yellow).
Development of near-infrared reflectance spectroscopic calibrations for sorghum stem quality

State-of-the-art instrument analysis backed by calibration data assembled in Mali by ICRISAT, the Malian Institut d’Economie Rurale (IER) and by the Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) in France is paving the way for rapid and precise screening and selection of valuable improved dryland cereals.

Sorghum is one of the first dryland cereals to benefit from the intervention in Mali of near-infrared reflectance spectroscopy (NIRS) to phenotype major plant traits in breeding programs. Stem quality is the first key trait being assessed in candidate progeny by a Fourier-transformation-based NIRS instrument, namely a multipurpose analyzer (MPA, Bruker Optics), at the Sotuba Biotechnology Laboratory of Mali’s Institute of Rural Economy (IER).

The MPA instrument sponsored by the CGIAR Research Program on Dryland Cereals (CRP-DC) will underpin a regional platform mainly for the characterization of dryland cereals in West Africa (WA).

NIRS has been widely recognized as an indirect, non-destructive and non-invasive approach for a rapid, low-cost and simultaneous estimation of multiple attributes of plant materials. In the NIRS approach, the spectral reflectance from target material over 700–2500 nm is linked with the attribute of interest by an efficient multivariate analyzer regression model (also referred to as calibration). The NIR wavelengths are characterized by weak overtones and the combinations of fundamental vibrations (stretching and bending) of spectrally active functional groups, mainly N–H, O–H, C=H and S–H in the mid-infrared frequencies, and hence those attributes with strong linkage with these functional groups are more likely to be estimated using NIRS. One of the major requirements for sorghum breeding in WA is to develop NIRS calibrations for their use in routine characterization of stem quality attributes.

Sampling and data analysis

The dataset used to develop NIRS calibration for sorghum stem quality attributes mainly comprised of representative samples from the CGIAR Generation Challenge Programme’s Sorghum Research Initiative on Backcross Nested Association Mapping (BCNAM) (n=46) and hybrid trials (n=16) at ICRISAT–Mali during 2013 in addition to 24 samples shared between ICRISAT and CIRAD during their past collaboration. All the samples were subjected to reference analysis at CIRAD for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), sugars and in-vitro digestibility of dry matter (IVD).

The absorbance spectra (12,489–3594 cm−1) of all these samples were recorded in the MPA instrument at a resolution of 16 cm−1 using ‘integrating sphere’ as the measurement channel. Each spectrum was set to be an average of 64 internal replicated spectra. Two spectra were taken for each sample and first derivative (FD) of their average spectrum was used for calibration development. A partial least squares regression (PLSR) model was built between each sorghum IR data set and its corresponding trait. The calibration performance of the MPA instrument was found to be excellent (RPD≥4.1), very good (3.5≤RPD≥4.0) for both IVD and ADF and fair (2.5≤RPD≥2.9) for CP, NDF and ADL as shown in Figure 2. The overall results of this study advocate the use of these NIRS calibrations to estimate the selected stem quality attributes for a fair to accurate screening in sorghum breeding programs in WA. However, it is necessary to incorporate samples with high variability (field, environment, variety etc.) in the existing calibration dataset to develop more accurate, reliable and robust NIRS calibration models for routine characterization of sorghum stem quality attributes.

Sorghum Breeding in Mali (BCNAM-NIRS)’.

Calibrations for Stover and Grain Quality for different WA plant breeding programs for rapid and low-cost characterization of plant materials. The established NIRS facility at IER appears to have immense potential to meet regional demand. However, the need for good quality reference values (uniqueness in both primary reference method and the reference analyses laboratory) to develop and update NIRS calibrations is a major challenge for the successful operation of the NIRS facility. Moreover, it is necessary to identify a focal person to co-ordinate NIRS activities in WA.”

Sarathjith M C
Post Doctoral Fellow
International Crops Research Institute for the Semi-Arid Tropics.
Designing effective groundnut breeding strategies through farmer-breeder interaction in northern Nigeria

Best-bet groundnut varieties are no gamble thanks to the effective participation of Nigerian farmers in the selection process.

Co-operation between ICRISAT and national partners has created a perfect alignment of farmers’ preferences with breeders’ concerns over the development of improved groundnut varieties with the prime assets of early maturity, high pod and haulm yields, high oil contents and tolerance to prevailing biotic stresses, which combine to offer escape from unpredictable end of season droughts.

Nigeria is the leading producer of groundnut in West and Central Africa, accounting for 51% of recorded total production in the region. The crop is produced in 15 out of the 19 States in the Sudan and Sahel savannas of the country. Demand for improved groundnut varieties has been increasing over the years, making it imperative to develop varieties suitable for the different agro-ecological zones, which take into account market preferences, the challenges of aflatoxin contamination and climatic variability.

In 2015, the co-operation team established multi-location validation demonstrations with the aim of proposing best-bet varieties for eventual release by appropriate authorities. On-farm trials were established at four locations, Gumel (Jigawa State) and Zango (Katsina State) where ICRISAT with support from extension agents of the Agricultural and Rural Development Authorities (ADPs), and at Minjibir (Kano State) and Samaru (Kaduna State) where Nigerian authorities. On-farm trials were established at four locations, Gumel (Jigawa State) and Zango (Katsina State) where ICRISAT with support from extension agents of the Agricultural and Rural Development Authorities (ADPs), and at Minjibir (Kano State) and Samaru (Kaduna State) where ICRISAT and the Institute for Agricultural Research established and directly managed similar validation demonstrations. At all locations, the demonstrations consisted of 15 elite breeding lines and three ruling varieties as checks, making a total of 18 entries, all selected for four exposures: rosette, aflatoxin, foliar diseases and drought. A standard randomized complete block design with three replicates and six entries per block was used with each replicate having three blocks.

Three independent participatory varietal selection exercises were conducted at three out of the four locations during the 2015 cropping season by involving a total of 92 (45 female and 47 male) farmers. A groundnut breeder led the ICRISAT team, while the participatory selection exercises were initiated by a farming systems agronomist. A rural sociologist, together with two research technicians, led the participatory paired-wise ranking exercises at the three locations. Results of the paired-wise ranking exercise revealed that resistance to pests and diseases, early maturity, pod yield, oil yield, haulm yield, and pod and kernel features, and drought tolerance are the important groundnut traits for the farmers involved in the participatory varietal selection exercise, irrespective of sex and location (Table 2).

Selected elite breeding lines are being further validated along with short and medium duration check varieties in targeted agro-ecological zones during the 2016 main cropping season for their eventual release by the competent Nigerian authorities.

<table>
<thead>
<tr>
<th>Farmer-desired attributes</th>
<th>Ranking</th>
<th>Additional information from discussion with farmers during participatory assessment sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance to pests and diseases</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Not cited 1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Attribute underlines varieties that withstand prevailing pests and diseases (reducing the need for investment in accompanying inputs)</td>
</tr>
<tr>
<td>Early maturity</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Not cited 9&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Escapes negative effects of end-of-season drought</td>
</tr>
<tr>
<td>High pod yields</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; 6&lt;sup&gt;th&lt;/sup&gt; 3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>High returns and brings cash income</td>
</tr>
<tr>
<td>High oil content</td>
<td>4&lt;sup&gt;th&lt;/sup&gt; 5&lt;sup&gt;th&lt;/sup&gt; 6&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Attribute mostly emphasized by female participants for processing into oil (preference for small kernel sizes with red color)</td>
</tr>
<tr>
<td>Easy to sell/?marketability</td>
<td>5&lt;sup&gt;th&lt;/sup&gt; 4&lt;sup&gt;th&lt;/sup&gt; Not cited</td>
<td>Attribute emphasizes color, oil content and haulm yield</td>
</tr>
<tr>
<td>By-products (cakes including Kuikuli)</td>
<td>6&lt;sup&gt;th&lt;/sup&gt; NA Not cited</td>
<td>Attribute emphasizes the ease of processing; argument put forward mostly by female participants</td>
</tr>
<tr>
<td>Household consumption</td>
<td>7&lt;sup&gt;th&lt;/sup&gt; NA Not cited</td>
<td>Attribute underlines the nutritious value of groundnut and derived products (soup, snacks, pap etc.)</td>
</tr>
<tr>
<td>Color of kernel</td>
<td>8&lt;sup&gt;th&lt;/sup&gt; 8&lt;sup&gt;th&lt;/sup&gt; 4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Varieties that are reddish are easily sold, have good oils and produce much more</td>
</tr>
<tr>
<td>High haulm yield</td>
<td>9&lt;sup&gt;th&lt;/sup&gt; 7&lt;sup&gt;th&lt;/sup&gt; 7&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Attribute underlines the dual purpose of groundnut; feed for ruminant livestock and cash income source, especially in the dry season</td>
</tr>
<tr>
<td>Pod and seed size</td>
<td>10&lt;sup&gt;th&lt;/sup&gt; 1&lt;sup&gt;st&lt;/sup&gt; 5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Attribute has two elements: yield ability, roasting and generation of cash income through sale as confectionary type</td>
</tr>
<tr>
<td>Generates cash income</td>
<td>Not cited 2&lt;sup&gt;nd&lt;/sup&gt; Not cited</td>
<td>Attribute seems to be included in others: pod size, seed size, color and oil content</td>
</tr>
<tr>
<td>Easy to process</td>
<td>Not cited 3&lt;sup&gt;rd&lt;/sup&gt; Not cited</td>
<td>Attribute underlines the need for varieties that are soft, hence easy for manual processing by women</td>
</tr>
<tr>
<td>Drought tolerance</td>
<td>Not cited Not cited 2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Attribute highlights the importance of early maturing varieties in a context of climate variability</td>
</tr>
<tr>
<td>Good taste</td>
<td>Not cited Not cited 8&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Attribute complements that of household consumption and marketability of emerging varieties</td>
</tr>
</tbody>
</table>

