Info Note

Exploring opportunities around climate-smart breeding for future food and nutrition security

Jean Balié, Laura Cramer, Michael Friedmann, Elisabetta Gotor, Chris Jones, Marta Kozicka, Gideon Kruseman, An Notenbaert, Frank Place, Camila Rebolledo, Philip Thornton and Keith Wiebe

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Key messages

- Foresight activities that include participatory processes as well as careful analysis can help address the great uncertainties concerning the future of food systems and the role of crop and livestock breeding.
- There would be big benefits to designing and carrying out a process to develop and support a value proposition for future CGIAR breeding activities.
- More multi-disciplinary team approaches are needed to work on trait prioritization for CGIAR and partners, embedded within a systems approach.
- Participatory methods to characterize stakeholders' needs and preferences are crucial to ensure that new varieties fulfil their expectations in highly dynamic market environments.

The challenge

There is a 95% chance that warming will exceed 2°C by the end of the century (Raftery et al. 2017). Global crop productivity is projected to fall by 5-10 % per degree of warming (Challinor et al. 2014), with even greater losses likely for some crops in some areas. The challenge of meeting future food demand is increasing, and climate change is already diminishing our ability to adapt through crop breeding (Challinor et al. 2016; Aggarwal et al. 2019). Recent research is suggesting that increases in climate variability are already affecting the number of food-insecure people, and that increasing atmospheric CO_2 concentrations may affect the nutrient content of some food staples, with serious implications for food and nutrition security (Smith and Myers 2018).

New crop varieties will be needed that can deliver higher yields as well as possessing the ability to withstand heat and greater tolerances for the secondary effects of a warmer world, such as increased pressures from drought, water-logging, pests and diseases, and reduced nutritional quality due to higher levels of CO_2. The systems for accelerated delivery of climate-resilient varieties into food producers' hands need to be massively upgraded (Cramer 2018). Innovative holistic breeding strategies for multiple traits will be needed that embrace the full pipeline from trait discovery to varietal deployment and seed system development.

What the world may look like in the future: which conditions and which needs should the CGIAR be breeding for?

There are many uncertainties around current trends that may affect food systems in the future. These include the feminization of agriculture in parts of sub-Saharan Africa and South Asia, migration of youth out of the rural areas, some land consolidation but hundreds of millions of farmers producing food on shrinking land holdings, increasingly globalized and regional trade subject to increasingly severe production and price fluctuations. At the same time, dietary change is occurring as a result of income growth, urbanization and other drivers. Animal source food consumption is increasing in lower- and middle-income countries (LMICs), though many countries are seeing less diversified diets (decreases in sorghum, millet, matoke, etc.) and more reliance on the big three staples (rice, wheat, maize). Obesity and over-nutrition are additional global challenges to food and nutrition security.

Box 1. Workshop on breeding foresight

A workshop was convened by CCAFS Learning Platform 1, “Ex-ante evaluation and decision support for climate-smart options”, at Bioversity International in Italy on 19-20 February 2019. The workshop objective was to identify concrete actions that can add value through linking future climate modelling and foresight work with commodity breeding programs to enhance the climate resilience of agricultural systems to the middle of the century. There was representation from seven CGIAR Centres (Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Maize and Wheat Improvement Centre (CIMMYT), the International Potato Center (CIP), the International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), the International Rice Research Institute (IRRI)), seven CGIAR Research Programs (CCAFS, LIVESTOCK, MAIZE, Policies, Institutions and Markets (PIM), RICE, Roots, Tubers and Bananas (RTB), WHEAT) and two CGIAR Platforms (Excellence in Breeding, Big Data). Workshop participants came with a wide variety of expertise, including plant biotechnology, plant breeding, agricultural and development economics, food policy, ex-ante impact assessment, foresight and targeting, systems analysis, spatial analysis, ecophysiology, crop modelling, and food security.

One of the tasks of the meeting was to explore the state of play and opportunities for collaboration concerning foresight and prioritization in climate-smart breeding. A second objective was to discuss the development of a compelling research strategy for possible inclusion as one of the global challenges in the CGIAR’s Special Initiative on Climate Change from 2022 onwards. The workshop report is here.

Other drivers of change may also have huge impacts on food systems in the future:

- Technology development beyond the agriculture sector. These include blockchain, big data, and plant-based meat substitutes, for example.
- Declining energy costs of renewables leading to new energy systems and increasing viability of vertical farming and alternative foods and feed.
- Food quality and safety issues being driven by consumer behaviour.

One critical question is: how might different combinations of these trends affect breeding strategies for food and nutrition security in a warmer, more populous future?

