

Sorghum and millet roadmap summary

The road towards sustainable sorghum and millet chains [2024-2034]



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Almost half of all sorghum and millet is produced in Africa. Although consumption has fallen over the past 20 years in favour of imported products such as rice, population growth, changing soil and climate conditions and increasing awareness of their merits on the part of national and regional authorities in Africa mean that they will have a key role to play in the coming years. At CIRAD, sorghum and millet are considered as a single value chain. They have identical target characters, are parts of the same agrosystems, are both worked on by our partners and will enable a rollout of strategies encompassing several species. While sorghum originated in northeastern Africa, it has travelled far and wide, and is now found in West and southern Africa, India, the United States and Australia. Millet, which originated in West Africa, also plays a major role in India. Compared to the world's leading three food crops (rice, maize and wheat), these two species have a triple advantage: they have better nutritional qualities, are more resistant to biotic and abiotic stress, and require less water and fertilizer. Both have a range of uses: in the human diet (porridge, couscous, biscuits, bread, fermented drinks, etc) and as animal feed (high-food-value fodder in various forms) but also as cover crops. Lastly, sorghum and millet both have considerable social, cultural and symbolic importance in many African countries.

Diverse production, varied uses

Sorghum production has been relatively stable over the past 60 years. The range of production systems – monocropping, intercropping, flood-recession cropping, etc. – favours its resilience. There are two distinct groups of producing countries, the first being those that produce sorghum

Sorghum and millet, the fifth and sixth most widely grown cereals in the world, are pillars of food security in semi-arid zones. Population growth and climate change have made them key crops for the future, which is why CIRAD is conducting substantial research on them. ■

for the international market and non-food uses (animal food and biofuels): western countries, Australia and China; and the second those that primarily use sorghum to feed local people and sell it on neighbouring markets: sub-Saharan Africa, the Middle East, North Africa and India. In 2023-2024, Africa produced 26 Mt, 45% of the world's total output. The main sorghum producing countries in 2023-2024 were the US, Nigeria and Brazil, which together accounted for a third of global output. The main markets are still to feed humans, accounting for 40% of the sorghum produced worldwide (60% in some African or Southeast Asian countries).

Climate-resilient cereals

In a context of climate change, sorghum could take on renewed importance as a food and industrial crop. Its high tolerance of abiotic stress, notably water

stress, and of low nutrient availability has been widely documented. Sorghum also has very high carbon capture potential. In sub-Saharan Africa, it has been shown that using 25% sorghum straw as a fodder supplement reduces enteric methane emissions from ruminants by 21%. All the signs point to the future of the sorghum economy being played out in sub-Saharan Africa, where its production and domestic consumption are growing, driven by population growth and consumer preference. To tackle the current challenges, CIRAD is notably working to develop varieties better suited to innovative cropping systems tailored to local issues, while capitalizing on local species. The challenge is to satisfy the growing needs of local people, without relying on imported cereals. Adapting products to people's needs is a major priority, which will mean both optimizing traditional processing techniques and developing new products. ■



| Sorghum diversity, a tool for adapting varieties to climate change and to users' and consumers' requirements

Promoting the sorghum and millet value chains of the future: four ambitions to frame operations

Sorghum has always been a target crop for CIRAD: the prime study site is West Africa, extending into central Africa, and major work has also been done in Latin America. In view of its vital importance for food security in the world's driest zones, millet has also been the object of substantial operations at CIRAD, focusing on cropping systems. For both millet and sorghum, the organization has developed multidisciplinary approaches blending work on genetic resources, cropping systems and value chain analysis. Its three departments – "Biological Systems", "Performance of Tropical Production and Processing Systems" and "Environments and Societies" – are providing resources with a view to achieving four main ambitions...

Ambition 1

Make sorghum- and millet-based systems more productive and resilient, through agroecological intensification

The aims of this ambition are (i) to make sorghum and millet more productive and sustainable while restoring soil fertility, by means of an approach based on co-constructing innovations and on agroecological intensification; and (ii) to make sorghum and millet production systems more resilient to climate hazards, using tools to characterize the environmental constraints and identify cropping systems and installations that could buffer the effects of climate hazards, and develop varieties more resilient to climate variability and change. Two strategic lines of work have been pinpointed: co-designing high-yielding, sustainable agroecological systems, and using genetics and breeding to develop varieties tailored to producers' requirements.

Ambition 2

Improve grain and biomass collection, storage and processing procedures in line with consumer demand

This ambition aims to build knowledge and optimize procedures for sorghum and millet postharvest operations, to satisfy demand from producers, processors and consumers. It will encompass the entire production chain, from raw material to end product consumption, to optimize added value. The main operations relating to this ambition include identifying quality characteristics, understanding the interactions between the initial properties of raw materials, processing operations and end products, and developing new products.

