CGIAR System 3-Year Business Plan (2019-2021) Companion Document

The 2-degree[1] initiative for agriculture and food system solutions in climate change hotspots: A CGIAR Special Initiative

Business Plan Action: **1.3 - Deepen the portfolio through new thematic strategies and initiatives**

Action Requested: This document sets out a draft CGIAR Special initiative on Climate Change, consisting of three main sections: (i) Vision, (ii) CGIAR Institutional Case, and (iii) Climate Case. The draft has benefited from two rounds of comments and virtual meetings of CGIAR Science Leaders and addresses strategic inputs provided during the SMB's 10th meeting (26-27 September 2018).

Action Requested: The System Council is requested to provide strategic input and guidance on the draft initiative, to inform its further development before submission to the System Management Board for approval and discussion on implementation actions at its 12th meeting in December 2018.

Document category: Working document of the System Council
There is no restriction on the circulation of this document

Prepared by: CCAFS in consultation with Centers/Science Leaders

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[1] The title speaks to the Paris Agreement and the important target of limiting the increase of global average temperature at no more than two degrees C above pre-industrial levels.

Vision

1.   Challenges and risks related to climate change are immense and urgent, as indicated by the 2018 IPCC report on 1.5 degrees. Because agriculture contributes to global warming, this Special Initiative includes a mitigation focus, but as the likelihood of keeping the global temperature below 2 degrees is receding – which means even higher temperature rises on land – and as the current 1 degree above pre-industrial levels is already leading to many extreme weather conditions, this initiative places much emphasis on adaptation and climate risk management. To illustrate urgency, in many rainfed agricultural systems, there are at most 12 harvests left to achieve the SDGs. Agricultural research for development (AR4D) needs to step up massively, to contribute to the productive, sustainable and equitable agriculture and food systems that are desperately needed around the world.

2.   Through this Special Initiative, CGIAR will rise to the adaptation and mitigation challenge – through rigorous climate-informed priority setting, making use of its "back catalogue" (the 50 years plus of CGIAR work) to tailor information for policy processes, fully embracing digital agriculture as a means of rapidly scaling solutions to millions of smallholders, and new innovative partnerships with the private sector, financial institutions and actors in the broader food system.

CGIAR institutional case for a Special Initiative

Expanding influence and impact

3.   CGIAR has an extensive track record on research and engagement dealing with climate change – both for adaptation and mitigation. This was accelerated in 2009 by the creation of a climate change Challenge Program and significant work on Reduced Emissions from Deforestation and Forest Degradation (REDD); further prioritised by the initiation in 2011 of a CGIAR Research Program (CRP) on climate change, and then climate change mainstreamed in all CRPs in Phase II starting 2017.

4.   There have also been significant CGIAR-facilitated successes related to: the uptake of climate-related technologies and practices; support to climate-related policy formulation; and input into major climate-related investments. This Special Initiative is designed to greatly expand that influence and impact, through: (i) improving coordination and integration across CGIAR Centers, programs and system entities, including through consistent use of some common tools; (ii) enhancing engagement at international, national, and subnational levels in on-going policy processes; (iii) fully integrating some common transformational approaches (see below); (iv) enhancing communication targeted at decision makers; (v) use of the massive "back catalogue" of CGIAR results for climate change-related analysis and advice; and (vi) expanding the depth of work, by focussing on six Impact Areas (see below). Because the Impact Areas will be geographically focussed, this Special Initiative will also contribute to greater coordinated action of the CGIAR in specific countries.

5.   The Special Initiative is intended to demonstrate and better communicate how the CGIAR is

rising to the challenge of climate change, to justify and maintain current levels of investment in research focussed on climate change, and to secure new funds for a deepened focus on Impact Areas.

Why is CGIAR uniquely placed to take on this Special Initiative?

6.   CGIAR is the only institution with a clear mandate for scientific research focussed on the food system in low and middle-income countries with offices in 50+ developing countries. It has the mandate of providing international public goods for eradicating poverty, hunger, and malnutrition and enhancing the environment. It is privileged to work from farmers' fields to national and international policy processes. It has extensive partnerships with public, private and civil society agencies, from local to global levels. The long-term presence of CGIAR in many countries has led to formation of important partnerships for policy engagement. CGIAR has diverse capacity strengths – technical, social and economic, covering agriculture, environment, nutrition, livelihoods, markets and trade. It also covers all the important sectors relevant to climate change: crops, livestock, fisheries, agroforestry, forestry, water and soils.

7.   CGIAR's decades of research ("back catalogue") can be capitalised on in the context of climate change for: adaptation and dealing with climate variability and weather events associated with extremes; and reducing GHGs and enhancing carbon capture. CGIAR's experience has led to many globally-significant databases, models and tools that are relevant to climate change (Box 1). It already has delivered many important outcomes for climate change policy and actions (Box 2). Climate action is extremely urgent, and requires cooperative actions across countries. CGIAR with its nation to region to global presence is uniquely placed to foster such collaborative action based on sound science.

Box 1. Significant databases, models and tools produced by the CGIAR
- AgTrials (>AgTrials (>35,000 trials with weather data) (Hyman et al., 2017)
- CCAFS-Climate (portal for downscaled climate model outputs with over 190,000 downloads per annum)
- SAMPLES (Emissions data for global accounting)
- SHAMBA tool is standard used for smallholder carbon credit
- REDD+ data (4.000 households in 6 countries) and global database of REDD+ projects
- Poverty and Environment Network (PEN) (database from 10.000 rural households)
- GCAN framework (developed for programming in climate, gender and nutrition)
- IMPACT modelling suite (to explore solutions to the global climate challenge)
- Ecosystem-based adaptation-cum-mitigation tools for water management
- Rural Household Multi-Indicator Survey (RHoMIS) (20,000 households)

Box 2. Examples of important outcomes that CGIAR research contributed to:
- Thailand secured initial NAMA funding to support reducing emissions in paddy rice among 100,000 rice farmers and 420 agricultural mitigation service providers potentially contributing to GHG reductions of about 1 million tons CO_2eq.
- KUSUM solar irrigation scheme (India) to replace 1.75 million diesel pumps and 1 million electric pumps (thus avoiding 4.55 million MT CO_2 (8.7% of national CO_2 emissions).

