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RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

Submission from the International Center for Tropical Agriculture (CIAT), on issues relating to agriculture (SBSTA) on behalf of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

These are views on the current state of scientific knowledge on how to enhance the adaptation of agriculture to climate change impacts while promoting rural development, sustainable development and productivity of agricultural systems and food security in all countries, particularly in developing countries, taking into account the diversity of the agricultural systems and the differences in scale as well as possible adaptation co-benefits (FCCC/SBSTA/2013/L.20 paragraph 2)

Enhancing agricultural adaptation to climate change: the science and practice of climate-smart agriculture

Climate-smart agriculture (CSA): Changes in diets alongside human and livestock population growth will continue to place substantial demands on agriculture, fisheries and forestry for increased and more sustainable production. This is especially true in low-income countries where rainfed agriculture is the main livelihood source for between 500 and 800 million small-scale farmers. Already subject to the season-to-season variability of rainfall and the associated risk that this implies, agriculture now faces the added challenge of adapting to progressively changing rainfall and temperature regimes together with a projected increase in extreme weather events. This has led to the recognition of the importance of climate-smart agriculture (CSA), defined as "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) and enhances achievement of national food security and development goals"[1].

Given the political, social, economic and biophysical constraints that can often hinder agricultural development in many parts of the world, the future challenge of large-scale adoption of CSA appears daunting. *Nevertheless, there is increasing evidence that given the right scientific, political and financial support, this is a challenge that can be and is being met.*

Statement on CCAFS: No single research institution working alone can address the critically important issues of global climate change, agriculture and food security. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) will address the increasing challenge of global warming and declining food security on agricultural practices, policies and measures through a strategic collaboration between CGIAR and Future Earth [2]. Led by the International Center for Tropical Agriculture (CIAT), CCAFS fosters collaboration on climate-related research across the CGIAR and a wide range of partners. CCAFS brings together researchers in agricultural science, climate science, environmental and social sciences to identify and address the most important interactions, synergies and trade-offs between climate change and agriculture. CCAFS research outputs, reports, policy briefs, decision tools and databases are freely available on the CCAFS website (www.ccafs.cgiar.org).

About this submission: In this submission, we highlight scientific approaches that are now available to support the scaling up of CSA and provide examples of where such support has already led to large-scale implementation of adaptation and mitigation actions in agriculture.

We consider three broadly defined categories of adaptation initiatives, namely:

1: Managing current climate-induced risk as a pre-requisite for adapting to future climate change
2: Adaptation initiatives that also include co-benefits of mitigation
3: Developing adaptation options for progressive climate change

Finally, drawing on a recent CCAFS analysis of 16 case studies,[3] we conclude by highlighting factors that have underpinned scaling up successes and some challenges that still remain.

1. Managing current climate risk: Given the uncertainty of climate change projections and the fact that they will be progressive in nature, adaptation initiatives must in the shorter term largely focus managing current climate risk. Helping farmers cope better with the current season-to-season weather variability is important for two reasons. Firstly, it can be assumed that all ongoing development initiatives targeting sustainable increases in food, nutrition, animal feed, income and environmental resources will translate into improved livelihood assets, and hence greater resilience and adaptive capacity. However, whilst this assumption is widely held to be true, it is not always easy to demonstrate since in practice there are pertinent and critical issues of uncertainty in determining adaptive capacity at different scales, from household to country [4]. We discuss this further in our concluding section. Secondly, and perhaps more important is the consideration of the already substantial current season-to-season variability in weather patterns (principally rainfall) and the production-risk that this imposes and to which small-scale farmers are vulnerable.

(i) Scientific targets

Scientific advances, targeted towards helping farmers mitigate that risk through a range of approaches have been developed and are increasingly being used. For example:

Climate services: Ways to improve the communication of weather and climate information to farmers and herders – from daily to seasonal forecasts with associated advisories – have been extensively investigated and are being widely implemented. The reach of ICT is increasingly being exploited. The need to address gender equity challenges is increasingly recognized [5 6 7 8].

Analysis of historic weather data: Risk analyses of long-term daily weather data, using statistical packages such as the freely-available Genstat, allow scientists to help farmers better understand the nature and frequency of important weather events that impact on management decisions and production [9 10 11].