Ambition 3

Build organizational capacity among sorghum and millet value chain stakeholders, to ensure market access as a lever for boosting incomes and food sovereignty

This ambition links the agricultural production context to the wider situation, encompassing downstream players focusing on local, national, regional and international markets. Those markets may be traditional (food security), new (diversification of end products, innovative use of by-products), or substitute (to replace rice and maize in particular), etc. Although a major share of millet and sorghum is consumed by the people who grow them, it is the way in which these value chains articulate with different markets that governs their capacity to give rural and urban populations greater food security, generate income and share that income fairly between the main stakeholders.

Ambition 4

Improve the organization and structuring of research networks and increase their interactions with development players to foster the emergence of appropriate innovations and more effective transfers

The aim will be to help structure research networks and build better connections and coordination with development structures working towards impacts for developing countries. In terms of optimizing links between players, this ambition will specifically focus on supporting skill building among national researchers with a view to co-construction with non-academic players. CIRAD will be following three lines of action on complementary geographical scales: renewed support for national agricultural research centres, consolidation of the links between Europe and Africa, and increased participation in international research. ■



| Millet earworm caterpillars sampling

Details

Sorghum and millet productivity, adaptation to consumer requirements, efficient value chains, stronger partnerships, etc. we look at the key details of the roadmap with CIRAD sorghum and millet research coordinators David Pot (researcher specializing in genetics in support of breeding programmes) and Julie Dusserre (researcher specializing in the ecophysiology and functioning of crop stands).



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How can we tackle the challenge of increasing sorghum and millet production and productivity?

David Pot: Identifying suitable varieties is key to optimizing cropping systems, and CIRAD can contribute on three levels: (i) an in-depth understanding of the parts of the genome that control the characters governing adaptation to the environment and to consumer requirements; (ii) the development of tools to predict varietal performance in current and future situations; and (iii) support for breeding programmes, from helping farmers with on-farm operations to approaches using the latest technologies.

Julie Dusserre: We are working on agroecological crop intensification, using participatory and multi-stakeholder

approaches to look at both how the available resources are and could be managed and crop diversification within systems (agroforestry, intercropping or crop rotations, etc). One of the main challenges of this ambition is federating the various disciplines and ensuring that they work together in order to make farming systems more productive.

How can we satisfy consumer demand more effectively?

D.P.: By working on grain and fodder quality, thanks to our strong historic expertise in these aspects, for both the human diet and animal feed. Populations in Africa are changing: more people now live in towns and cities, and they have less time to cook. The challenge is to adapt what is produced to these new ways of life, by adapting traditional products or introducing new ones such as plant-based yoghurts made with fermented products.

J.D.: Reaffirming the key role of local cereals in food security and promoting new products to consumers is one of the priorities of ambition 2.

What does building stakeholder capacity mean to you?

J.D. and D.P.: There are many players involved in the value chain, and they sometimes have different agendas. CIRAD is aiming to optimize value chain functioning as a whole. It brings in researchers from different disciplines, to cover the entire value chain and thus pinpoint decision support levers. The VCA4D project is a great example. Using a standard multidisciplinary method, it aims to understand and measure how value chains contribute to sustainable, inclusive growth. CIRAD

is building forward-looking strategies aimed at conceiving desirable futures. Among various possible levers, it is focusing on building scientists' capacity to interact with the world around them (farmers' organizations, decision makers, etc). Building stakeholder capacity means using participatory approaches and co-design, involving tools such as living labs and multi-stakeholder platforms.

How and why can we and should we boost the synergies between research in the global North and South and between countries?

J.D.: CIRAD is constantly reaffirming its strong links with historic partners in the sorghum and millet value chain, in various ways. It is involved in a number of partner networks on the ground, alongside national agricultural research organizations and universities. It is promoting South-South partnerships by means of platforms in partnership for research and training (dPs).

D.P.: While sorghum and millet originated in the tropics, they are increasingly common in the western world. Research is now looking at cereals in the US, Brazil and Australia, among others. CIRAD is calling for research done in the global North to be useful and transferable to the South, and for the considerable research skills available in the global South to be taken into consideration. It has connections across Europe, and is also heavily involved on an international level, for instance in the Global Sorghum Association, where it works to ensure that its partners' interests are taken into account. ■

Find out more : sorghum_millet@cirad.fr

ABEE: Varietal innovation and networking

The ABEE (West Africa Breeding Networks and Extension Empowerment) project is taking a coordinated approach, modernizing varietal breeding practices for five target crops (millet, sorghum, fonio, groundnut and cowpea) in order to respond better to market demand. The project aims to coordinate varietal breeding operations on a national and regional level. A database will serve as a source of information for breeding programmes. The existing breeder networks, which are central to research operations, will be strengthened to facilitate genetic material exchanges. With strong support from international partners, breeders

will be encouraged to modernize their breeding practices by installing and using equipment and methods that are as yet little used in Africa: digitization, molecular genetics and IT development plans (internet connectivity, servers, computer equipment), etc.