- UNFCCC decision 2011 for a stepwise approach on setting, measuring and reporting reference levels for forests under climate change; and to Indonesian National REDD+ Strategy development.
- 2013 IPCC Supplement on Wetlands that significantly improved countries' ability to report on GHG emissions in wetlands.
- Philippine Government proposed a carbon tax based on combined Climate-Energy-Economy-wide Analyses.
- WHO and FAO safety options for the use of untreated wastewater in agriculture, an area of an estimated 30 million hectare.
- Flood risk insurance products for resource-poor farmers in India
- Key player in informing negotiators, especially of demand for adaptation and mitigation in NDCs leading to the Koronivia decision on agriculture in COP23

CGIAR organizing for climate change-related R&D

8.   Currently, CCAFS takes leadership in representing the climate agenda of CGIAR, but much more climate change related efforts are being achieved across CGIAR beyond CCAFS. Under this Special Imitative, the capacity of the whole CGIAR must be brought to bear on the climate challenge, with much greater concerted action and coordination. The Impact Areas, and the broader Special Initiative, are not new programs of work, but rather fit within the current structures and programs of the CGIAR. Even though CCAFS is already a cross-cutting program, this Special Initiative will take the cross-cutting of climate change to a new level. We are not proposing to create new bureaucratic structures and governance bodies. CCAFS will take on a coordinating role, working across the existing CRPs and Platforms to implement this agenda, and represent CGIAR more widely in global processes related to the climate change SDGs and in UNFCCC and other climate action related global and regional processes. To implement the Special Initiative, Themes (Figure 1) and Impact Areas (see below) will be allocated to appropriate CRPs, Platforms or Centres for leadership, synthesis and delivery.

9.   Extra resources ("stretch targets") acquired for the Impact Areas would be allocated to appropriate CRPs with targets and activities revised through the POWB. As will be seen below, Impact Areas are geographically and/or value chain focused. In Year 1, foresight and ex-ante analyses will be conducted to select hotspots, key value chains and to prioritise activities and actions. Meetings with key stakeholders will be conducted to prepare theories of change and investment cases, with associated targets and budgets. In this process, the relationship to other Special Initiatives will be clarified and collaboration fostered.

10.   To sharpen the focus on climate change in the CGIAR, CCAFS would ensure all CRPs have at their disposal some basic tools, e.g. tools for ex ante analysis when determining priorities, climate risk assessment tools, consistent methods for GHG emissions estimates, mitigation option tool for targeting mitigation options, maladaptation assessment procedure, and guidelines for improving theories of change to tackle climate change adaptation and mitigation. Reporting of climate change research activities and outcomes across the CGIAR research portfolio will be strengthened.

The climate case for a Special Initiative

Why focus on climate change?

11.   Evidence is accruing that the effects of climate change on food systems are probably being under-estimated; these include the impacts of increasing frequency and intensity of extreme events as well as the temporal and spatial extent of climate variability on food systems, and the effects on nutritional content of a wide range of commodities. By 2030, AR4D will have to reach 600-700 million smallholder farmers with climate-informed advisories if adaptive capacity is to be enhanced and the SDGs are to be achieved. Current crop yield and livestock productivity growth rates per year are already seriously lagging behind what is likely to be required to ensure food security for the global population (Aggarwal et al., 2018). Despite some successes, in many developing regions there is only limited evidence of farmers making the changes needed to enhance food security.

12.   Smallholder farmers in the tropics and subtropics will be exposed to some of the worst impacts of climate change: sea-level rise and coastal inundation and salinization in the big river deltas of Asia and the small island states of the Pacific; considerable shortening of growing seasons in southern Africa and parts of eastern Africa; high temperatures combined with increased weather variability in large parts of West and South Asia and West and North Africa. In some of these places, planetary boundaries with respect to the nitrogen and phosphorus cycles, land-use change and freshwater use are already in danger of being exceeded, and these will be compounded by climate change effects. For highly vulnerable and dis-empowered groups such as women, the poor and the youth, there will be few livelihood alternatives, given likely continued dependence on agriculture.

13.   Because of lags in the climate system, we are already locked in to a temperature rise of 1.5-2.0 °C, whatever happens to GHG emissions in the future. Humankind needs to ensure that this temperature rise is only temporary, by redoubling mitigation efforts as soon as possible and scaling up countries' commitments under the Paris Agreement. Livestock, paddy rice and nitrogen fertilizer are the major sources of emissions. Agriculture is also a major driver of deforestation in the tropics. Opportunities for reducing emissions in ways that are compatible with development are available for most agricultural systems, especially if accounted for using emissions per unit food (emission intensity). Improved feeding, more productive breeds, better animal health care and manure management can reduce the emissions intensity of livestock. Managing irrigation to periodically dry paddy rice fields can reduce methane. Efficient use of nitrogen can reduce nitrous oxide emissions. At the same time, agriculture can also remove emissions from the atmosphere, by sequestering carbon in the soil or perennials, providing negative emissions, which are now recognized as critical for meeting the two degree target, let alone the one degree target.

Current CGIAR portfolio

14.   CGIAR already covers many areas relevant to climate change as illustrated in Figure 1. The Themes include climate-smart breeding, developing climate-smart practices, climate risk management, securing value chains against climate change and making them carbon neutral, dealing with climate impacts on pests and diseases, building resilient landscapes

and reducing deforestation, policies and institutions for promoting climate-smart actions, and climate-smart nutritious food systems. The work also involves foresight to identify priorities and vision futures with stakeholders. Gender considerations are mainstreamed in all activities, and youth-related initiatives have now begun. Annex 1 lists the CRP Flagships with significant climate change work.