Addressing weather data gaps: Many opportunities to manage risk depend on historic weather data, and are constrained when observations are missing or unavailable. Gaps in historic daily weather data can be filled at a moderately high spatial resolution by merging sparse observations with satellite data, as work by CCAFS and partners in Africa and Latin America demonstrates [12 13 14]. Stochastic weather generators produce synthetic time series of weather data of unlimited length with appropriate statistical and mathematical characteristics for a given location where real-time daily data are not available [15].

Weather-driven agricultural models: Such models, when used in combination with historical weather data, can provide an *ex ante* simulation of the impacts of seasonally variable weather across a range of scales, ranging from crop production at the field level to landscape-level processes [16 17], and hence the risk associated with potential innovations. Agricultural models can be integrated with seasonal climate forecasts and remote sensing data to forecast crop production[18][19]. CCAFS and partners are developing a software package, CRAFT, to support forecasts of crop production within the growing season [20].

Weather related insurance schemes: The challenge of providing crop and livestock weather-index insurance schemes for small-scale farmers in developing countries have been successfully studied, piloted and introduced in several countries [21][22].

Climate-ready crops: The development of drought and heat tolerant crops has been a mainstream activity in many on-going development initiatives [23][24] and the widespread adoption of improved varieties has already occurred in many countries. In a warming world, and one in which droughts are likely to become more frequent in certain regions, drought and heat tolerance will become increasingly important.

Social safety nets: Research shows that gaps in the availability and use of tailored climate information are a key limitation for social safety nets net programs, which inhibit the targeting and timing of assistance for those most vulnerable to current climatic hazards. Safety net programs effectively linked to interventions that increase long-term resilience are now well recognized as an innovation that replaces the continual need for emergency food aid. [25]

Enhancement of existing local risk management: The nature of climate-induced risk, environmental conditions and socio-economic welfare are spatially very variable. Community level participatory approaches that enable a firsthand understanding of farmers' livelihood objectives, the local nature of climate-induced risk and existing risk management approaches are therefore important and are becoming widely used. For example, CCAFS is currently piloting such an approach with 'Climate-Smart Villages' in Africa and South Asia.[26]

(ii) Large-scale successes

However, advances are not only limited to 'new scientific tools and approaches'. Evidence is also emerging of large-scale adoption and impact of climate risk management innovations. For example*:*

Integrated Agrometeorological Advisory Services, India*:* The service generates four products: (i) a meteorological component consisting of weather observation and forecasts for the next five days, (ii) an agricultural component, which identifies 'weather sensitive stresses' and converts weather forecasts into appropriate farm-level advisories, (iii) an extension component, with two-way communication between farmers and agricultural scientists and (iv) an information dissemination component employing mass media. Currently the project provides services to over 2.5 million farmers. To date, the program has had an estimated economic impact of more than $10 billion.[27]

Drought tolerant maize for Africa (DTMA): Drought tolerant maize varieties are a crucial component in the battle against the risk of climate-induced crop failure for over 300 million farmers in Africa. Launched in 2006, DTMA is comprised of a broad partnership across Africa. To date more than 34 new drought tolerant maize varieties have been deployed to approximately 2 million smallholders across [13] African countries. An *ex-ante* assessment study on the potential impacts of the project suggests that the project could lead to a cumulative economic benefit of US$ 0.9 billion to farmers and consumers.[28]

Weather Based Crop Insurance Scheme, India: The Weather Based Crop Insurance Scheme was launched as a pilot in 2007 with the objective of '*mitigating the hardship of the insured farmers against the possibility of financial loss associated with low crop yields or crop failure resulting from adverse weather conditions.*' By the 2010-11 agricultural year over 9 million Indian farmers held policies with premium volume of over US$ 258 million and total sum insured over US$ 3.17 billion. The volume of paid claims in 2011 amounted to US$ 125 million. These policies covered over 40 different crops and 9.5 million ha.[29]

***Productive Safety Net Programme, Ethiopia**:* The Ethiopian Government launched the multi-donor programme in 2005 with the objective of providing *transfers to the chronically food insecure population in a way that prevents asset depletion at household level and creates productive assets at community level*. Both direct and indirect beneficiaries receive cash and food support. Direct support beneficiaries are required to attend temporary employment in 'public workfare projects', whilst the indirect support beneficiaries, unable to contribute to public works due to labor constraints, are not required to work. The 'public workfare projects' include the establishment of woodlots, construction of hillside terraces, shallow wells and ponds and stream diversion for irrigation. Implemented in seven out of ten regions in Ethiopia, the programme has reached about 8 million people.[30]