ABEE is being implemented in Burkina Faso, Mali, Niger and Senegal, is coordinated by the West and Central African Council for Agricultural Research, and is funded by the European Union under the DeSIRA programme.

Find out more:



Inventing the sustainable sorghum and millet sector of the future

CIRAD is addressing the challenges facing the value chain

Major cereals

● Pillars of food security in arid zones...

Species	Production (Mt)	Worldwide: staple food for (M people)
Sorghum	60*	300-500
Millet	30**	90

*Africa: 27 Mt, West Africa: 13 Mt; **Africa: 13 Mt, West Africa: 10 Mt

● ... synonymous with a balanced diet

Share of cereals	Africa [%]	Europe [%]
In dietary energy intake	48	29
In protein intake	50	29
In fat intake	15	3

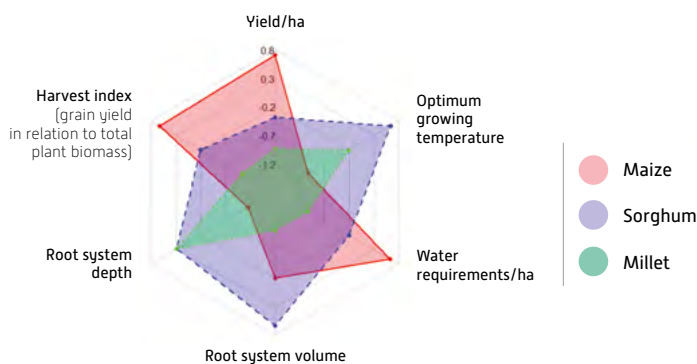
● ... but with inadequate yields

Sorghum yields* (t/ha)	Millet yields* (t/ha)
West Africa 0.5-1.3	West Africa 0.5-0.8
France 5.6	USA 2

*Increase in yields: very small over the past 20 years

Climate-resilient cereals

● Species suited to hot, dry climates



● A regional study to adapt them further

The ABEE project and IAVAO platform have studied **61 elite sorghum varieties** in **5 countries** (Burkina Faso, Mali, Niger, Senegal and Togo) **since 2018**.



Our ambitions...



Make sorghum- and millet-based **systems more productive and resilient** through **agroecological intensification**



Analyse grain and biomass **quality** and improve **processing** in line with demand



Build the **organizational capacity of players** in sorghum and millet value chains, to boost incomes and food security



Improve **research network structuring and leadership** and promote **interactions with development players**

... in partnership

Several platforms in partnership for research and training (dPs) work on sorghum and millet



CIRAD is a member of the Global Sorghum Association

Our means and resources

60

scientists from **10 research units**

23

varieties registered or disseminated since 2014

31

PhD students supervised by CIRAD since **2010**

2023

Global Sorghum Conference organized in Montpellier

141

publications in impact-factor journals on sorghum and millet, 98% of them co-published, between 2011 and 2021

Partnerships, at the heart of CIRAD's research

CIRAD's research on sorghum and millet involves a broad and varied range of partnerships, primarily with public organizations but also with the private sector, including producer organizations and NGOs. In particular, the establishment has strong historic links with the network of breeders and geneticists in West Africa, which was formalized several years ago within the framework of the IAVAO platform in partnership for research and training and the DeSIRA ABEE project. This roadmap is calling for renewed partnerships with the entire range of players involved in value chains, to foster stronger links between research, users and consumers. Numerous partnerships will take the form of participatory structures, to co-construct the technical, social, organizational and institutional changes required. While CIRAD's work on sorghum and millet continues to focus on the semi-arid parts of the global South, the North-South dynamics that exist for these species can be seen as levers for stepping up research that will be of use to partners in the global South, just as the expertise built up in the global South can benefit research in the North. In this context, strengthening international partnerships (North-South, South-South and North-North) is a priority, to optimize the efficacy of CIRAD's research. ■



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Blanco Tortillero variety developed by a participatory breeding programme in Nicaragua

A word from our partners



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Interview with Aminata Ganeme,
teacher researcher
specializing in agroecology
and crop modelling,
Joseph Ki-Zerbo University
(Burkina Faso)

What is your background and how did you come across CIRAD?

I have a Masters in Environment and Ecosystem Pathology from the University of Tiaret (Algeria), and worked for two years as an environmental assessment consultant. As I was keen to have a greater social impact, I decided to continue my studies, with a Masters in Biodiversity and Environment from Joseph Ki-Zerbo University. I then received a DAAD-CERAAS regional grant to do a thesis on agroecology and agrobiodiversity. I focused on the agronomic performance of cereal-legume intercropping systems and their potential to adapt to climate change, and I defended my thesis in Burkina Faso in 2022. My work was done under the umbrella of the ORACLE project on optimizing cereal-legume rotations and intercropping, coordinated by CIRAD. I worked hand in hand with both producers and researchers from various fields (breeders, agronomists, modelling specialists, etc).