Objectives of the Special Initiative

15.   The overall goal of this Special Initiative is to support and add value to country efforts to deliver on agriculture- and food system-related[2] goals of the Paris Agreement and to achieve the targets of SDG 13 on Climate Action. While the objectives are climate-focussed, agriculture and food systems are connected to almost all SDGs, thus this initiative also has important links to many other SDGs (see Figure 1 for main SDGs). Through this Special Initiative, the CGIAR will:

  I.   Chart a pathway for agriculture to meet Paris agreement targets, so that by 2030, we have reduced agricultural emissions by about 1 Gt CO_2e yr^{-1}, reduced emissions from food loss and waste by about 20%, achieved zero deforestation and restored millions of hectares of degraded and deforested lands. [3]

 II.   Prepare policy, institutional and financial analyses with development agencies, national governments and the private sector and engage in policy processes to systematically mainstream practices, technologies and information systems into farming and food systems, and in so doing, reach millions of hectares with climate-smart agriculture (CSA)[4], and reach 100s of millions of urban and rural consumers with climate-smart food by 2030.[5]

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[2] Agriculture is used in the broad-sense of covering crops, livestock, fisheries and forests
[3] Targets will be clarified in Year 1 through foresight and ex-ante analysis.
[4] "Climate-smart agriculture" is merely used as shorthand for agriculture and food systems that deal with climate impacts and attempt to reduce greenhouse gas emissions or sequester carbon (where feasible), while also meeting many other challenging goals in the food system. See Campbell, 2018.
[5] Targets will be clarified in Year 1 through foresight and ex-ante analysis.

III. Develop new agricultural technologies and practices which stand up to 2+ degrees of global warming and its associated impacts on climate variability and extreme weather events, maintain (or enhance) productivity, contribute to resilient farming communities and do not increase GHG emissions.

Figure 1. Current climate change Themes in the CGIAR
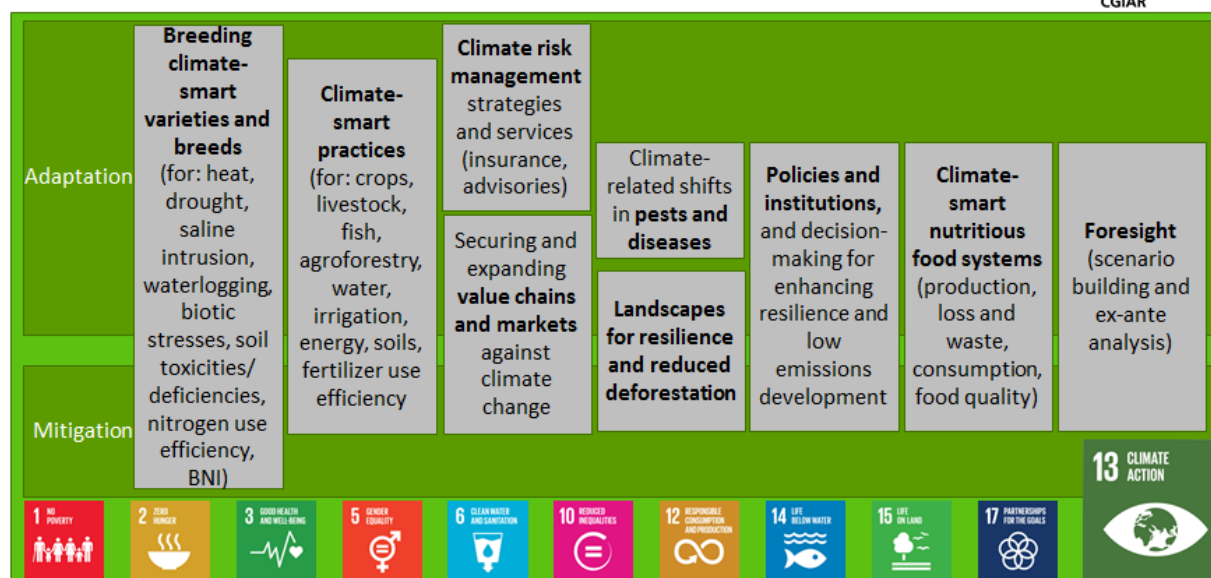
16. Delivering climate change-related outcomes will require strong partnerships and joint initiatives. By working closely with diverse partners we will provide solutions that are relevant and that can be taken up by partners and other actors. These partnerships and joint initiatives will include working with national agencies that have signed up to climate targets, but also working with the agri-tech companies, digital service providers, value chain actors, certification stakeholders, climate financiers, landscape investors and other actors interested in mainstreaming the climate variable into their businesses.

Taking a transformative approach

17. Climate change adaptation and mitigation in agriculture and food systems will be challenging to realize. The magnitude and complexity of these challenges is enormous and most likely requires a transformational approach. This Special Initiative will include a focus on 6 Impact Areas that are geographically targeted and time bound. The theory of change for each Impact Area will include, to differing degrees, the following five cross-cutting elements that are regarded as key to bringing about transformational change (Figure 2).