Funding support for this intervention is provided by the Bill & Melinda Gates Foundation within the framework of the implementation of the Tropical Legumes-III (TL-III) and the Groundnut Up-scaling Projects under the CGIAR Research Program on Grain Legumes (CRP-GLs).
Groundnut shows new traits of tolerance to drought stress conditions under lysimeter system in Niger

Previous studies under field conditions have investigated the response of 300 accessions from a groundnut reference collection to drought stress as well as selected contrasting lines. Groundnut is largely grown in rainfed areas in the semi-arid tropics, and known pod yield decrease can reach 72%. Now assessment of a sub-set of 60 genotypes from the groundnut reference collection in lysimeters, which give similar conditions to fields and allow measurement of crop water requirement, could lead to the identification of new sources and/or traits of tolerance to drought for improving groundnut productivity.

This involved placing the genotypes under intermittent drought stress at flowering time (50%) in the lysimetric system at ICRISAT’s Sahelian Centre (ISC) in Sadoré (45 km south of Niamey, Niger, from September to December for investigating (i) the genotypic variation in phenology, (ii) the effect of intermittent drought on agromorphological traits, and (iii) select drought-tolerant and high-yielding genotypes, and identify traits related to drought tolerance.

Three seeds were sown by hand into each lysimeter tube filled with soil collected from the station farm, then seedlings were thinned to two plants per tube at 14 days after sowing (DAS), and the lysimeter tubes were weighed twice weekly to measure transpired water.

The experimental design was a randomized complete block design with five replications and two water regimes, well water (WW) and water stress (WS), at either side of the trench. WW soil was kept at 90% of field capacity until harvest, while drought stress (WS) was imposed at the 50% flowering time of each genotype. On the first day of WS imposition one plant from each lysimeter tube was sampled for measuring the initial biomass (IDM). The transpiration efficiency was determined using IDM, the biomass at harvest (FDM) and the total of transpired water. Phenology and agromorphological traits were investigated.

Significant genotypic variation was observed on flowering time ranging from 22 to 30 days after sowing. Drought stress decreased the pod yield (68%), haulm yield (30%), harvest index (47%) and grain weight by up to 76%. The high grain weight decreased under WS suggesting that drought affected flower numbers and the resulting photosynthesis inhibition led to less grain filling. Transpiration efficiency (TE) decreased by up to 47% under WS, and TE determined biomass production of pods under drought (Figure 3). The findings revealed that ICG 3312 and ICG 81 were short duration and drought tolerant. Grain weight and harvest index were traits associated with drought tolerance under lysimetric conditions. ICG 81, ICG 9666, ICG 10053 and ICG 7969 were dual-purpose accessions under well water conditions. Water requirement and use could be determinant in tolerance to drought in groundnut.

Experiments with water extraction, roots systems, soil water content and canopy temperature measurement could confirm drought-tolerant genotypes identified in this study.

Differences in genotype performance under well water and drought conditions were revealed by the study. Under well-watered conditions, ICG 81, ICG 9666, ICG 10053 and ICG 7969 revealed dual-purpose performance for pods and haulm biomass. Water stress decreased pod yield and its components but the observed genotypic variation indicated that the negative effects varied among investigated accessions. Grain weight showed the greatest decrease under drought, suggesting that water stress during flowering time had significant effect on groundnut reproduction. Genotypes showing high grain weights were revealed as drought-tolerant.

### Figure 3. Relationship between transpiration efficiency, pod and haulm weight of 60 groundnut genotypes under drought stress (WS) conditions

The opposite: Sub-set of the groundnut reference collection under well water (WW) and drought stress (WS) conditions in lysimetric system at ICRISAT Sadoré, Niger.

The reference collection under well water (WW) and drought stress (WS) conditions in lysimetric system at ICRISAT Sadoré, Niger.

Opposite: Sub-set of the groundnut reference collection under well water (WW) and drought stress (WS) conditions in lysimetric system at ICRISAT Sadoré, Niger.
I am a PhD student from the Université des Sciences, des Techniques et des Technologies de Bamako, Mali, working on the integration of crop modelling and crop screening methods to better identify drought-tolerant traits in Malian sorghum genotypes. This will help crop improvement programs develop progenies with the highest values in terms of productivity and yield stability in the face of dwindling resources, especially water.

This knowledge will help Malian breeders to more efficiently develop climate-smart breeding lines that better cope with specific stress patterns. Part of my work currently entails improving the model’s capacity to accurately predict photoperiod responses, which is a key trait for adaptation in the Malian genotypes.

Madina Diancoumba, currently with ICRISAT in Mali and India.
Potential to improve the common systems mixing crops, livestock and trees is revealed in Niger studies

Livestock manure may be the key to overcoming the very low productivity that characterizes mixed crop-livestock-tree systems favored by many West African farmers.

A study carried out at ICRISAT’s Sadoré research station in Niger targeted the depressive effect of Acacia species, millet and cowpea planted in close proximity. Mixed crop-livestock-tree systems are common in West and Central Africa but are characterized by very low productivity. Some of the causes include low inherent soil fertility, soil degradation through nutrient and organic matter (OM) depletion, and recurrent droughts exacerbated by erratic rainfalls and climate variability.

The objectives of the study were: (1) to assess the effect of Acacia sp. husbandry through mapping millet and cowpea production when grown in pure stands or strip cropping; (2) to assess whether applying organic fertilizer could compensate for the potentially depressive effect of Acacia sp. husbandry on millet and cowpea grown in pure stands or strip cropping.

Millet and cowpea were planted in 2013/14/15 in a 7-year Acacia tumida plantation in which the tree crowns were pruned each year by removing the lower branches. The experiment was laid out at the Sadoré ICRISAT research station in random complete block design (RCBD) with four replications. Crops were planted in strips following treatment combinations. In each replication two rows of Acacia tumida 10 m apart and 5 m within row spacing and one row of improved zigzhus (buckthorn family member) were planted. The following treatment combinations were adopted:

- millet only – with/without manure
- two lines each of millet and cowpea – with/without manure
- one millet line to one of cowpea – with/without manure
- cowpea only – with/without manure
- two millet lines to three of cowpea – with/without manure.

Planting was carried out on 2 July 2013, 17 June 2014 and 10 July in 2015. Cumulative rainfall on the experimental plot was 519.6 mm in 2103, 668 mm in 2014 and 483 mm in 2015. Frequent dry spells were observed in 2013 and 2014, leading to crop failure and replanting in 2014. In addition, rainfall stopped 75 days after planting in 2103. Rainfall distribution in 2015 was even with fewer dry spells.

To account for the effect of the Acacia tree, the crops were harvested in strips starting from the trunk of the shrub. Four strips of 1 m width, two at each side, were delineated around the trunks that are considered to experience a tree effect. Following the same approach, we delineated four other strips of 1.5 m width starting 2 m from the areas to the side of the trunk that are considered to be less affected by the shrub. A total of 36 strips were harvested in each plot per replication.

**Total millet biomass**

Total biomass was low in 2014 due to the crop failure mentioned earlier. Total millet biomass across the three experimental years was 1.6 times higher on strips that were 2 m away from the trunk of the shrub, compared to strips closer on average to the shrub (Figure 4a). Application of 200 g manure per hill led to 2.2 times greater total biomass being produced on the strips that are 2 m away from the trunk. Furthermore, an indication that nutrient addition compensated slightly for the suppressive effect of the shrub on millet biomass production was demonstrated by higher biomass (2.6 times) being obtained on the strips that are less than 2 m around the shrub. A comparison contrast from the data indicates that strip intercropping reduced total biomass by 174 g/m² two meters away from the trunk and 74 g/m² in the vicinity of the shrub.

**Total cowpea biomass**

Total cowpea biomass was very low in 2013 and 2014 due to the earlier reasons but also because no crop protection measure was applied. In the three years of experimentation, total cowpea biomass production was not affected by shrub husbandry (Figure 4b). However, applying 200 g per hill of manure resulted in seven times more biomass production compared to no application of manure. The comparison contrast shows that, even though not statistically different, strip intercropping reduced cowpea total biomass by 234 g/m² two meters away from the trunk and by 192 g/m² at two meters diameter around the shrub.
Tillage practices and nitrogen application can boost soil health and the productivity of sorghum-based systems in the dry savanna

The marriage between modern conservation agriculture and traditional farmer practices with sorghum in West Africa is being mediated through tillage and fertilizer management trials.

Minimum tillage and N application have been shown by ICRISAT to have a significant positive effect on yields and leaf health of sorghum in the Sudan savanna of Nigeria. Rotating sorghum with soybean has also produced dividends in grain and fodder yield.