One way in which such questions can be explored is through the use of foresight methods, widely used in the business and defence sectors. CGIAR also undertakes work in this space, using foresight to explore what the world may look like in the future based on alternative scenarios. Such information can then feed into priority setting and ex-ante evaluations, to hone the portfolio of research activities that can deliver the outputs, outcomes and impacts that are needed to help meet the Sustainable Development Goals. Examples of this work include the “Crops to End Hunger” initiative, the planned CGIAR foresight report, and scenarios work reaching into the policy arena.

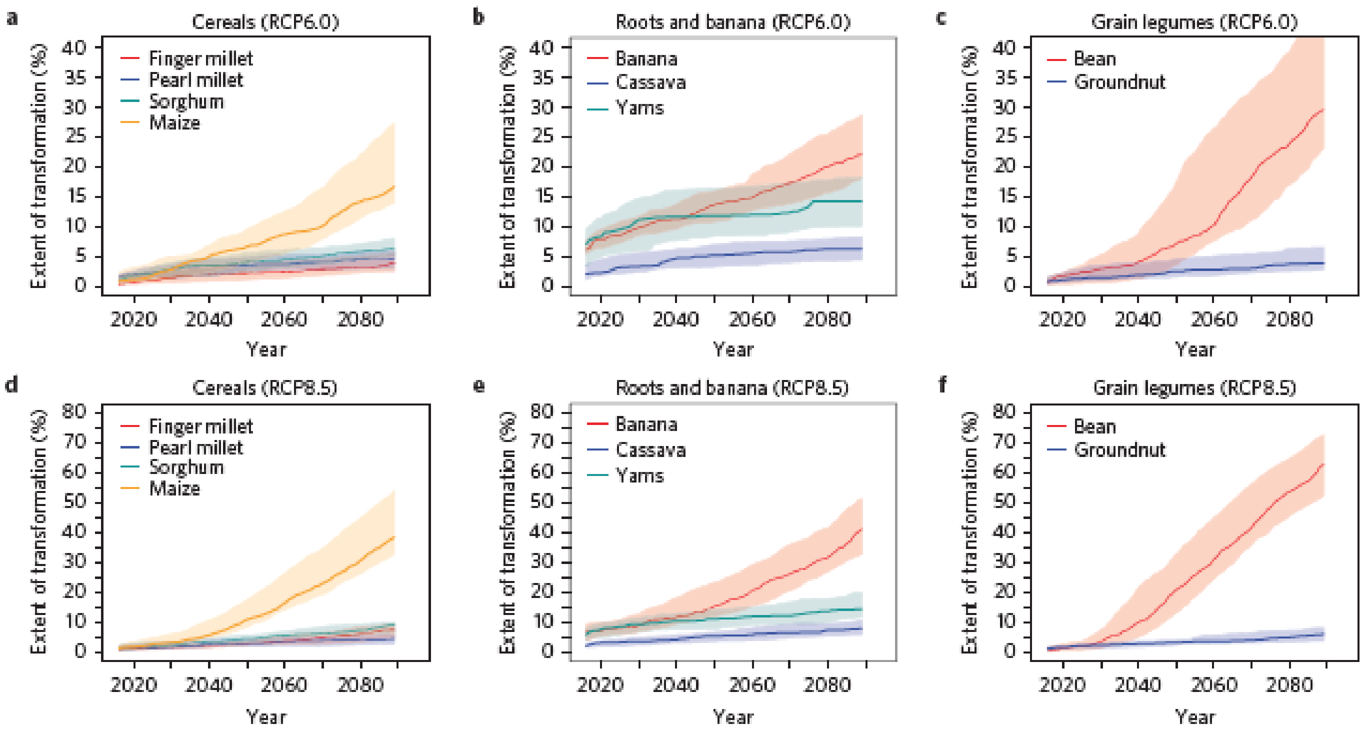
Priorities for climate-smart breeding: which crops, traits, activities should CGIAR be concentrating on?

Thiele et al 2017 explored implications, some unexpected, of climate change for key traits with RTB crops. However, the global food system is facing other key challenges as well as those associated with climate change. These include the prevalence of hidden hunger (micro-nutrient deficiencies) that affects more than 2 billion people. In highlighting the need to re-evaluate decision-making processes about priorities and investments in CGIAR breeding, DeFries (2018) identified a broad set of dimensions for cereal production systems in LMICs that need to be considered, including productivity, nutrition, climate resilience, greenhouse gas emissions, distributional equity, and dietary and cultural preferences. The study of Manners and Van Etten (2018) suggests that current allocation of research investments among different crops may need to be reconsidered, if international agricultural research for development is to support climate adaptation and enhance healthy human nutrition effectively.