Figure 2: Five key elements to achieve transformed food systems under climate change
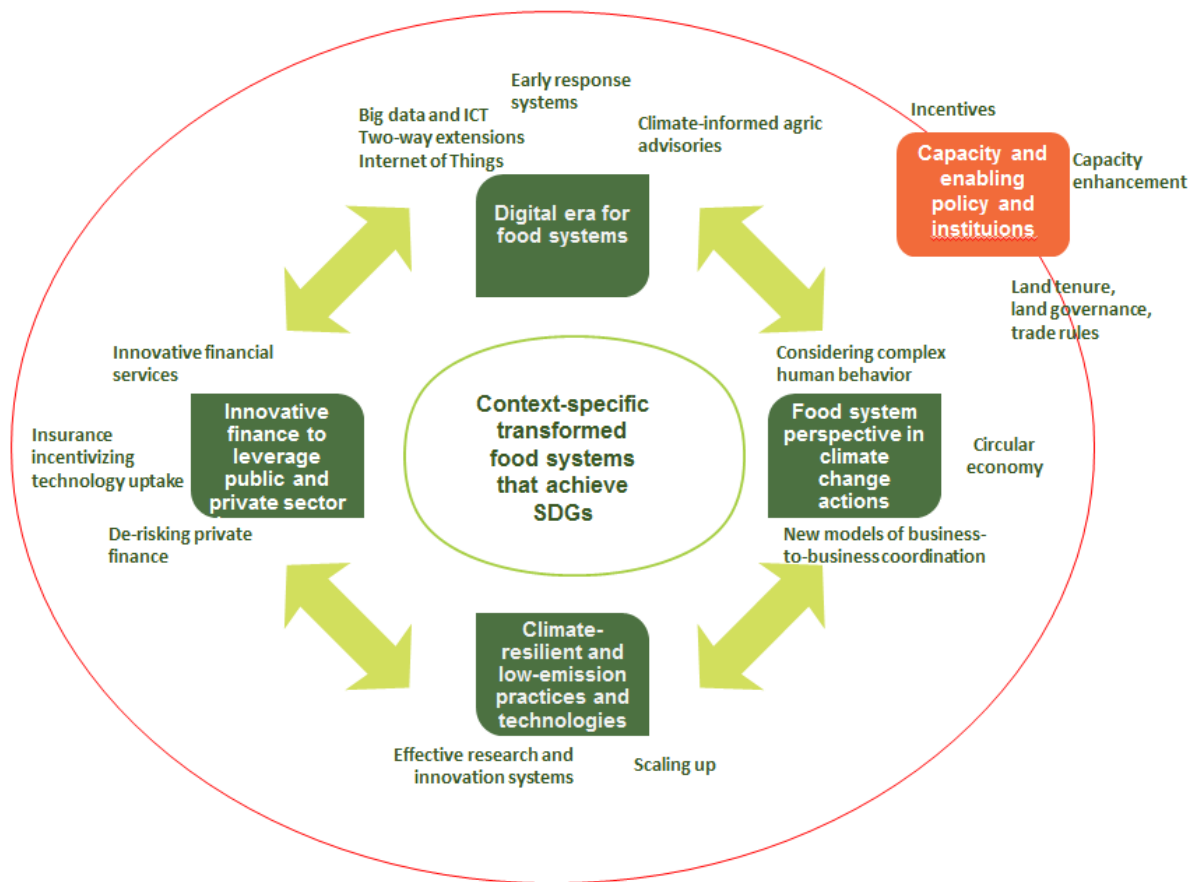
I. Developing and promoting **climate-resilient and low-emission practices and technologies**. New technologies and practices will be needed for the challenges ahead, and some of the currently available ones will need to be scaled up. For example, because of expected increase in the frequency and intensity of extreme weather events and variable weather, we will need technologies that deal with multiple stresses, e.g. drought, floods, heat waves. In addition, it is estimated we only have technologies to deal with 20-40% of the emissions reductions required in agriculture. The research and innovation system will need to be highly effective, with researchers working seamlessly with other stakeholders.

II. Ushering in the **digital era** in food systems: Agriculture and allied sectors have lagged behind in the use of information and communications technologies. This needs to change, ushering in the digital era in food systems to generate efficiency gains for farmers, to foster two-way agricultural advisory systems that are climate-informed, to estimate emissions in more efficient ways based on big data and better models, and to facilitate adaptive safety nets, such as index-based insurance that can be made more efficient through use of digital platforms. Many opportunities with respect to big data, blockchain technologies, precision agriculture, farmer profiling and e-extension have the potential to transform food systems for a climate-impacted world. This Special Initiative will work closely with the CGIAR Platform for Big Data in Agriculture.

III.   Mobilizing **innovative finance to leverage public and private sector investments.** Innovative models of financing will be needed to drive food system transformation, as current levels of financing are totally inadequate to the task ahead. Researchers will need new skills to link with banking, credit, investment and insurance communities; and R&D financial specialists will be needed to design schemes that incentivise investment, including schemes where public sector investment de-risks agriculture and increases private sector investment.

IV.   Strengthening the **food system perspective in climate change actions.** Climate solutions have to go beyond production. For example, it will be crucial to deal with food loss and waste, the consumption shifts that will be needed from a climate and health perspective, building resilience in supply chains and making supply chains more carbon neutral. Many of these areas are relatively new to the CGIAR, stressing the need for new partnerships. Food system changes will take a combination of incentives for individual behaviour change and wider institutional shifts.

V.   **Capacity and enabling policies and institutions.** This cross-cutting element is key to all Impact Areas. Initiatives are needed to create a conducive enabling environment which encourages innovation, investment and action, and is sensitive to differentiation and fosters equity. The right policies and incentives need to be in place, with policy involving not only agricultural policy, but policy related to such things as digital infrastructure, ease of doing business, land tenure etc. Through this Special Initiative, current policy work will be greatly expanded, including through an action research approach. Policy research and action will be complemented by capacity enhancement efforts at various levels. Decades of research of CGIAR ("back catalogue") will be reinterpreted using a climate change framework and brought up to date to develop policy messages for addressing climate change. This cross-cutting work will contribute: to the scaling of climate-resilient and low-emission practices and technologies; and to the expansion of digital advisory systems etc.; through reshaping incentives and investments. It will also generate quantitative information about the synergies and trade-offs between adaptation and mitigation strategies, through integrated modelling (for farms, landscapes and/or supply chains); develop innovative ways to address MRV (monitoring, reporting and verification); and develop policies and strategies to mainstream gender and youth in climate actions.

Climate Change Impact Areas

18.   The current Themes of the CGIAR (Figure 1) will be brought to bear on "Impact Areas" for climate change adaptation and mitigation (as illustrated in Figure 3). In the first three years of the business plan, the focus will be on 6 Impact Areas, with additional Impact Areas to be considered in future three-year periods, and with some Impact Areas being phased out if unproductive or having achieved targets. For each Impact Area foresight and ex-ante work will be initiated in Year 1, followed by partner workshops to define target outcomes, theories of change, investment cases and priority activities and actions.

19.   Adaptation is the priority in developing countries. Many agriculturally-dependent countries will have to absorb millions of young people into agriculturally-related jobs in the decades up to 2030, and they are ill-prepared to meet the demands of climate change. Thus, many of the proposed Impact Areas address adaptation. However, agriculture is also part of the emissions problem, so some of the Impact Areas contribute to the mitigation agenda. The Impact Area on the **climate-informed One Health approach** (#1) focuses exclusively on adaptation. Adaptation is also the primary focus of the Impact Areas on **multiple climate-induced stresses** (#2) and **climate resilience in MENA** (#3), though in these cases actions will endeavour to consider low emissions development pathways, where appropriate. The Impact Areas on **securing the Asian mega deltas against climate change** (#4) and **resilient and adaptive water systems** (#5), while still prioritizing adaptation, will give considerable focus to emissions, given the importance of rice and methane emissions for the former, and solar power and the climate-energy nexus for the latter. The Impact Area on the **circular bio-economy** (#6) will primarily focus on mitigation, but even here adaptation will be crucially important.