Conservation agriculture (CA) relies on the simultaneous use of three practices: minimum or zero-tillage; maintenance of a permanent soil cover; and diversified profitable crop rotation. Soil cover is very important due to its impact on the soil water balance, biological activity, soil organic matter build-up and fertility replenishment. However, in West Africa’s dry savannas farmers and livestock keepers allow their animals to roam about – especially in the long dry season – grazing freely on any available forage on fields around the villages, while the transhumance livestock rearers graze their livestock on ranges and farms, both far and near the villages.

Under such circumstances, and where crop residues may have higher value uses than mulching, CA with crop residue as mulch is unlikely to be adopted by farmers in the short run. In the design of CA for WA, it is therefore necessary to make use of traditional practices and farmers’ knowledge on soil fertility management using local resources to ensure sustainable soil health and crop yield improvement.

A long-term trial was established in 2013 in Samaru and Minjibir in the Sudan savanna zone of Nigeria to evaluate the crucial effects of minimum tillage, different cereal-legume cropping systems and organic and inorganic fertilizer management on soil health and crop productivities.

Tillage practices in the experiment included a conventional tillage practice of double harrow and ridge, while the second practice was a minimum tillage where herbicide was used to control weeds, followed by gentle scratching of the soil with hoes or cutlass to remove stubborn weeds and stubbles. The dead weeds were left as mulch on the field. Tillage was applied as NPK 15.15.15 to obtain the initial 30 kg N, P and K, while urea was applied to balance for treatment with 60 kg N. Cropping systems included sorghum-sorghum continuous cropping, sorghum-cowpea relay, sorghum-soybean rotation and sorghum-groundnut rotation. These were selected because they are the most common systems applied in farmers’ fields in the region.

In Minjibir, mean sorghum grain and stalk yields were significantly (5%) higher under minimum tillage (1761 kg/ha and 6789 kg/ha, respectively) compared to the conventional tillage yields (651 and 2839 kg/ha, respectively). SPAD measurements revealed the effects of tillage practices on chlorophyll content of sorghum leaves, which was significantly higher in the minimum tillage (40) than in the conventional tillage (28). However, the effect of tillage on soil moisture content was not significant at 5% though minimum tillage significantly had higher mean moisture content at a 10% significance level.

The effects of tillage on sorghum were less evident in Samaru where there was neither significant effect on grain and stalk yields nor on chlorophyll content of the plants, although minimum tillage had significantly higher mean soil moisture (30.8%) than conventional tillage (19.7%).

The impact of N on grain and stalk yields was significant in both locations, with higher N application producing significantly higher grain yields (2015 and 1598 kg/ha, at 0, 30 and 60 kgN/ha, respectively, in Minjibir and 2077, 2150 kg/ha at 0, 30, and 60 kgN/ha in Samaru). Stalk yields of 3378, 4909, 6156 kg/ha, at 0, 30, and 60 kgN/ha, respectively, showed N treatment had significant effect on chlorophyll content of sorghum in Minjibir where 60 kgN/ha (39.2) was significantly higher than 30 kgN/ha (35.3) which was significantly higher than 0 kgN/ha (28.2). N treatment also had significant effect on chlorophyll content or leaf health of sorghum in Samaru. Despite there being no significant difference between 60 kgN/ha (47.3) and 30 kgN/ha (46.5), both treatments had significantly higher values than 0 kgN/ha (35.6). N treatment did not have significant effect on soil moisture content in the wetter Samaru location.

Significant differences were observed among the sorghum-based cropping systems evaluated. Sorghum-groundnut rotation produced significantly less sorghum yield while sorghum-soybean rotation produced significantly higher grain and fodder yields in both locations. The systems did not have significant effect on plant health and soil moisture content in both locations.

It is now evident that minimum tillage and N application have significant positive effects on yields and leaf health of sorghum in the Sudan savanna of Nigeria. The cultural practice of rotating sorghum with legumes, especially soybean, should be encouraged.

### Table 3. Effect of tillage and nitrogen fertilizer on sorghum yields (grain and stalk kg/ha) and soil moisture in Sudan savanna of Nigeria

<table>
<thead>
<tr>
<th></th>
<th>Minjibir</th>
<th>Samaru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sorghum</td>
<td>Stalk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P of F</td>
<td>0.004</td>
<td>0.046</td>
</tr>
<tr>
<td>LSD</td>
<td>391.6</td>
<td>3758.7</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kgN/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>549</td>
<td>3377</td>
</tr>
<tr>
<td>30 kgN/ha</td>
<td>1111</td>
<td>4909</td>
</tr>
<tr>
<td>60 kgN/ha</td>
<td>1958</td>
<td>6156</td>
</tr>
<tr>
<td>P of F</td>
<td>0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LSD</td>
<td>168.5</td>
<td>463.3</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S/Cowpea relay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorg Sorg</td>
<td>1303</td>
<td>4778</td>
</tr>
<tr>
<td>Sorg-Soy rotn.</td>
<td>1373</td>
<td>6023</td>
</tr>
<tr>
<td>Sorg-Gnut rotn.</td>
<td>957</td>
<td>3893</td>
</tr>
<tr>
<td>P of F</td>
<td>0.056</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LSD</td>
<td>121.8</td>
<td>767.8</td>
</tr>
<tr>
<td>Mean</td>
<td>1206</td>
<td>4814</td>
</tr>
<tr>
<td>CV</td>
<td>15.1</td>
<td>23.6</td>
</tr>
</tbody>
</table>
Resistance genes retain a vital role in the face of climate change

Genes giving resistance to aphid attack will still bolster the protection of groundnut varieties even if climate change brings increased drought stress.

An ICRISAT study shows that drought-stressed groundnut plants or low phosphorus (P) conditions do not systematically lead to rapid increases in the population of Aphis craccivora Koch, which is the common aphid transmitting the groundnut rosette disease (GRD) that can have a significant effect on production and yield of groundnut crops.

Sustainable crop production in sub-Saharan Africa is constrained by the limited availability of water, low soil fertility and by crop losses to insect pests and diseases. The advent of climate change means that drought, high temperature and low P continue to be major concerns for groundnut production in the Sahel region. An increase in the drought associated with climate change could increase the frequency and severity of insect population outbreaks, and thus, the occurrence of disease epidemics.

To obtain an understanding of the combined effects of drought and low P on aphid dynamics on groundnut, and to strengthen control strategies for GRD and reduce losses to small-scale farmers, the study investigated the effects of water and P stress on A. craccivora development on four groundnut varieties.

In addition to the negative effects of water stress on plant growth, drought stress increased plant nitrogen and potassium content, while low P stress reduced plant P and nitrogen contents.

Aphids feed exclusively on phloem sap, and their association with plants is believed to depend on the quality of the sap. The independent effects of water and P deficits were not the same on the four groundnut varieties, suggesting that groundnut genetic background outweighed the growth conditions of the plants.

Water stress had an unfavorable effect on A. craccivora development on the aphid-resistant groundnut variety ICGV 12991, while aphids performed better on the aphid-sensitive varieties Fleur 11 and 55-437 under combined drought stress and low P conditions. Such findings suggest that drought-stressed groundnut plants or low P conditions do not systematically lead to rapid increases in the A. craccivora population. In other words, genes of resistance to aphids are still needed regardless of changing growing conditions.
Stable future for millet and sorghum as improved varieties penetrate Niger and Nigeria

Improved sorghum and millet varieties to withstand impending climate stress will ensure stable pricing and availability of these crucial crops in the diets and livelihood of poor rural dwellers.

A recent study by ICRISAT and partners has confirmed the importance of both crops and set out the major influences on consumption, demand and associated price and spending elasticities.

In Niger and Nigeria, as in most Sahel countries in West and Central Africa (WCA), millet and sorghum are crucial to the diets and livelihood of the rural population. In Niger, consumption of millet and sorghum averaged 144 and 38 kg/capita/year, respectively, over the last two decades, making these crops key to household food security (FAO, 2015).

There was a slight decrease in per capita millet consumption over the last two decades in Niger, which was estimated at 157 kg/year in 1991 compared to 141 kg/year in 2011. Per capita sorghum consumption increased during the same period, reaching its highest in 2010 at about 48 kg/year.

In Nigeria, per capita millet and sorghum consumption average, respectively, 32 and 40 kg/year over the last two decades (FAO, 2015). Unlike in Niger, this makes sorghum a more important food commodity than millet. Consumption trends are also more stable for the two crops in Nigeria. Per capita millet consumption fluctuated only mildly between 1991 and 2010 (estimated at 30 kg/year in both years). For sorghum, per capita consumption was 38 kg/year in 1991, reached its peak in 1996 at about 46 kg/year, and has been decreasing since then. In 2011, per capita consumption of sorghum was estimated to be 32 kg/year. The contribution of millet and sorghum to household diets over the past two decades is on average 260 and 320 kcal/capita/day.

While informative in providing an overview of food commodity consumption, FAO statistics being based on country aggregate net supply provide no information on how consumption may vary by different categories of households such as urban/rural and poor/non-poor households. Such information is important to understand the importance of sorghum and millet in household diets and how demand for these two crops is expected to evolve with income growth and urbanization.

Using nationally representative household survey data from the World Bank, ICRISAT in collaboration with Virginia Tech University under the leadership of Dr Catherine Larochelle (Virginia Tech, USA) and Dr Alphonse Singbo (ICRISAT) analyzed the consumption and demand for sorghum and millet in Niger and Nigeria.