***The Central American Climate Outlook Forum (CA-COF)*:** CA-COF brings together the capacities of all seven weather services in the region and issues three seasonal outlooks per year. It aims to analyze the effects, impacts, and climatic variability projections in sectors including agriculture, water, fisheries, health and nutrition, risk management and energy, and to produce disaster prevention and mitigation strategies according to the climate scenarios proposed at the end of each forum. The objective is to turn Seasonal Climate Outlooks into risk scenarios used by food-related sectors to support their decisions and minimize food insecurity [31]. The impact of this initiative has yet to be assessed but according to a survey conducted by USBC in 2005, 78% of regional stakeholders said that they used the CA-COF forecasts in daily decision making.

2. Adaptation initiatives that also include co-benefits of mitigation: Direct GHG emissions from agriculture are estimated to account for between 10-12% of the global total anthropogenic emissions; in addition, agriculture contributes indirectly to emissions from land use change. Of the greenhouse gases emitted by agriculture, the non-CO_2 gases, notably nitrous oxide and methane, are by far the most important, accounting for 84% of the global nitrous oxide emissions and 54% of the global methane emissions [32]. By 2030, they are projected to be 24% higher than in 1990 [33]. However, agriculture also has a substantial potential to mitigate climate change through sequestering soil organic carbon or through reducing emissions of nitrous oxide and methane [34].

Recognizing this, national policies have been designed to explicitly encourage reductions in non-GHG emissions and carbon sequestration. For example, Brazil's Low Carbon Fund has an overall goal of a reduction of more than 160 million tonnes CO_2e emissions annually by 2020 [35], Denmark's Agreement on Green Growth Agriculture has succeeded in combining agricultural growth with an overall 19.4% reduction in nitrous oxide and methane emissions [36] and Australia's Carbon Farming Initiative is designed to help Australia achieve its GHG reduction obligation along with protecting and improving the environment and climate change resilience [37].

However, equally importantly, large-scale initiatives are also underway that are designed to improve farmers' social welfare, livelihood resilience and adaptive capacity but that also have potentially substantial co-benefits of climate change mitigation. Examples include:

***Sustainable Intensification in Rice Production in Vietnam**:* The system offers two important CSA related benefits, (i) reduced demand for water through intermittent draining of the paddy fields and (ii) as much as a 50% reduction in methane gas emissions through paddy soils being intermittently dried [38] [39]. Launched in 2007, the programme had reached over 1 million farmers by 2011 on 185,000 ha across 22 provinces. Compared with conventional practice, yields have increased by 9-15% and inputs have been reduced: 70–75% less seed, 20–25% less nitrogen fertilizer, and 33 % less water [40].

***Grain for Green Programme in China**:* This programme, launched in 1999, has the objective of *reducing erosion by restoring forest and grasslands on low-yielding sloping cropland and secondly to help alleviate poverty*. The programme targets three types of land use conversion – cropland to forest, cropland to grassland and wasteland to forest. Participating households are compensated according to the amount of farmland they set aside with grain provision, cash payments, and free seedlings. By 2008, the area of land use conversion in the Loess Plateau had already amounted to 2 million ha and has benefitted 2.5 million households. It is estimated that the programme has had significant positive impacts on carbon sequestration, with increased carbon levels in soils and rehabilitated vegetation found to be 11.54 megatonnes and 23.76 megatonnes respectively [41].

Participatory Forest Management in Tanzania: Since the late 1990s, Tanzania has promoted community participation in forest management to protect forests against degradation and enhance the benefits derived from participatory forest management (PFM) for farming communities living within forest margins. Since agricultural expansion is the major driver of forest cover loss, from a CSA perspective, success in PFM is important in reducing deforestation, hence carbon dioxide emissions. In addition, PFM enables the diversification of livelihood strategies of participating agricultural communities, hence building adaptive capacity. By 2008, there were 1,800 villages across 60 or more districts, providing for the rehabilitation and preservation of nearly 4.0 million ha of forest [42].