Figure 3. Illustrative diagram for how Themes (grey) would interact with example Impact Areas (blue)
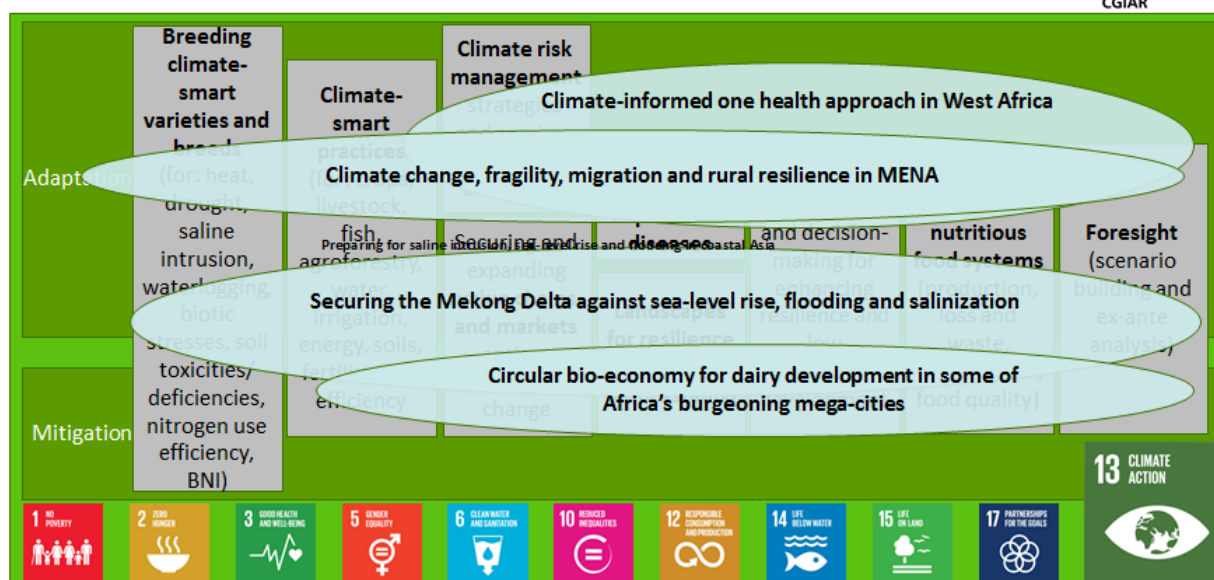
Note: Impact Area examples are purely illustrative, with final choices of foci in Impact Areas to be decided through ex-ante analysis and independent expert input

Impact Area #1: A climate-informed One Health approach: managing climate-driven pests and diseases in key climate change hotspots

20.   Climate-driven biotic stresses and climate-sensitive diseases are major threats to food and nutrition security, animal and human health, and ecosystem services. Documented changes in the distribution and severity of pests and diseases has resulted in losses of plant and animal productivity, and of agro-biodiversity. Extreme climatic events, such as flooding and drought, may affect the ecosystem services of biological control agents and beneficial soil biota.

21.   Predicting, detecting and managing climate-driven pests and diseases can help prevent shocks (e.g. through rapid response to invasive alien species such as the fall armyworm or

to El-Nino driven outbreaks of vector-borne diseases). Initial work by the CGIAR Agri-Food CRPs and others has helped identify those pests and diseases of importance, which include alien invasive species, emerging plant and animal pests and diseases, and post-harvest food contaminants. Spatial modelling has started to identify potential future hotspots.

22.   CGIAR has long-standing partnerships and a considerable back catalogue on climate and biotic stresses. CGIAR scientists have worked for several decades on epidemiology of climate-sensitive livestock and agriculture-associated human diseases and more broadly on adaptation of agricultural systems. The proposed initiative is an opportunity to foster novel synergies by taking advantage of new developments in CGIAR. As an example, a regional Biorisk Management Facility (BIMAF) has been established to engage researchers, civil society (including farming communities and NGOs through, e.g., citizen science) and public and private agencies, to sustainably address challenges posed by climate-induced biotic stresses.

23.   The Impact Area would:
- Establish a One Health platform for agriculture-associated and climate-driven plant, animal, human, and environmental biorisks in low and middle income countries.
- Identify three climate change hotspots where CGIAR collaboration would be stepped up as learning laboratories.
- Develop and deliver practices, tools and policy options to 1) improve capacity to pro-actively forecast biorisks e.g. by enhanced surveillance and monitoring through ICT and geo-spatial approaches; 2) increase resilience by innovative and environmentally-friendly biorisk management approaches.

24.   This Impact Area would address the lack of early warning and rapid response systems. Horizon scanning, modelling and forecasting tools will be designed and deployed to guide decisions and enhance preparedness amidst stakeholders and farming communities. Policy analysis, capacity enhancement and targeted investments will advance early warning and response in focus countries. Knowledge generated by this Impact Area will also be instrumental for ongoing breeding efforts, by providing detailed information on future targets for resistance breeding under different climate change scenarios. This Impact Area will be aligned with the initiative on "Rapid-response preparedness to newly emerging pests and diseases, and crises: What the CGIAR can deliver quickly". This impact area works at the intersection of SDGs 2, 3 and 13.

Impact Area #2: Tackling multiple climate-induced stresses on food systems in three global food baskets

25.   CGIAR's foundations lie in solving a global food security threat in the 1960s and 1970s that required global concerted efforts and resulted in the Green Revolution. Hothouse earth raises a similar global problem that affects every country and requires collective action. Scientists assign a 5% probability on the earth's climate staying within the 2 degree target set out in the Paris Agreement, hence adapting food systems to warming, and the new variability and extremes that this already implies, is no longer a target but an absolute necessity. Two degrees is highly significant to agriculture as indicated in the IPCC's 1.5 degree report. In the absence of adaptation, on average, global crop productivity is expected to decrease by 5-10% per degree of warming (Challinor et al., 2014). Whilst a range of options exist to abate this impact, the gap between what is needed and what is

feasible today is huge, and research has already shown the rate of climate change outstrips our ability to adapt through breeding (Challinor et al. 2016).