Such considerations highlight the need for better information to support priority setting, to help identify which avenues of research to pursue based on what we think the future is likely to hold. Thus one question to think about is whether CGIAR needs to broaden its scope beyond the crop staples that it has traditionally focused on, to include research and possibly breeding on fruits and vegetables (key components of healthy and diverse diets) and to give more emphasis to some of the minor (or “orphan”) crops than it did in the past. Some of these other crops may be more climate resilient, too (Box 2).

Box 2. Different crops, different climate resilience

Cumulative percentage of suitable area in sub-Saharan Africa projected to require transformational change for RCP 6.0 (A, B, C) and RCP 8.5 (D, E, F) during the 21st century for (A, D) cereals, (B, E) roots and banana, and (C, F) grain legumes. Thick lines represent the mean and shading corresponds to interquartile range. Dashed lines at the beginning of each time series indicate no simulations were carried out for that period. Source: Rippke et al. 2016.



To tackle such issues, we need to understand the broad context of breeding in different situations. This implies being able to address the following, for example:

- How much yield increase may be achieved by breeding compared with other ways of addressing availability and access to food, such as market development via physical infrastructure development;
- Under which circumstances, and where, breeding is the limiting factor for increasing production of different crops, compared with other factors that limit adoption of high-yielding improved varieties such as inadequate seed systems or under-developed output markets.

The process and design of priority setting are equally important. The salience, credibility and legitimacy of any priority setting activity is dependent on who is doing the priority setting; without these, broad buy-in to the results is not likely. There are also several possible next- and end-users of the results of a foresight exercise to inform priority setting, including funders, breeders, the agricultural research-for-development community at large, and the private sector. Having a clear idea of the primary target audience of a foresight exercise to inform priority setting is crucial.

Developing “product profiles” of new varieties that respond to the requirements of farmers, processors and traders as well as to consumer preferences is not easy, and sometimes all of these requirements may be hard to reconcile.

To meet the diverse needs of rural smallholders as well as rapidly-growing urban populations, breeding will need to be embedded in a systems perspective to include livestock, agroforestry, fish, fruit and vegetables. Without such a perspective, it will be difficult to increase our understanding of system resilience in different situations and to identify the trade-offs (as well as the synergies) that may occur between different development outcomes and between shorter-term and longer-term benefits.

Gaps and needs for improved climate-smart breeding

The workshop (Box 1.) identified several current gaps and needs that could lead to improved climate-smart breeding for crops and livestock feeds.

Foresight

- Facilitating an on-going process of foresight analysis and dialogue that links ex-post and ex-ante to inform decision-making;
- Understanding smallholder development and different pathways of evolution in relation to breeding objectives and targets;
- Better understanding of the potential role of new technology, such as novel gene methods and alternative proteins for food and feed, for instance;
- Better understanding of the potential role of changing diets and consumer demand on food systems at different scales.

Data

- Data from the latest generation of climate models, that can be used to address future climate variability, changes in species and varietal spatial and temporal appropriateness, and performance in future environments;
- Interoperability of, and access to, repositories that bring together trial data, trait preferences, and household data.

Knowledge

- Better understanding of the future trait preferences (both existing and yet-to-be-discovered) of different food system actors;
- More robust information on genetic responses to future environments, both quantitative and qualitative;
- Testable hypotheses that allow us to reduce system complexity so that it becomes model-tractable;
- Better understanding of the effectiveness and efficiency of breeding versus other interventions that work towards food and nutrition security and diet diversity (i.e., defining the value proposition of CGIAR breeding activity).

Methods

- Development of “Homologues+”, tools that bring together information on climate, soils and farming systems to identify locations with shared characteristics in different geographies to enhance the efficiency of exchange, testing and multiplication of genetic material;
- Methods that can capture interlinkages horizontally and vertically in relation to scale and substance;
- Better methods to evaluate the impacts of genetic gain, particularly with respect to multiple traits.

Behaviour

- More multidisciplinary team approaches that combine national agricultural research partners and policy partners;
- Better engagement outside CGIAR (with farmers, seed companies, and others) and inside (processes across CGIAR Centres, Platforms and Research Programs (CRPs) that can influence the debate);
- While quick results are important, more focus on longer-term outputs and processes.

New plant breeding technologies and gene editing are being developed apace, and while they have great potential to help improve food security, there are considerable issues around their societal acceptance. Workshop discussions focused mainly on the use of already-accepted technologies, but many other techniques may be available soon. Societal acceptance of some of these may be problematic, highlighting the need for regulation and broad communication (Zaidi et al. 2019). These have not been typical or traditional areas of CGIAR intervention in the past, but will become increasingly important in the future.