The study objective was to document sorghum and millet consumption patterns by population sub-groups, and to estimate the responsiveness of sorghum and millet demand to changes in the crops’ own prices (own-price elasticities), other food group prices (cross-price elasticities), and household expenditures (expenditure elasticities). The rationale for the study was to inform ICRISAT scientists and the research community regarding changes and drivers in sorghum and millet consumption demand in WCA.

Results reveal that millet is of high importance in the diet of households in Niger, and particularly the poorest households in rural areas. The latter devote about 40% of their food budget to millet but have lower per capita expenditure on millet than households in the upper wealth quintiles. Sorghum is consumed by 59% and 18%, respectively, of rural and urban households in Niger. Compared to millet, the diet and sorghum are less important in the diet of Nigerian households: a quarter of households in Nigeria consume millet and a third consume sorghum. However, sorghum plays an important role in the diet of the poorest rural households in Nigeria as indicated by its average share of 10% in the household food budget for this group.

The claim that urbanization has shifted consumer food preferences was strongly supported in this study. In both countries, urban households consume less sorghum and millet than rural households even at similar income levels. Significant variation of millet and sorghum consumption is also observed across regions.

Demand for sorghum and millet is more responsive to income changes in Nigeria than Niger. In both countries, the unconditional expenditure elasticity for sorghum and millet is higher in urban areas than rural areas, meaning higher demand growth rate in urban centers. Based on population growth rate, per capita income growth rate, and expenditure elasticity estimates, the rate of growth in the demand for sorghum and millet is estimated for both countries.

In Niger, the demand for sorghum is expected to grow at 5.1% and 7.0% annually in rural and urban areas, respectively, while the demand for millet is estimated to grow at respective rates of 4.6% and 7.3%. Combining rural and urban estimates, demand for sorghum in Niger is expected to grow at a rate of 5.2% annually and the demand for millet is estimated to have a rate of growth of 4.8%. In Nigeria, the growth rate in the demand for sorghum is estimated to be 4.2% in rural areas and 8.0% in urban areas, and demand for millet is expected to grow at 4.3% and 8.0% annually in rural and urban areas, respectively. This corresponds to an expected national growth rate of 4.9% in the demand for sorghum and 5% in the demand for millet.

Therefore, in both countries and for both crops, the growth rate of demand is expected to be higher in urban areas than in rural areas. In Niger, sorghum demand is expected to grow faster than millet, while in Nigeria the former is expected to grow slightly slower than the latter. Although national demand and household demand for the two crops continue to increase, their share in household food budgets will decrease considering the increasing urbanization and lower share of the two crops in the diet of urban households.

In both countries, the uncompensated own-price elasticities for sorghum and millet are larger in absolute value in urban areas than rural areas. Therefore, price increases will generate a greater response among urban households, meaning a greater shift away for sorghum and millet. Since the diet of poor households is heavy in sorghum and millet, an increase in the price of these cereal crops could have significant impact on their well-being.

Given the limited amount of additional land that can be put into cultivation, additional demand for sorghum and millet will have to be met mainly through increased productivity. Therefore, research efforts aiming at developing improved varieties that are high yielding and perform well under climate changes, such as more frequent droughts and floods, should help meet the additional demand. In addition, varieties that perform well despite climatic stress should help limit price fluctuations, for example those associated with production shocks, which should particularly benefit poor households that rely more heavily on sorghum and millet for nutrition.
Sub-Saharan Africa (SSA) is a rapidly developing region of over 800 million people, but its population is projected to reach 1.5 billion people with profound implications for agricultural production and food security. Sustainable agricultural intensification is seen as a serious option in the SSA region for satisfying 2050 global food requirements. At the same time, many challenges still hinder crop intensification in the region.

Although agriculture constitutes approximately 40% of the gross domestic product in Mali, and seeds are the basic input of farming, the seed market still remains underdeveloped. In the last two decades many high-yielding and short-duration varieties (e.g., fada, lata, grinkan, fleur11 and icgv86124), both for food and cash crops have been released. However, despite the potential of these varieties, only small quantities of their certified seed are available to farmers in local markets because the approach to seed management is disconnected from the context at the local level.

Seed management is organized around (i) research entities to create foundation seed, and (ii) farmers’ associations and some private seed companies multiplying and disseminating the new cultivars. Despite a growing seed multiplication movement during the last decade, the gaps still persist in the sector.

In Mali, seed production, distribution and use are guided by the new agricultural development framework – Loi d’Orientation Agricole – a policy enacted in 2006 to promote sustainable and competitive agriculture. Following this Seed Law, when offered for sale, seeds must be certified with an official label indicating the kind and variety, germination rate, date of testing etc. Any seed that is not properly labeled is not supposed to be sold. This Seed Law aims to achieve increased agricultural productivity and improved seed dissemination, and to facilitate farmers’ access to high quality seed.

Although a Seed Law is enacted with positive goals, the majority of farmers revert to using the unregulated traditional and informal seed systems because farmer associations find the certification process quite lengthy and they hardly afford the associated certification costs. On average, the certification of one ton of sorghum seeds, for instance, costs almost US$146 for both field inspections and laboratory operations. These costs are too expensive for most farmer cooperatives, and particularly prohibitive for individual farmers.

Given this challenge, although farmers still register as seed producers, they often continue to sell their seed via informal networks without any quality control, which affects crop yields and undermines the effort to promote improved varieties and to adapt to the changing agricultural conditions.

To help deal with these challenges, private enterprises have recently begun partnering with farmer associations; the private enterprises pay for the seed production and certification costs and buy the resulting seeds from the farmers. The aim of this partnership is to decentralize and increase the number of seed distribution points at the community level, improve the quality of the seed and help professionalize small-scale seed production and distribution.

But there are challenges with this arrangement too. For instance, the agreement between seed producers and private enterprises does not allow for direct trade, so seed farmers cannot sell their production to their peers. At the same time, the private enterprises sell the certified seeds at a relatively higher price than most smallholder farmers can afford. Furthermore, with private companies buying all the seed, seed producers do not develop the necessary skills and knowledge to properly market their seed (e.g., determining market preference, developing mechanisms of price formation, and strategies of advertising, packaging and branding).

As a result, many formal seed producers begin to see themselves simply as service providers to the private enterprises, and yet again the majority of farmers revert to using the traditional and informal seed systems.

In general, although the Seed Law was enacted to facilitate the access of high quality seed to farmers, the majority of the seed used still comes from the traditional systems. The gaps between the national seed framework and the local context hinder the effective implementation of the Seed Law and prevent the farmers from having easy access to clean seed.

Through the science policy platforms established in three pilot districts of Mali, namely Bougouni, Koutiala, and Segou, under the Climate Change, Agriculture, and Food Security (CCAFS) program, lobbying is on-going to inform high-level policy actors on the seed challenges. These actions aim at enhancing the awareness of high-level actors on supporting interventions to improve the living conditions of the most climate-vulnerable by facilitating easy access to good quality seed.
Opportunities and barriers in purchase of sorghum hybrid seeds in Mali: a qualitative assessment

A market breakthrough for hybrid sorghum varieties could follow comprehensive questioning of smallholder farmers to determine why some are ready adopters and others hold back.

In West and Central Africa, there is limited development of hybrid sorghum varieties and those that do exist often don’t reach or meet the needs and preferences of smallholder farmers. Over the past decade in Mali, scientists at ICRISAT and the national Institute of Rural Economy have developed hybrid sorghum varieties, based on West African guinea-race landraces and guinea-caudatum interzonal breeding lines. Along with improved and local sorghum varieties, these hybrids are being produced for seed and marketed by local cooperatives. The potential improved yields from the hybrids present an opportunity to growers but there are also many barriers to their uptake.

Several factors complicate the adoption of these hybrid varieties, including the novelty of hybrid seeds, specific trait preferences, the complex challenges associated with adoption of new varieties, and the fact that purchasing sorghum seed is not even a common practice. Scientists conducted semi-structured interviews with second year buyers of sorghum hybrid seeds in order to investigate these issues, and elucidate the factors why others may not purchase various types of sorghum seeds.

From the ongoing analysis, three salient concepts emerged. These pertain to the amount of exposure and experimentation necessary before the purchase of new varieties, specific traits farmers seek, and knowledge about hybrids. It required an average of four years of exposure to new varieties, either through demonstration trials, neighbors, media, and/or a close relationship with a cooperative member before interviewees were willing to purchase hybrid seeds. Knowing that the seeds were produced locally and by someone they knew in the area increased the chances of purchase. Even after purchase, farmers said they would test the varieties between 2–5 years before they would more often incorporate them permanently into their selection of varieties. The primary reason for long-term experimentation was due to variability in rainfall and varietal adaptation to different farm environments. Farmers maintained 2–4 types of varieties in order to manage this variability. However, about 10% of those interviewed had already switched the majority of their production into hybrid varieties.

The overwhelming reason why people liked hybrids was yield and improved fodder quality that provided “more profit”. Other traits, important to growers for all variety types, were timely maturity, panicle form, grain hardness, and hardy and high quality sorghum. Farmers liked photo-period sensitive varieties for two reasons: 1) when the rains come late and late planting is necessary, they still reach maturity, and 2) there are many field activities for other crops that must be completed before sorghum is planted. Grain storability was a trait farmers associated with local varieties and guinea-race hybrids. The available hybrid varieties had many of these qualities, increasing early farmer approval.