26.   The challenge of adapting to 2 degrees is unprecedented. Not only does this require new tolerances to heat, but also traits that address secondary impacts of two degrees which include new pest and disease pressures, drought, waterlogging, and even reduced nutritional quality as a result of increased carbon dioxide. Hence, holistic breeding strategies are needed, that target multi-trait characteristics. New crop and livestock management practices will need to be devised to reduce the risks associated with extreme events and weather variability. In addition, a systems approach will have to be implemented, to diversify farming and food systems as an adaptation strategy, but also from a nutrition perspective. Food system thinking must be applied to meet new demands from consumers and to tackle consumption changes and food loss and waste.

27.   For this Impact Area, three major food baskets will be selected through ex-ante assessment of climate impacts and broader socio-economic assessment. Priority setting and stakeholder consultation in each food basket will identify the required actions and theory of change. Research will focus on the multi-trait requirements for key staple crops, livestock and fisheries and the management and diversification strategies that are needed. Technical work to manage climate risks, will be complemented by institutional and policy work on, for example, seed systems, index-based insurance, public-private partnerships that are needed for achieving scale, gender empowerment in the face of the feminization of agriculture in many regions, and mechanisms to empower farmers and other local groups. Digital advisory systems will be key to getting information to millions of smallholders. In each food basket, key policy makers will be engaged in an action research format, and research results and the back catalogue will inform on-going policy processes, both in the selected food baskets but also in other regions through partnerships with global agencies.

28.   This work will build on the breeding and systems work of the relevant agri-food CRPs in each food basket, on PIM for foresight, advisory services and policy analysis, on A4NH in relation to diversification and nutrition, and on CCAFS and PIM in relation to insurance and other institutional mechanisms for climate risk management.

Impact Area #3: Climate change, fragility, migration and rural resilience in the Middle East and North Africa (MENA)

29.   MENA represents a substantial area of land encompassing several countries and agro-ecosystems. Although it is generally drier and warmer compared to the rest of the world, agriculture is a critical source of employment and also a potential option of engaging rural youth. However, it has extreme resource limitations that are highly vulnerable to a changing climate and land degradation. Climate change threatens the viability of agriculture and rural livelihoods in MENA. For example in the Fertile Crescent, millions were displaced in the mid 2000s from rural to urban areas in what was the worst drought in instrumental history, compounding problems in a region already beset by geopolitical instability and a declining oil sector. Migration flows affect economies and, when international, affect national policies in countries at both ends of the migration streams, straining international

relations.

30.   Considerable investment is needed to understand the complexity of climate change and variability in MENA on agriculture and the broader food system, both in terms of long term likely trajectories in the food system but also in terms of variability and extremes driving rapid changes. This would include attention to the factors shaping change in demand and consumption patterns in the region. Much more work is required on the impact of climate change on involuntary rural-urban migration, and the links through to international migration, refugees and conflict. Technical, institutional and policy options need to be devised to strengthen the resilience of rural livelihoods drawing both on the CGIAR back catalogue and on-going AR4D. These options should aim to give people the opportunity of remaining where they are, thus minimizing involuntary displacements. Climate change adaptation pathways in MENA will need to deliver viable rural livelihoods and high-value jobs for young people. This will require increased focus on agricultural value chain transformations and fostering vibrant, diversified rural economies, along with the policy and institutional interventions that can promote such changes. Development of climate-smart agricultural technologies specific to MENA include the possibility of substantial gains in water-use efficiency, improved heat and drought tolerant crops, enhanced crop-livestock integration and strategies to reduce soil salinity and increase waste water use. Diversification will be a key strategy for the food systems, not only for climate adaptation but also for nutrition.

31.   The use of big data and digital agricultural advisory services for rapid advancement of climate-smart agriculture in the MENA should also be examined. Policy and institutional work, and the appropriate national engagement, will include a focus on gender, given that in many cases there is feminization of agriculture through out-migration of males. Options for productive social safety nets, index-based insurance and early warning/response systems for extreme events will be an important part of the AR4D.

32.   Several CRPs and regional research and private-sector partners would contribute expertise and South-South learning in this Impact Area, led by the CRPs on Grain Legumes and Dryland Cereals, Livestock and WLE. Crop breeding programs need to target probable changes in plant physiological mechanisms under a changing climate and elevated CO2, adoption of increased drought and heat tolerance in existing crops, as well as expansion of C4 plants (maize, millets, sorghum etc.). PIM will contribute policy and value chain work.

Impact Area #4. Securing the Asian mega-deltas against sea-level rise, flooding and salinization

33.   Almost 40 per cent of the world's population lives within 100 km from a coast, and Asian deltas are often crucial to country food and economic security. Delta communities face immense risks from sea level rise (currently rising at 3.4 mm per year), and associated salinity intrusion and coastal flooding. High intensity rains and tropical storms, made more severe by climate change, aggravate such risks. Besides direct loss of assets and lives, these communities face additional risks of soil degradation, contamination of groundwater and coastal erosion. Agricultural practices that achieve high productivity under fluctuating water levels have been achieved, but this fine-tuned balance is very vulnerable to climate change, and if negatively impacted could witness massive out-migration. In Asia many of

the deltas are dominated by rice-based systems, with rice production a major contributor to GHGs.

34. While the impact of climate change on coastal mega-cities and strategies to build their resilience have received considerable attention, adaptation efforts in coastal agriculture and fisheries have remained largely neglected. The agricultural sector could witness large-scale impacts of climate change, even in short-term, in the form of salinization of soil and water resources and therefore loss of land for rice production and loss of fresh water fish habitats.