Some next steps

Key questions from the workshop are shown in Box 3, together with some suggested activities to be undertaken within CGIAR and involving external partners over the near- and medium-term. To summarize:

- Foresight activities are needed to ensure the release of varieties that are adapted to changing conditions that we expect, including the changing pest and disease context. Target populations of environments need to accommodate future hotter, harsher and more variable climate conditions.
- The CGIAR foresight report offers an opportunity for engagement and longer-term dialogue both within CGIAR and with other partners.
- One key need is the identification of breeding strategies that can integrate seamlessly with delivery systems that enable farmers’ access to and adoption of new varieties, rapidly and effectively.
- Another key need is the use of participatory, multi-disciplinary processes for development of product profiles for alternative crops, feeds and forages, also livestock breeds and fish; as climatic suitability changes, moving the food system in a particular place so as to include different food or cash crops, for example, or new niche crops.

- Where we can, facilitate work towards coherence within CGIAR on foresight in breeding. This could be helped by developing a Theory of Change laying out the unique contribution and including a value proposition that can help guide future activities.

Box 3. Key questions from the workshop and activities towards providing answers

Question	Possible activities towards providing answers	Partners needed*
1. How can we better understand future pathways for smallholder systems and the possible roles of breeding in rural transformation?	■ Synthesis of Global Commission on Adaptation report & background papers (2019) ■ Development of the CGIAR foresight report (2020)	GCA, ISDC, BMGF, CGIAR, others
2. How do we better inform priorities between breeding and other work on agricultural research for development?	■ Detailed development of the CGIAR Special Initiative on Climate Change (2020) ■ Detailed development of the GCA Action Track (2019-2020) ■ Crops to End Hunger initiative and CGIAR Excellence in Breeding Platform	CGIAR, ISDC, GCA, BMGF, others
3. What will be the role of new technology in future farming and food systems? How will lower energy costs and other emergent trends affect the priorities for breeding?	■ Synthesis of recent transformation initiatives (WRI, CCAFS / CSIRO, …) ■ Integrated assessment modelling of a “top 10” food-system-related technologies for near-term application in LMICs ■ Horizon scanning, including renewable energy system development and potential impacts on food systems (e.g. irrigation, desalination)	CSIRO, WRI, CCAFS, CGIAR, others IIASA, PBL, IFPRI, others
4. To what extent should CGIAR prioritize technological (i.e., breeding) solutions over social behavioural change interventions on topics like dietary diversity?	■ Expert consultation and synthesis (2020)	CGIAR, external partners
5. What role is there for improved breeding (feeds as well as animals) within livestock and aquaculture systems?	■ Expert consultation and synthesis (2020)	CGIAR, external partners
6. What would the impacts be of increases in support to other commodities such as the minor cereals, fruit and vegetables?	■ Development of the CGIAR foresight report (2020)	CGIAR, external partners

* Partner acronyms: GCA–Global Commission on Adaptation; ISDC–Independent Science for Development Council; BMGF–Bill and Melinda Gates Foundation; CSIRO–Commonwealth Scientific and Industrial Research Organisation (Australia); WRI–World Resources Institute; IIASA–International Institute for Applied Systems Analysis; PBL–Netherlands Environmental Assessment Agency; IFPRI–International Food Policy Research Institute

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*Authors: **Jean Balié** (j.balie@irri.org) works for the International Rice Research Institute (IRRI). **Laura Cramer** (l.cramer@cgiar.org) works for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). **Michael Friedmann** (m.friedmann@cgiar.org) works for the CGIAR Research Program on Roots, Tubers and Bananas (RTB). **Elisabetta Gotor** (e.gotor@cgiar.org) works for Bioversity International. **Chris Jones** (c.jones@cgiar.org) works for the International Livestock Research Institute (ILRI). **Marta Kozicka** (m.kozicka@cgiar.org) works for Bioversity International. **Gideon Kruseman** (g.kruseman@cgiar.org) works for the International Maize and Wheat Improvement Center (CIMMYT). **An Notenbaert** (a.notenbaert@cgiar.org) works for the International Center for Tropical Agriculture. **Frank Place** (f.place@cgiar.org) works for the CGIAR Research Program on Policies, Institutions and Markets. **Camila Rebolledo** (c.rebolledo@cgiar.org) works for the CGIAR Research Program on RICE. **Philip Thornton** (p.thornton@cigiar.org) works for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). **Keith Wiebe** (k.wiebe@cgiar.org) works for the International Food Policy Research Institute (IFPRI).*

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The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is led by the International Center for Tropical Agriculture (CIAT). CCAFS brings together some of the world's best researchers in agricultural science, development research, climate science and Earth System science, to identify and address the most important interactions, synergies and tradeoffs between climate change, agriculture and food security. Visit us online at **https://ccafs.cgiar.org**.

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