Regarding knowledge about hybrids, there was confusion amongst the buyers, despite numerous trainings and information sessions provided to seed sellers. Only eight farmers of the 43 knew that a hybrid plant would segregate, while four knew it would segregate but still experimented with the F2.

Identification of farmers that have not purchased hybrid seeds but have been exposed for a sufficient time period is challenging but they are an obvious group of people that are not included in this analysis. These interviews with buyers do emphasize which varietal attributes are appealing and not appealing to buyers, thus capturing the potential reasons (including exposure and risk factors) why others may not purchase various types of sorghum seeds.

In addition, women are neglected in this study because they are not traditional purchasers of sorghum, which is generally considered a crop grown by men. However, women are often given the leftover seed to grow in small plots and they play a major role in all field activities, thus it is likely they influence some decisions on the purchase of these varieties. One woman interviewed stated she grew hybrid sorghum after seeing it in a neighbor’s field and comparing it with her local variety. Her husband liked it so much they selected it for the family fields. To further understand these perspectives, future interviews will include both male and female buyers, and the wives of buyers.

Sorghum hybrids are beginning to emerge as a viable option that meets farmer demand for higher yield and dual-purpose varieties, but it is a long-term process that can take anywhere from 4–10 years of exposure and individual experimentation with the varieties before adoption. Hybrids fill an important niche on-farm, and varieties developed from local germplasm fit best with preferred attributes such as photo-period sensitivity and grain hardness, although some found the caudatum varieties ideal for fodder. Farmer management of diverse varieties for different purposes indicates that diverse variety types, such as improved, hybrid, and combined trait qualities of different races, need to continue to be maintained and developed. Importantly, local availability of improved seeds through decentralized seed production increases farmer confidence and willingness to purchase new varieties.

In the interviews, seed buyers were asked when they first bought the seed, for how many years they had purchased it, the quantities, and the names of all the other varieties they grew or had grown in the past five years. Then for each of these varieties the reasons were established for growing or abandoning these varieties, and the traits liked and disliked. This was done for hybrids and non-hybrids alike in order to determine if there were distinct or similar traits of interest between the types of varieties. Thematic coding was used to analyze the interviews.

Research-development partnerships for large-scale use of priority proven technologies of millet and sorghum in Mali

Closer liaison between farmers and scientists in strengthened research-development partnerships are taking sorghum and pearl millet based production systems in the Mopti and Sikasso regions of Mali to new beneficial levels.

The objective of this work is to expand large-scale utilization of priority proven technologies that improve nutrition, benefit women and children and enhance the sustainability of smallholder agriculture.

A multi-stakeholder consortium is being used innovatively to enhance the value chain from production to marketing and end use. At the farm level, the focus has been to improve production by increasing access to the identified new technologies and enhancing awareness and ‘know-how’ for use of existing technologies for enhancing sorghum and millet production.

One approach enables farmers to see the new technologies at the field level under their own conditions. These are marketing plots, either 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 involving a hundred or more people per village, as well as local and regional radio programs that reach thousands.

In Mopti region, the major technologies targeted for dissemination have been related to millet production:

- a) the use of seed treatment such as Apron Star 42WS;
- b) seeds 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 millet head-miner.

The major technologies targeted for dissemination in Sikasso region have been focused on sorghum:

- a) seed treatment using Apron Star 42WS;
- b) seeds of improved varieties of sorghum (both hybrid and open pollinated varieties), and groundnut adapted to the Sudanian and northern Guinea agro-ecologies; and
- c) integrated Striga and soil-fertility management practices (see next feature).

Among the fertilizer application rates proposed, the dose of 1/1 is the most preferred by farmers as it doesn’t require additional manpower for its application. On top of that, the yield has been increased by around 39% compared to the farmers’ practices.

Seed treatment with Apron Star of millet seed 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 plots than the untreated (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, described by producers as a late seeded variety.

In relation to sorghum varieties, all producers from Koutala appreciated Pablo and Fadda varieties for their high yield, their tolerance to drought and ease of cooking in contrast with the Sewa variety, which is hard milling and less appreciated in the diet.

Korobalen is the most popular cowpea variety because of its high yield and adaptation to the Mopti region compared to the Willbaly variety that producers found to be low yielding.

Growers have realised that the money invested in integrated Striga management has generated higher benefit ($US400) for every ToT site compared to the farmers’ practices ($US184). Farmers are very happy to apply this technology as this allows them to harvest two commodities on the same plot and additionally sell vines of cowpea.

Indeed, it has been realized that farmers are very happy with all the proposed technologies. While requests for seed of the new varieties are high, growers are being linked directly with seeds producers located in their areas so that the delivery transport costs can be reduced.

A public private partnership (PPP) is being created with two institutions; one providing seed treatment chemical (Apron Star) and another specialized in micro-financing systems. The mechanism stemming from the PPP collaboration will allow farmers to get a loan for purchasing this particular input and a large number of farmers will be able to apply the chemical to their seeds.
Integrated management of soil fertility and the Striga parasitic weed gives a 60% boost to sorghum and pearl millet yields

Follow-up analysis of farmer participation in the Large Scale-Diffusion of Technologies for Sorghum and Millet Systems project (ARDT_SMS) highlights the tremendous benefits flowing to farmers.

Low fertility and the parasitic Striga weed cause serious limitations to sorghum and pearl millet productivity but technologies to tackle both in the Mopti and Sikasso regions of Mali are available through strengthened research-development partnerships for large scale utilization of priority proven technologies. Major advances have been made in grower knowledge of Integrated Striga and Soil Fertility Management technology through the cluster-based farmer field school approach used by the project.

The follow-up impact analysis at the project intervention sites uses household survey data gathered in Sikasso in December 2015, and in Mopti in January 2016. A total of 216 household beneficiaries of the project were interviewed, of which 108 were sorghum producers and 36 pearl millet producers in Sikasso region, and 72 were pearl millet producers in Mopti region. Collected information covered the 2014 and 2015 agricultural seasons. Data were gathered on household socio-demographic and economic profiles such as land stocks, area under modern technologies, agricultural equipment, agricultural production, and other characteristics. The methodology used in this analysis was to evaluate the impact of Integrated Striga and Soil Management on the yields, household consumption, and production allocated to market compared to farmer’s practice.

Clear benefits are evident. The results show that sorghum production yields under integrated Striga management in the Sikasso region were 1225 kg/ha and 1469 kg/ha during the agricultural seasons 2014 and 2015, respectively, compared to those from farmer’s practice, which were respectively 759 kg/ha and 876 kg/ha over the same years.

Regarding the pearl millet, the average yields under integrated Striga management in Sikasso and Mopti regions were respectively 1330 kg/ha and 1134 kg/ha in 2014 and 2015 compared to those of farmer’s practice estimated at 801 kg/ha and 752 kg/ha. The overall boost for yields of both crops is 60% higher than those under farmer’s practice.

Furthermore, the results show that farmers applying control options to improve soil fertility and to fight against Striga generate a marketable surplus estimated at about 40% of their production of pearl millet or sorghum, and that 60% is consumed. About 85% of the production of pearl millet or sorghum derived from the farmer’s practice is consumed, with only 15% allocated to the cereal market. Therefore, the application of integrated Striga management improves the market participation of smallholder farmers and enables farm income increases.

To achieve positive change in pearl millet and sorghum production systems, there is a need to increase the number of farmers training in Integrated Striga and Soil Fertility Management, to develop the efficient extension mechanisms to reach large numbers of farmers, and to make the agricultural inputs available. The project undertakes support actions to establish a connection between the farmers and seed companies, and set up a public private partnership combining a credit mechanism with improved supply of inputs, including Apron Star for seed treatment and chemical fertilizers.
Making improved groundnut seed available to boost productivity in West Africa

A multi-stakeholder partnership is reinforcing the building blocks for production of Basic and Certified groundnut seed in West Africa.

At the same time as enhancing seed production and seed marketing to a grand scale, the partnership’s project objective aims to build farmers’ knowledge of improved groundnut production technologies, including improved groundnut varieties and complementary crop management practices.

Groundnut is a very important grain legume crop for the region’s smallholder farmers, and a major cash crop for many households as a nutritious food rich in protein, oil and micronutrients such as iron and zinc that contribute to the improved health of the rural population. It contributes to soil fertility with biological nitrogen fixation, and its haulm is a good source of animal feed.

Despite this importance, crop productivity remains low at an average of 1.5 tons ha⁻¹ compared with a global average of 3 tons ha⁻¹ in the USA and China. The low levels of groundnut productivity are not just a result of the unavailability of seed and inadequate crop management, means regional consumer demand is not being met.

The project Increasing Groundnut Productivity of Smallholder Farmers in Ghana, Mali and Nigeria adopts a combination of approaches to achieve its objectives. A multi-stakeholder partnership of research institutions, national services, non-government organizations (NGOs), farmers’ organizations, and private sector actors has been assembled to ensure implementation. In order to enable farmers meet their seed requirements, community seed production was promoted as a model for seed production.