We chose to study a system that is widely used by producers, who plant a mix of sorghum and cowpea seeds in the same hole. We set up on-station trials of such combinations, and provided 80 producers with selected seeds, to allow them to conduct field trials. Since then, I have been a teacher researcher at Joseph Ki-Zerbo University in Ouagadougou and am doing a post-doc with CIRAD on multi-criteria assessments of different production systems, to analyse the effects of diversification on agronomic, environmental and economic performance and household food security. I'm hoping to continue working with CIRAD after my post-doc, and why not to launch inter-institutional collaboration?

What do you think about the CIRAD roadmap?

As far as I am concerned, agroecological intensification of sorghum and millet growing is a hugely relevant issue, particularly in Sub-Saharan Africa, as well as in Burkina Faso, which I know well. Population growth, urban development and sprawl, security issues, etc., are all increasing the pressure on land availability, resulting in an urgent need to optimize agricultural production in a sustainable way. I think ambition 2, which concerns processing and storage, is crucial, as what is the point of producing more if we can't store what we produce, be it to feed humans or animals? This also means having access to varieties with a long shelf life. Lastly, ambition 4 echoes my experiences: it sometimes happens that for a potential yield on stations of 1 t/ha, farmers achieve barely 500 kg/ha. We have to find ways of shrinking the gap between a variety's potential yields and actual productivity in the field. ■

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Interview with Emmanuel Njukwe,

Director of Research
And Innovation, West and
Central African Council for
Agricultural Research and
Development (CORAF)

What is the history of the links between CORAF and CIRAD?

CORAF has always had collaborative and partnership links with CIRAD. Indeed, it was CIRAD that was behind the founding, in March 1987, of the then Conference of African and French Leaders of Agricultural Research Institutes (CORAF), associating 15 French-speaking research organizations in West and Central Africa and Madagascar, with a head office in Paris. CORAF and CIRAD worked together *via* research networks and base-centres. Following the transfer of its head office from Paris to Dakar in 1992 and the move to include English- and Portuguese-speaking countries in West and Central Africa, CORAF became the West and Central African Council for Agricultural Research and Development (CORAF/WE CARD). Although the links between CORAF and CIRAD were strong, they remained informal, and it was not until December 2009 that the two organizations

decided to formalize them, with the signing of a framework agreement. Since then, CORAF and CIRAD have conducted joint projects, and CIRAD is currently involved in four major projects coordinated by CORAF.

What do you think of the ambitions in the roadmap?

I think ambition 1 is really important. To make sorghum- and millet-based systems more productive and resilient, the priority is to improve varieties, which need to be more resistant to drought as well as to pests and diseases, and higher-yielding. However, it also means taking a holistic approach, working on natural resource management, soils, water, etc. As regards ambition 2, we think it is important to build capacity in terms of genetic research and analyses aimed at improving sorghum and millet storage, postharvest product quality and processing, and building new markets. It is vital that we work on storage and processing, to avoid producers selling to the biggest buyers at low prices, for want of a better solution. In many West African towns and cities, bakers add sorghum flour to their bread. This could potentially be a substantial market, subject to satisfactory yields and quality. Lastly, ambition 4 is very important for CORAF, and covers several aspects. Training is a key factor, particularly since a whole generation of scientists is coming up to retirement and will need to be replaced. Infrastructures are also very important for us: we need to guarantee that junior scientists trained overseas will have quality, operational equipment at their disposal when they return home. ■



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| A local sorghum variety from Mali, Keninkeni, is used as a parent in breeding programmes in West and Central Africa



© D. Pot, CIRAD

| Sorghum is a plant with many uses. Analysis of sugar extracted from stems at IER in Mali



CIRAD is the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions.

CIRAD works with its partners to build knowledge and solutions and invent resilient farming systems for a more sustainable, inclusive world. It mobilizes science, innovation and training in order to achieve the sustainable development goals. Its expertise supports the entire range of stakeholders, from producers to public policymakers, to foster biodiversity protection, agroecological transitions, food system sustainability, plant, animal and ecosystem health, and sustainable development of rural territories and their resilience to climate change.

CIRAD is a public establishment (EPIC) under the joint authority of the Ministry of Higher Education and Research and the Ministry for Europe and Foreign Affairs.

CIRAD hopes that multi-stakeholder partnerships and alliances will discuss, share and support its four ambitions for sustainable sorghum and millet growing.

Contact us to find out more: sorghum_millet@cirad.fr

Working together for tomorrow's agriculture

Find out more about the sorghum and millet value chain at CIRAD



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