Farmer Managed Natural Regeneration in Niger: FMNR was developed during the 1980s by several NGOs after the natural tree cover had been reduced to about 10% of its original density.[43] The practice was only picked up at large scale after the Government of Niger relaxed the strict policies regarding the ownership and felling of parkland tree species [44]. Within two decades this combination of government policy and private extension service led to re-greening of about 5 million ha of formerly barren bush savannah with an estimated 200 million new trees. In addition to improving household incomes by between 18% and 24% [45], this has contributed to the mitigation of millions of tonnes of CO_2e over this period of time.

Integrating Climate Change into the Plan Maroc Vert, Morocco**:** Launched in 2011, and integrated into the Maroc Plan Vert (PMV) it is estimated that the project will result in carbon gains of 63.5 million tonnes CO_2e over 20 years, largely from the sequestration of soil carbon from improved agronomic practices. The PMV itself, launched in 2008, seeks to create one million new agricultural jobs and to improve the livelihoods, incomes and adaptive capacity of three million vulnerable rural poor by two- to threefold. By 2011, 64 PMV projects covering 468,000 ha had been initiated and compared with the period 2005-2007, production has increase by 190 % in the olive sector, by 20 % for citrus production, 52% for cereals, 45% for dates and 48% for red meat.[46]

3. Developing options for progressive climate change: Climate change will be progressive and adaptation strategies are likely to evolve from '*Incremental adaptation*', through '*Systems adaptation*' to '*Transformational adaptation*' as the degree of climate change becomes progressively more pronounced [47]. Even though ongoing adaptation initiatives are currently most usefully focused on managing current climate risk, it is also important to start developing and testing options for adaptation to future climate change scenarios. Useful approaches and tools are available to support such work.

Access to down-scaled climate change projections: In developing adaption options, it is clearly essential to understand the likely climate change projections for the geographic area of research interest. Whilst there still remains a relatively high degree of uncertainty in such down-scaled projections, ease of access to such projections has presented problems for many researchers, especially in the developing world. However, climate change projections can now be accessed through 'CCAFS Climate', an open access source for downscaled GCM data.[48]

Climate analogue locations: The identification and use of climate analogue locations is a very useful field-based approach for testing potential adaptation options. A climate analogue location is one which has *today* a climate with similar statistical and mathematical characteristics to the climate that is projected in the *future* for the research site of interest, thus allowing the direct testing of adaptation options. CCAFS has developed a Climate Analogue Tool for matching sites with analogous agricultural climates over space and time [49]. The CCAFS "Farms of the Future" project will use the climate analogue tool to connect farmers to their possible climate futures via farm visits. This novel approach of farmer-to-farmer exchanges between spatial analogues will integrate participatory learning principles in order to promote knowledge sharing between producer communities [50], and has been successfully piloted in Nepal, Tanzania and Ghana.

Stochastic generation of future rainfall data: We have already referred to the usefulness of a wide range of weather driven agricultural models for assessing the impacts of current climate variability on production risk and landscape processes [5] [6], and the value of stochastic weather generators when real-time data is not available [7]. It is now possible to generate future daily rainfall data for locations of interest. *MarkSIM GCM* is a stochastic downscaling tool that provides geographically specific simulations of future rainfall series, which in turn can be used in other applications, such as crop models, to simulate the performance of potential adaptation options over future time [51].

Conclusions: Feeding an ever increasing global population in the face of a changing climate provides an enormous challenge to the scientific, development and policy formulation community. That much is certain. However, from this brief review of recent scientific innovations we have presented here, together with lessons that have been learnt from successful large-scale adaptation and mitigation actions in agriculture [2], there are good reasons to believe that this is a challenge that can be met when the required scientific, political and financial support is in place. We conclude by highlighting six considerations that are important for success in enhancing agricultural adaptation to climate change.

1. Scientific tools and approaches: A range of useful tools that improve understanding of the agricultural production and environmental impacts of current and future climates have been developed, tested and made easily available (e.g. http://ccafs.cgiar.org/resources/tools-maps-models-and-data). These decision tools are widely used, increasingly in conjunction with an iterative and participatory learning approach, with investment in capacity strengthening being recognized as critical[52]. This is especially important since research activities and emerging solutions will need to be locally appropriate and should be under local governance as far as possible.