In collaboration with seed inspectors and regulators, the project provides training and technical backstopping to individuals and/or community organizations to produce and market certified and quality-declared seed to their communities in particular and others at large. At the farm level, the focus is to improve production by increasing access to improved groundnut varieties and enhancing ‘know-how’ for groundnut production.

Strengthening local seed systems is achieved largely through assisting community-based organizations to produce seed by alleviating existing bottlenecks to accessing early generation seed, and increasing awareness and demand for improved varieties; this is paramount in conjunction with the adoption of good agricultural practices to reach yield potentials.

Breeder seeds and foundation seeds that are the progeny of the breeder seed have been produced by ICRISAT, the Institut d’Économie Rurale (IER) in Mali, the Crop Research Institute (CRI) and the Savannah Agricultural Research Institute (SARI) in Ghana, and the Institute of Agricultural Research (IAR), the Federal University of Agriculture Makurdi (FUAM) and the Bayero University of Kano (BUK) in Nigeria.

During the 2015 growing season, different classes of seed of improved varieties were produced in the three countries. In Ghana, 2 tons of breeder seed, 3 tons of foundation seed and 33 tons of certified seed were produced. Nine tons, 24 tons and 109 tons of breeder, foundation and certified seed, respectively, were produced in Mali. In Nigeria, 12 tons of breeder seed, 26 tons of foundation seed and 382 tons of certified seed were produced and injected into the country’s seed systems.

Seed of improved varieties can be seen as a basic tool for a secure food supply and offer high returns per unit area as the genetic potential of the crop can be fully exploited. The level of breeder and foundation seed production is still very low to meet the demand for the basic seed so the project is developing strategies to increase the production of breeder and foundation seeds as they are critical inputs for enhancing the seed system, agricultural production and productivity.

**Partners:**

**Ghana**
- Savanna Agricultural Research (SARI)
- Crops Research Institute (CRI)
- Catholic Relief Services (CRS)
- Peanut and Mycotoxin Innovation Lab-Ghana (PMIL-Ghana)
- Ministry of Food and Agriculture (MOFA Northern Region)
- Ministry of Food and Agriculture (MOFA Upper West Region)
- Management Aid
- Centre for Sustainable Local Development (CSLD), Heritage Seeds.

**Mali**
- Institut d’Économie Rurale (IER)
- Groupe de Recherche d’Action et d’Assistance pour le Développement (GRAADECOM)
- European Cooperative for Rural Development (EUCORD)
- Centre d’Appui à l’Autopromotion pour le Développement (CAAD)
- Catholic Relief Services (CRS)
- Aga Khan Foundation (AKF)
- Associations des organisations professionnelles paysannes (AOPP)
- World Vision
- ADAB Galale
- Association Malienne pour la Sécurité et la Souveraineté Alimentaires (AMASSA)
- Association Malienne d’Éveil au Développement Durable (AMEDD)
- Sahel 21
- Plan Mali
- Bornefonden
- Faso Kaba

**Nigeria**
- Institute for Agricultural research (IAR), Centre for Dryland Agriculture/Bayero University, Kano (CDA/BUK)
- National Agricultural Seeds Council (NASC)
- Federal University of Agriculture, Makurdi (FUAM)
- Green Sahel Agricultural and Rural Development Initiative (GSARDI)
- Catholic Relief Services (CRS)
- Women Farmers Advancement Network (WOFAN)
- Kano Agricultural and Rural Development Authority (KNARDA)
- Women Farmers Advancement Network (WOFAN)
- Jigawa Agricultural and Rural Development Authority (JJARDA)
- Sokoto Agricultural and Rural Development Authority (SARDA)
- Katsina Agricultural and Rural Development Authority (KARDA)

**Partners:**

**Future-proof science for upcoming generations**

**ICRISAT West and Central Africa**

Farmers in Mali adopt soil and water conservation measures to offset climate change

Soil and water conservation measures are critical to offsetting the impact of climate change on agriculture in sub-Saharan countries.

The effectiveness of such measures in differing farming systems has been examined under a USAID Global Climate Change (GCC) project, in the Mopti region of Mali, that aims to address farmers and community perceptions of causes and effects of climate change and barriers to adoption of the resilient practices paying special attention to gender and farming systems in the region.

Climate change remains a major development challenge in developing countries, particularly in the sub-Saharan economies, including Mali, where the majority of the population resides in the rural areas and derives livelihoods directly from the agricultural sector. Sustained livelihood improvements in many of the rural communities will require implementation of inclusive interventions that promote adaptation of the agricultural sector. Formulation of robust policy interventions and programs thus requires a better understanding of how male and female farmers adapt to the changing climatic condition, evaluation of implemented intervention practices, and their perceived effects of climate change and the barriers to climate adaptation strategies.

Three farming systems – those for rice, cereals, and mixed farming – were considered for the study according to the main crops grown by the farmers. Data were collected from 297 farmer households, 16 NGOs, and 11 focus group discussions (FGDs) from 11 villages. The sample of individual households comprised 13% female- and 87% male-headed households, a proportional representation of the actual heads of households in the region.

SWC measures are the most critical entry points for improving land resource resilience and productivity. SWC measures maintain long-term productivity and ecosystem functions (land, water, and biodiversity) and increase productivity (quality, quantity and diversity) of goods and services (including safe and healthy food).

In the studied villages at least one soil and water conservation technology was implemented by more than half of the farmers. However, the rate of adoption of the individual measures is generally low. Zai (planting holes) was the most common SWC measure used by the households (43%). The likelihood of adoption of any of the other SWC measures is less than 25% (Table 4). The low uptake of SWC measures may hamper farmer households from achieving sustainable resilience to climate change.

Significant variations in adoption of most of the SWC measures were found in the farming systems; with the exception of vegetative filter barriers, contour bunding, and wells. The results also showed more adopters of the SWC measures in the mixed farming system compared to the rice and cereals systems. For example, about 69% of farmers residing in the mixed farming system used zai compared to only 34% and 32% of those residing in the cereals and rice farming systems, respectively.

About 35% of farmers in the mixed system used artificial ponds relative to only 16% of the users in the cereals system. There are no gender differences in adoption of the soil and water conservation measures in the region. However, the proportion of female adopters of SWC measures is slightly higher than male adopters, except for zai (Table 5).

Analyzed results further indicated farmers noting diverse constraints to SWC with the most popular including lack of finances (cited by 29.5%) and limited labor (28%) (Table 6). Comparable proportions of male- and female-headed households cited financial and labor constraints as the main barriers to using SWC practices (Figure 7).

Other constraints noted by farmers include limited land rights since most of the land in the region is communally owned, and agro-ecological factors including soil and water attributes. These barriers were more markedly noted by farmers in the mixed farming system.

### Table 4: Soil and water conservation practices in Mopti region by farming system

<table>
<thead>
<tr>
<th>SWC measure</th>
<th>All households</th>
<th>Rice system</th>
<th>Cereal system</th>
<th>Mixed system</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zai</td>
<td>0.42 (0.49)</td>
<td>0.24 (0.43)</td>
<td>0.34 (0.48)</td>
<td>0.69 (0.47)</td>
<td>19.88</td>
<td>0.0000</td>
</tr>
<tr>
<td>Artificial ponds</td>
<td>0.23 (0.42)</td>
<td>0.22 (0.43)</td>
<td>0.16 (0.37)</td>
<td>0.35 (0.48)</td>
<td>5.64</td>
<td>0.0040</td>
</tr>
<tr>
<td>Vegetative barriers</td>
<td>0.23 (0.42)</td>
<td>0.22 (0.42)</td>
<td>0.20 (0.40)</td>
<td>0.30 (0.46)</td>
<td>1.51</td>
<td>0.2231</td>
</tr>
<tr>
<td>Contour bunding</td>
<td>0.23 (0.42)</td>
<td>0.22 (0.42)</td>
<td>0.19 (0.40)</td>
<td>0.30 (0.46)</td>
<td>1.73</td>
<td>0.1786</td>
</tr>
<tr>
<td>Wells</td>
<td>0.23 (0.42)</td>
<td>0.22 (0.42)</td>
<td>0.19 (0.39)</td>
<td>0.30 (0.46)</td>
<td>1.99</td>
<td>0.1393</td>
</tr>
<tr>
<td>Stone bund</td>
<td>0.21 (0.41)</td>
<td>0.24 (0.43)</td>
<td>0.14 (0.34)</td>
<td>0.33 (0.47)</td>
<td>5.93</td>
<td>0.0030</td>
</tr>
<tr>
<td>Dams and dykes</td>
<td>0.20 (0.40)</td>
<td>0.24 (0.41)</td>
<td>0.13 (0.34)</td>
<td>0.30 (0.46)</td>
<td>5.28</td>
<td>0.0056</td>
</tr>
<tr>
<td>Dug gullies</td>
<td>0.20 (0.40)</td>
<td>0.22 (0.42)</td>
<td>0.14 (0.34)</td>
<td>0.29 (0.46)</td>
<td>4.06</td>
<td>0.0183</td>
</tr>
</tbody>
</table>

Note: Standard deviations in parentheses; Common superscripts across indicate equal mean values.
Table 6. Barriers to adoption of SWC measures, by farming system

<table>
<thead>
<tr>
<th>Barrier</th>
<th>All households</th>
<th>Rice system</th>
<th>Dry System</th>
<th>Mixed system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Lack of financial capital</td>
<td>83</td>
<td>29.5</td>
<td>11</td>
<td>26.8</td>
</tr>
<tr>
<td>Labor constraints</td>
<td>79</td>
<td>28.1</td>
<td>11</td>
<td>26.8</td>
</tr>
<tr>
<td>Hydraulic characteristics</td>
<td>35</td>
<td>12.5</td>
<td>3</td>
<td>7.3</td>
</tr>
<tr>
<td>Plant characteristics</td>
<td>30</td>
<td>10.7</td>
<td>4</td>
<td>9.8</td>
</tr>
<tr>
<td>Land tenure</td>
<td>14</td>
<td>5.0</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Soil characteristics</td>
<td>11</td>
<td>3.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Official regulations</td>
<td>3</td>
<td>1.1</td>
<td>1</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Developing Climate-Smart village models through integrated participatory action research

Climate-smart villages are evolving in five West African countries from Senegal to Niger thanks to integrated participatory action research aimed at protecting food security.