35. CGIAR Centers, together with national partners, will be involved in promoting the use of weather and flood forecasts; developing innovative adaptation strategies such as water and salinity management at a landscape level; conservation of fragile ecosystems; and identifying opportunities for reducing involuntary migration. In addition, there will be attempts to identify new agriculture opportunities created by the changing climate including sea level rise, and changing demands in the food system. Introducing stress-tolerant rice varieties and scaling up crop management practices in paddy rice, e.g. alternate wetting and drying, will be a means of addressing water variability and salinization in deltas, while also reducing emissions and carbon footprints. To achieve scaling, attention will be given to digital advisory services that reach huge numbers of farmers, both women and men. Policy actors will be engaged through action research to strengthen institutions, market access and policies that will minimize impacts of climate change, incentivize new practices and enhance diversification of the food system. Diversification into high value crops will be important for incomes, adaptation and nutrition. There is an extensive back catalogue of research in rice-based systems which can be brought to bear on policy processes.

36. This Impact Area will draw heavily on the Rice CRP and WLE and build on the systems work of relevant AFS-CRPs, notably Wheat, Fish and FTA, and enabling policy work from PIM.

37. For this Impact Area, two different mega-deltas will be selected through ex-ante assessment of climate impacts, and broader assessment of economic and food system trajectories. Priority setting and stakeholder consultation in each will identify the required actions and theory of change. While the focus will be on achieving concrete targets in the two action areas, through partnerships with key global agencies the work will also lead to South-South learning and action.

Impact Area #5. Resilient and adaptive water systems for agriculture in dryland Africa

38. Key impacts of climate change in drylands are mediated by water and droughts. Risks of more frequent and more severe droughts are increasing due to climate change and land degradation. Vulnerability to water scarcity and drought is highest where infrastructure for storing water, regulating flows and irrigating crops is poorly developed, as in much of arid and semi-arid Africa. Vulnerability is also high in degraded landscapes, as less water is stored, reducing availability of surface and groundwater during drought. Research shows that water scarcity leads to high competition, with impacts across economic sectors and risking development gains. Resilient and adaptive water systems are therefore important

for agricultural development and poverty reduction in drought-prone areas of Africa.

39. Opportunities for building resilient and adaptive water systems extend well beyond business-as-usual irrigation development. Innovation is key to change at two levels. If developed together, they offer the opportunity to manage threats to water security while supporting farmers to leapfrog to new, climate-smart technologies that foster adaptation while contributing to low-carbon development. On-going innovation will need to be complemented by use of the CGIAR back catalogue, where there is rich experience of "what works where".

40. At national and basin scales, research and engagement is needed to support climate-resilient water resource planning and management that achieves system-wide gains in water productivity and water-use efficiency. This needs to be put into a food system perspective, with good understanding of possible trajectories of the food system and future consumption patterns. Governments, basin and aquifer management agencies, the private sector and sector groups need data and tools that enable them to assess water-related risks under changing climates and make decisions on infrastructure investment, water allocation, landscape management, forest landscape restoration etc.

41. At the farm level, recent developments in solar-powered pumps have potential to transform irrigation development in drought-prone regions of Africa, and solar energy will be a particular focus of this Impact Area. The opportunity is not only to reduce climate change vulnerability, but also to make low-cost, small-scale irrigation in electricity-constrained Africa a reality. Several pilots, even large-scale, have been attempted, which have provided mixed results on environmental benefits, costs and market opportunities. Key research needs now are to link technological advances to development of business models that will underpin climate resilience, incentivize water productivity at farm level and support expansion of renewable energy. Technical research on particular crop management options need to include attention to value chain development, and diversification of diets and incomes. Research on governance is also key to understand the policy, legal frameworks and institutions needed to safeguard social equity, support women's economic empowerment, ensure sustainable use, and enable coherence across the water-energy-food nexus.

42. Climate hotspots (at national or sub-regional scale) in countries where governments have prioritised solar irrigation development will be selected for action research. While the R4D will be focused on Sub-Saharan Africa, there is rich experience of solar-powered irrigation in China, India and northern Africa, thus South-South learning will be a key component of this Impact Area. This Impact Area will be led by WLE, but with strong participation by other Agri-Food CRPs, depending on the geographies targeted, and by PIM on governance, equity and policy issues.

Impact Area #6. Circular bio-economy for low emissions development in key value chains

43. This Impact Area aims at fostering low-emissions value chains for food, feed, bioenergy, and biomaterials and supporting growth of the circular bio-economy. It will address replacing fossil fuel products with recyclable bio-based materials sourced from agriculture,

agroforestry and forestry. This Impact Area aims at maximizing development and mitigation potentials of the bio-economy in three ways:

- Phase-in bio-based renewable materials that reduce country dependence on fossil fuels.
- Maximize opportunities for co-products, by-products, and waste use for food, feed, energy and materials in key value chains with high emissions (e.g. animal-sourced food) or high carbon sequestration potential (e.g. bamboo), reducing loss, waste and emissions.
- Strengthen bio-economy value chains to be sustainable and economically viable, contributing to other development objectives (increasing smallholders' resilience, food security, gender equity, youth employment, providing for decent jobs).

44.   A holistic approach to all material fluxes enables optimizing input/output flows in crop and livestock production, forestry and fisheries, and diversifies farm and forest revenues, thus reducing risks and the C footprint. To contribute significantly to climate change mitigation goals, the bio-economy supports agriculture and forestry to avoid conversion of high carbon landscapes (e.g. peatlands), replace fossil fuel use, and maximize reductions of emissions in supply chains. These developments require supportive regulations, public procurement, incentives and consumer engagement.

45.   This Impact Area explores three main areas of work:
- Developing, testing and scaling-up climate-smart bio-resources (for food, feed, energy, and materials) derived from tree crops and agricultural goods or waste (re-engineered wood products; modern biofuels, livestock, crop by-products and co-products).
- Conceiving innovative farm-to-fork value chains, and developing enabling policy environments (e.g. incentives, rights, tenure) and economic incentives.
- Assessing the impacts of these innovations on climate, land and people, including indigenous peoples and local communities and developing value chain information systems (e.g. MRV and accounting frameworks, reduction targets, ecological footprints, life-cycle analyses, including but not limited to BECCS).

46.   This Impact Area requires a broad multi-Center, multi-CRP approach; and a food system approach given that there will be trade-offs across value chains; and trade-offs for sustainability and healthy food system outcomes. FTA could address the bioenergy and wood-based materials systems, social considerations, as well as impacts on forests. PIM together with WLE and FTA could work on resource governance and policies. CCAFS, with Agri-Food CRPs could contribute with specific production systems. To maintain focus, foresight analysis will be used to select five key value chains with significant climate change mitigation potential and significant development potential. A number of these are expected to be in peri-urban areas.