2. Synergies between development needs and climate change mitigation: We have referred to policies that are designed to encourage and reward agricultural mitigation activities. These are important. Equally important is the recognition that a large number of current development and climate risk management initiatives also offer the potential synergy of meeting current development goals while also contributing to climate change mitigation through carbon sequestration or reduction in non-CO_2 greenhouse gas emissions. Importantly, for example, sustainable intensification that raises yields in smallholder farming systems will benefit food security, adaptation and mitigation[53]. However, while these synergies exist at present, we may be less able to ensure synergies in the future. The same issue pertains to spatial scale: while synergies may exist locally, there is potential for 'leakage'. For example, in one case study, reduced emissions in Danish pig farming associated with reduced production may simply displace the emissions to another country if demand remains the same.[54]

3. Monitoring GHG fluxes: The literature we accessed, describing large scale adaptation initiatives with co-benefits of mitigation, often provided estimates of what might have occurred or described the potential GHG gains that the innovation offers, but these were seldom backed by *in situ* evidence. For such initiatives to become eligible for possible climate change financing, it is important that on the ground monitoring of changes in soil carbon stocks or non-GHG emissions is initiated. This is especially the case in the smallholder sector where usually a wide range of agricultural enterprises exist at the farm and landscape level. Protocols for these measurements are available. For example, the CCAFS' SAMPLES program (Standard Assessment of Mitigation Potential and Livelihoods) aims to develop farm and whole-landscape protocols for assessing the feasibility, value and trade-offs for different mitigation options available to smallholder farmers. The SAMPLES program includes both technical (measurement of GHG fluxes) and institutional components.[55]

4. Measuring and monitoring adaptive capacity: We have already referred to the difficulty in measuring and monitoring adaptive capacity and the fact that hard evidence of 'enhanced adaptive capacity,' a key component of CSA, is seldom available. The Africa Climate Change Resilience Alliance (ACCRA) has described a Local Adaptive Capacity framework,[56] which is an attempt to incorporate the intangible and dynamic dimensions of adaptive capacity, as well as capital and resource-based components, into an analysis of adaptive capacity at the local level. It recognises five characteristics of adaptive capacity which development interventions should concentrate on augmenting, (i) the assets base, (ii) institutions and entitlements, (iii) knowledge and information, (iv) innovation, and (v) flexible, forward-looking decision-making. It is important that such initiatives which aim to identify cost effective indices for measuring and monitoring adaptive capacity are supported, further developed, tested and widely applied in order to increase both confidence in and financing of CSA and development research.

5. Strong government support is crucial for scaling up: In the 16 case studies we have referred to,[2] strong leadership and support from governments was essential for successful scaling up in all but one. Appropriate support entailed changes in legislation, government-administered programmes, provision of finance and incentives, or partnership among multiple agencies. In addition, in almost all instances government support was invaluable in elaborating approaches and frameworks for scaling up initiatives in their countries. This would seem essential to future initiatives, since the implementation of large-scale programmes, particularly those that target millions of small-scale farmers will always be complex and require the participation of a wide range of institutions at different levels in each country.

6. Upfront costs may be substantial: High start-up costs appear inevitable in large-scale adaptation initiatives, even if the programme is designed to be financially and economically sustainable and self-supporting in the longer-term. This is especially true where they are targeted towards millions of small-scale farmers who are unable to bear the brunt of implementation costs themselves. In some countries costs are being met from government sources, but elsewhere initiatives are being funded through collaboration with one or more donors. An important lesson here is that finance to start up such programmes is more likely to come from national government revenues, official development assistance and the private sector than from dedicated international climate funds under the UNFCCC which in reality are slow to materialize and insufficiently reliable. However, as these funds do begin to flow, perhaps two priorities for investment are (i) transition funds to cover upfront costs and (ii) support to transactions costs in order to lower the barriers for smallholder farmers to participate in adaptation and mitigation activities.

Contact details for CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): ccafs@cgiar.org
CCAFS Director Bruce Campbell: b.campbell@cgiar.org
International Center for Tropical Agriculture (CIAT): ciat@cgiar.org
DCP Andy Jarvis: a.jarvis@cgiar.org

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