Climate change creates new challenges for food security in the region. To overcome these threats, the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) developed among other tools and approaches, the Climate Smart Village (CSV) as a model for local action research to achieve food security, enhance livelihood, and improve environmental management, i.e., Climate-Smart Agriculture (CSA).

Based on the CSV model (Figure 8) designed by communities at site level, CCAFS in partnership with NARES, NGOs, local authorities etc. have tested and validated several agricultural interventions with the intention of integrating climate-smart agriculture into village development plans, using local knowledge and expertise and supported by local institutions. A range of achievements have already been successful, including:

**Development and dissemination of climate-smart technologies**

In all the countries, several promising CSA technologies and practices including soil and water conservation (SWC) techniques such as zai (planting holes), bunding, tie ridging and no-tillage; agroforestry practices, farmer-managed natural regeneration, shorter cycle varieties of crops, drought-tolerant crop varieties; have been tested and validated in the CSVs. As CSA options are context specific, some could be scaled up to the same agro-ecological zone in each country. In addition, the CSV model could be adapted at a medium scale, such as commune or district in the countries.

**Capacity building**

- Technical staff in all countries capacitated in participatory monitoring and evaluation tools;
- More than 500 farmers have been capacitated in integrated water management options, anti-bushfire squads, compost preparation and use, land reclamation and soil fertility management practices;
- Gender Climate-Smart Groups created and members capacitated in soybean production and post-harvest loss reduction in Ghana;
- New participatory and interactive dynamic groups created at community level to address climate-change challenges in Senegal;
- Functional innovations platform for the management of climate risks established in Senegal;
- Awareness by individual farmers and communities of natural resource (land and forest) management and climate-change challenges.

**Partnership**

- A strong partnership involving all relevant actors working on climate-change issues at site in each country has been established for the development of CSVs;
- CCAFS Flagship Projects led by ICRISAT, ICRAF and IWMI are working currently on site to consolidate the main achievements for the scaling-up purpose of the CSV model;
- The promising results obtained from the CSA activities in WA convinced many institutions including World Bank and FAO to integrate the CSV approach within funded projects in Niger.

Led by the CCAFS-WA regional program based at ICRISAT and implemented in Burkina Faso, Ghana, Mali, Niger and Senegal, the project’s main objective is to develop Climate-Smart village models in West Africa in order to boost farmers’ ability to adapt to climate change, manage risks and build resilience. Specific objectives are: (i) to coordinate integration of flagship projects (FPs) and other research work at CSV sites; (ii) to provide evidence of climate-smartness of promising CSA options emerging from the CSVs; (iii) to simulate how the current CSV models translate into upper levels in a bid to guide climate change adaptation planning; and (iv) to prioritize investment in CSA at national level.

In all the countries, several promising CSA technologies and practices including soil and water conservation (SWC) techniques such as zai (planting holes), bunding, tie ridging and no-tillage; agroforestry practices, farmer-managed natural regeneration, shorter cycle varieties of crops, drought-tolerant crop varieties; have been tested and validated in the CSVs. As CSA options are context specific, some could be scaled up to the same agro-ecological zone in each country. In addition, the CSV model could be adapted at a medium scale, such as commune or district in the countries.
CORAF/WECARD and ICRISAT renew their partnership agreement

After more than six years, the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) and ICRISAT took stock of their partnership agreement and decided to renew certain points of its contents to reflect the evolution of the scientific environment in Africa and elsewhere. The updated agreement was signed on 27 February 2015 in Saly Portudal in Senegal by Dr Harold Roy-Macauley, Executive Director of CORAF/WECARD and Dr David Bergvinson, Director General, ICRISAT.

Training on coordinated field and UAV campaigns organized in Bamako, Mali

From 20–30 April, the ISABELA\(^1\) team, which leads STARS\(^2\) operations in West Africa, organized a training workshop at the ICRISAT-Bamako campus to train Mali and Nigeria team members on coordinated field and UAV\(^3\) measurement campaigns and data processing. Main objectives were to train i) field operators in recording agronomic and field-level information, ii) scientific officers and research technicians in UAV operations (flight planning, flight execution, equipment maintenance etc.), and iii) back-office operators in the securement and post-processing of field and remote sensing data using CAN-EYE and cloud point processing software. All operations followed standardized protocols, building on data evidence from measurement campaigns deployed in Sukumba in 2014.

\(^1\)Imagery for Smallholders: Activating Business Entry points and Leveraging Agriculture
\(^2\)Spurring a Transformation for Agriculture through Remote Sensing
\(^3\)Unmanned Aerial Vehicles

Large-scale diffusion in Mali of technologies for sorghum and millet systems (ARDT_SMS)

The first of a series of agricultural input fairs was held on 11 June 2015 at Bougouni (Sikasso region of Mali) by the large-scale diffusion of technologies for sorghum and millet systems (ARDT_SMS) project in its mission to provide quality inputs to boost agricultural production and improve food security. The objective of the fairs was to link quality input suppliers and distributors to farmers in a quality and timely manner for the cropping season.

“The fairs promote the establishment of exchange and partnership platforms between producers, agro-dealers and inputs suppliers,” said Mrs Aminata Coulibaly Tangara, National Director of the Mali Agricultural Market Development Trust (MALIMARK), both partner and organizer of the fairs in the Sikasso region as part of the communication creation strategies of the Africa RISING ARDT_SMS. After the launch in Bougouni, agricultural inputs fairs were organized by MALIMARK in five other Sikasso locations, namely Koutiala, Kila, Sikasso, Niena and Zamtiebougou as part of the ARDT_SMS project.

ICRISAT Director General visits Mali, Niger and Nigeria

During his visit to West Africa in March 2015, Dr David Bergvinson reiterated ICRISAT’s commitment to support smallholder farmers through demand-driven research for agricultural development to improve their livelihoods through a close partnership with Mali’s Institut d’Economie Rurale, NGOs and the private sector.

“As ICRISAT delivers science findings to farmers, nutrition of farming households, especially of women and children remains a key driver,” said Dr Bergvinson. He also stressed the importance of strategies like Inclusive Market-Oriented Development that could enable better inclusion of youth and women in the agricultural sector.

Dr Bergvinson visited ICRISAT locations in Niger and Nigeria were he met with officials and key players in their agricultural sectors, including farmers, government officials, donors, private sector members and NGOs.
Innovations platforms and technology parks to boost technology uptake in Mali

New platforms activities were launched in Koutiala and Bougouni for the Africa RISING research program and beyond in southern Mali as part of the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) research-for-development project in Mali. The project is supported by the United States Agency for International Development as part of the U.S. government’s Feed the Future initiative.

Media professionals are trained to support the implementation of upscaling groundnut technologies in Mali, Nigeria and Ghana

The training courses were conducted from 1–3 October in Mali, from 12–14 October in Nigeria and from 19–21 October 2015 in Ghana to enable media professionals to support the implementation of the upscaling of groundnut technologies. In Mali, the training session was attended by 19 media professionals, including community radios, print media, TV and drama producers. In Nigeria, it brought together a total of 35 participants, comprising agronomists, extension agents and media professionals, all from the five states where the project is being implemented. Fifteen media professionals attended the course in Ghana.

Bauchi State Government of Nigeria recognizes ICRISAT extension agent on dry season groundnut cultivation

The Bauchi State Governor, His Excellency Mr. Muhammed Abdullahi Abubakar, in a ceremony to flag off the 2015 planting season in Bauchi, presented a motor cycle and certificate to Mr Mohammed Sadisu Abdulsalam. The presentation was based on recognition of the work of Mr Abdulsalam for ICRISAT in Ningi Local Government Area (LGA) in particular and Bauchi State in general. Mr Abdulsalam is an Extension Agent of Ningi LGA, Bauchi State seconded to ICRISAT since 2012.