Annex 1: CRPs and their Flagships involved in climate change-related research

Focus area: A = Adaptation; M = Mitigation

Climate change integrating CRP

CGIAR Research Program on Climate Change, Agriculture and Food Security

> CCAFS generates evidence and supports adoption of climate-smart agricultural policies, practices, and services that alleviate poverty, increase gender equity, and support sustainable landscapes. CCAFS also plays an integrating role across all the CRPs

CCAFS FP1 (A): Priorities and policies for CSA
CCAFS FP2 (A/m): Climate smart technologies and practices
CCAFS FP3 (M): Low Emissions Development
CCAFS FP4 (A): Climate services and safety nets

Other integrating CRPs

CGIAR Research Program on Agriculture for Nutrition and Health

> A4NH is built on the notion that agriculture can do much more than reduce hunger and poverty – it has an enormous potential to significantly improve the nutrition and health of people around the world. The links between nutrition and climate change is a focus area.

A4NH FP1 (A): Food Systems for Healthier Diets

CGIAR Research Program on Policies, Institutions, and Markets

> PIM is action-oriented research to provide support for policies that help poor farmers, both men and women, improve their lives; produce nutritious and affordable foods; and protect the soil, water, and biodiversity in rural landscapes.

PIM FP1 (A): Technological Innovation and Sustainable Intensification
PIM FP3 (A/M): Inclusive and Efficient Value Chains
PIM FP4 (A): Social Protection for Agriculture and Resilience
PIM FP5 (A/m): Governance of Natural Resources

CGIAR Research Program on Water, Land and Ecosystems

> WLE works on transforming agricultural food systems, making them the key to healthy, functioning ecosystems, human well-being and resilient livelihoods. Agriculture doesn't have to be the cause of degradation, it can be the cure.

WLE FP1 (M): Restoring Degraded Landscapes
WLE FP2 (A): Land and Water Solutions for Sustainable Intensification
WLE FP4 (A/m): Managing Resource Variability, Risks and Competing Uses for Increased Resilience

Agri-food CRPs

CGIAR Research Program on Forests, Trees and Agroforestry

➢ FTA aims to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change.

FTA FP1 (A): Tree genetic resources to bridge production gaps and promote resilience
FTA FP2 (A/m): Enhancing how trees and forests contribute to smallholder livelihoods
FTA FP3 (a/M): Sustainable global value chains and investments for supporting forest conservation and equitable development
FTA FP4 (A): Landscape dynamics, productivity and resilience
FTA FP5 (A/M): Climate change mitigation and adaptation opportunities in forests, trees and agroforestry

CGIAR Research Program on Fish

➢ FISH aims to enhance sustainability, productivity and access to fish by those most in need to reduce poverty, enhance food and nutrition security and improve natural resource systems.

FISH FP1 (A/m): Sustainable aquaculture
FISH FP2 (A): Sustaining small-scale fisheries

CGIAR Research Program on Grain Legumes and Dryland Cereals

➢ GLDC aims to increase the productivity, profitability, resilience and marketability of critical and nutritious grain legumes and cereals within the semi-arid and sub-humid dryland agroecologies of sub-Saharan Africa and South Asia. These agroecologies are where poverty, malnutrition, climate change and soil degradation are among the most acute globally.

GLDC FP1 (A): Priority settin
GLDC FP3 (A): Integrated far... ...ousehold management
GLDC FP4 (A): Variety and hybrid development
GLDC FP5 (A): Pre-breeding and trait discovery

CGIAR Research Program on Livestock

➢ LIVESTOCK focuses on seizing opportunities presented by rapid increases in demand for animal-source food in developing countries, including a focus on low emissions development.

LIVESTOCK FP1 (A/m): Livestock genetics
LIVESTOCK FP2 (a/M): Livestock health
LIVESTOCK FP3 (a/M): Livestock feed and forage
LIVESTOCK FP4 (A): Livestock and the environment

CGIAR Research Program on Maize

➢ MAIZE is an international collaboration between more than 300 partners that seeks to mobilize global resources in maize research and development to achieve a greater strategic impact on maize-based farming systems in Africa, South Asia and Latin America.

MAIZE FP1 (A): Enhancing MAIZE's R4D strategy for impact
MAIZE FP2 (A): Novel diversity and tools for increasing genetic gains
MAIZE FP3 (A): Stress tolerant and nutritious maize
MAIZE FP4 (A/m): Sustainable intensification of maize-based systems for improved smallholder livelihoods

CGIAR Research Program on Rice

> ➤ RICE is a forward-looking, holistic, global partnership that focuses on the win-win proposition of the social, economic, and environmental sustainability aspects of rice.

RICE FP3 (A/M): Sustainable farming systems
RICE FP4 (A/m): Global rice array

CGIAR Research Program on Roots, Tubers and Bananas

> ➤ RTB is working globally to harness the untapped potential of those crops in order to improve food security, nutrition, income, climate change resilience and gender equity of smallholders.

RTB FP1 (A): Discovery research for enhanced utilization of RTB genetic resources
RTB FP2 (A): Adapted productive varieties and quality seed of RTB crops
RTB FP3 (A): Resilient RTB crops
RTB FP5 (A): Improved Livelihoods at Scale

CGIAR Research Program on Wheat

> ➤ WHEAT is an unprecedented global alliance for productive, climate-resilient and profitable wheat agri-food systems in lower and middle-income countries.

WHEAT FP1 (A): Enhancing WHEAT's R4D strategy for impact
WHEAT FP2 (A): Novel diversity and tools for improving genetic gains and breeding efficiency
WHEAT FP3 (A): Better varieties reach farmers faster
WHEAT FP4 (A/m): Sustainable intensification of wheat-based farming systems

Platforms

Genebank Platform

> ➤ Development of trait-based subsets for climate resilience; Conservation and characterization of diversity for both staple and underutilized crops for future climate options.

Platform for Big Data in Agriculture

> ➤ Agriculture to harness the capabilities of big data to accelerate and enhance the impact of international agricultural research.