West Africa Agricultural Productivity Project (WAAPP) Nigeria and World Bank officials visit ICRISAT–Kano Nigeria

Representatives of the West Africa Agricultural Productivity Project (WAAPP)–Nigeria Project led by its Agricultural National Project Coordinator, Mr. James A坡chi, and a World Bank Supervision Mission, led by Dr. Abdoulaye Toure and Mr. Obadiah Tohomdet, along with 14 other delegates, visited ICRISAT–Nigeria on 4 November 2015. The team visit to the station in Kano was in respect of the two WAAPP–Nigeria-funded projects in ICRISAT–Nigeria: 1) Enhancing the Adoption of Improved Sorghum Varieties for increased Agricultural System Productivity and Food Security in Nigeria, and 2) Popularization of Improved Groundnut Varieties through Seed Production for Increased Agricultural Productivities and Food Security in Northern Nigeria.
ICRISAT–Nigeria planning meeting to target capacity building of youth and women

A planning meeting to develop training of youth and women in agribusiness was held at the ICRISAT Kano office on 28–29 October 2015 for the Agricultural Transformation Agenda Support Program phase 1 (ATASP 1). The objective of the two-day planning meeting was to identify activities and elaborate detailed plans on training youth and women in small-scale agricultural mechanization, processing, value addition and entrepreneurship.

STARS project Nigeria partners organized Farmer Field day

The Centre for Dryland Agriculture (CDA), Zonal Advance Space Technology Application Lab (ZASTAL) and ICRISAT-Nigeria under the Spurring a Transformation for Agriculture through Remote Sensing (STARS project) organized a farmers’ field day on 19 November 2015, which attracted over 168 participants, including 38 women farmers, as well as ZASTAL scientists led by the Officer-in-Charge, Dr Ibrahim Tudunwada, and CDA partners led by Dr Sani Momale. Further participants included representatives of Kano State Agricultural and Rural Development Authority and the College of Agriculture, Danbatta, along with traditional leaders from Kofa and adjacent communities. The occasion was graced with the presence of Dr Anthony Whitbread, Director of the CGIAR research program on Resilient Dryland Systems, who was on an official visit to Nigeria.

ICRISAT to support the Agricultural Transformation Agenda (ATA) of the Federal Government of Nigeria

ICRISAT scientists in Nigeria have been key partners in the Agricultural Transformation Agenda (ATA) of the Federal Government of Nigeria since 2012 with their work on Sorghum and Groundnut value chains leading to high impact. These efforts are set to continue with the launch of a US$174m African Development Bank-funded project Agricultural Transformation Agenda Support program Phase 1 (ATASP-1) in Abuja on 6 March 2015.
**Who we are**

### Bamako, Mali

- **Ramadji Tabo**
  - Director, West and Central Africa
  - Chad

- **Eva W Rattunde**
  - Principal Scientist, sorghum breeding and genetic resources – dryland cereals
  - Germany

- **HFW Rattunde**
  - Principal Scientist, sorghum breeding and genetic resources – dryland cereals
  - Germany

- **Pierre CS Traore**
  - Senior Manager – GIS – resilient dryland systems
  - France

- **Robert B Zougmore**
  - Regional Program Leader – CCAFS
  - Burkina Faso

- **George E Okwach**
  - Manager, HOPE project for sorghum and millet – dryland cereals
  - Kenya

- **D Hailemichael Shewayarga**
  - Scientist – groundnut breeding
  - Ethiopia

- **Birhanu Zemadim Birhanu**
  - Scientist – land and water management (WCA)
  - Ethiopia

- **Felix Badolo**
  - Scientist – agricultural economics
  - Burkina Faso

- **Baloua Nebie**
  - Scientist – sorghum breeding
  - Burkina Faso

- **Alphonse Gbemayi Singbo**
  - Scientist – market economics (WCA)
  - Benin

- **Giangmimon G Edmond Totin**
  - Scientist – policy and institutions
  - Benin

- **Mathieu Ouedraogo**
  - Scientist – participatory action research (CCAFS)
  - Burkina Faso

- **Samuel Tetteh Parrey**
  - Scientist – climate change, agriculture and food security (CCAFS)
  - Ghana

- **Monica Petri**
  - Program Manager/Agronomist
  - Italy

- **Sarathjith Madathiparambil**
  - Post-doctoral Fellow
  - India

- **John Ruxagara Nzungize**
  - Project Manager and Technology Uptake Specialist
  - Rwanda

- **Hippolyte Allognon**
  - Senior Project Manager and Technology Uptake Specialist – Increasing Groundnut Productivity of Smallholder Farmers in Ghana, Mali and Nigeria (USAID funded project)
  - Benin

- **Ayoni Ogumbayo**
  - Country Project Manager – Mali, Increasing Groundnut Productivity of Smallholder Farmers in Ghana, Mali and Nigeria (USAID funded project)
  - Benin

- **Krista Isaacs**
  - Post-doctoral Fellow - Gender and participatory plant breeding - Dryland Cereals
  - USA

- **Amadou Bila Belemgoabga**
  - Regional Administrator
  - Burkina Faso

- **Agathe Diama**
  - Regional Information Officer
  - Mali

- **Amadou Sidibe**
  - Agro-Socio-Economy - Special project scientist-Adaptation at Scale in Semi-Arid Regions
  - Mali

### Niamey, Niger

- **Malick Ba**
  - Senior Scientist – entomology
  - Country Representative (Niger)
  - Burkina Faso

- **Hamidou Falalou**
  - Scientist, Crop Physiology - Responsible Regional Genebank and Biotech Lab
  - Ghana

- **Fatoum Djoumaydi**
  - Senior Scientist – agronomy
  - Benin

- **Tom Hash**
  - Principal Scientist – pearl millet improvement program
  - USA

- **Dr Boudie Vincent Bado**
  - Principal Scientist – dryland systems and livelihood diversification
  - Burkina Faso

- **Patrice Sayadogo**
  - ICMP/ICRISAT Agroforestry Systems Scientist
  - Burkina Faso

### Kano, Nigeria

- **Hakeem Aljinde Ajeigbe**
  - Principal Scientist – agronomy
  - Country Representative (Nigeria)
  - Nigeria

- **Babu Nagabhushan Motagi**
  - Senior Scientist – groundnut breeding
  - India

- **Ijantiku Ignatius Angarawai**
  - Scientist – sorghum breeding (WCA)
  - Nigeria

### Ghana

- **Paul Tanzubit**
  - Country Project Manager (Ghana) Increasing Groundnut Productivity of Smallholder Farmers in Ghana, Mali and Nigeria (USAID funded project)
  - Ghana

---

**ICRISAT West and Central Africa | 2015 Highlights | Future-proof science for upcoming generations**
<table>
<thead>
<tr>
<th>Page</th>
<th>Authors/Members, Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover</td>
<td>Emmanuel Daou, Malidjaw</td>
</tr>
<tr>
<td>Page 3</td>
<td>Emmanuel Daou, Malidjaw</td>
</tr>
<tr>
<td>Page 4</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 6-7</td>
<td>Agathe Diama, ICRISAT</td>
</tr>
<tr>
<td>Page 8-9</td>
<td>Baloua Nebie, ICRISAT</td>
</tr>
<tr>
<td>Page 10</td>
<td>Ignatius Ijantiku Angarawa, ICRISAT</td>
</tr>
<tr>
<td>Page 13</td>
<td>Sarathjith M C, ICRISAT</td>
</tr>
<tr>
<td>Page 14-15</td>
<td>Benjamin Kura and Shiyanbola</td>
</tr>
<tr>
<td>Page 16</td>
<td>Abdulkalam, ICRISAT</td>
</tr>
<tr>
<td>Page 18-19</td>
<td>Agathe Diama, ICRISAT</td>
</tr>
<tr>
<td>Page 21</td>
<td>Fatondji Dougbedji, ICRISAT</td>
</tr>
<tr>
<td>Page 24-25</td>
<td>Malik Bu, ICRISAT</td>
</tr>
<tr>
<td>Page 26-27</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 29</td>
<td>Krista Isaacs, ICRISAT</td>
</tr>
<tr>
<td>Page 31</td>
<td>Emmanuel Daou, Malidjaw</td>
</tr>
<tr>
<td>Page 33</td>
<td>Zoumana Diakite, ICRISAT</td>
</tr>
<tr>
<td>Page 34</td>
<td>ICRISAT, Nigeria</td>
</tr>
<tr>
<td>Page 35</td>
<td>Zoumana Diakite, ICRISAT</td>
</tr>
<tr>
<td>Page 36</td>
<td>ICRISAT, Nigeria</td>
</tr>
<tr>
<td>Page 37</td>
<td>Emmanuel Daou, Malidjaw</td>
</tr>
<tr>
<td>Page 38-39</td>
<td>Agathe Diama, ICRISAT</td>
</tr>
<tr>
<td>Page 40-41</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 42-43</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 44-45</td>
<td>Mathieu Ouedraogo, ICRISAT</td>
</tr>
<tr>
<td>Page 46-47</td>
<td>Zoumana Diakite, ICRISAT</td>
</tr>
<tr>
<td>Page 48-49</td>
<td>Agathe Diama, ICRISAT</td>
</tr>
<tr>
<td>Page 50 (1-2-3)</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 51 (1-2-3)</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 51 (1-3)</td>
<td>ICRISAT, Nigeria</td>
</tr>
<tr>
<td>Page 52 (1-2)</td>
<td>ICRISAT, Nigeria</td>
</tr>
<tr>
<td>Page 53</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 54-55</td>
<td>ICRISAT</td>
</tr>
<tr>
<td>Page 56</td>
<td>ICRISAT</td>
</tr>
</tbody>
</table>

Photos credits:
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.

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