Submission to the Subsidiary Body for Scientific and Technological Advice

Agriculture for Impact
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SBSTA 44: Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agro-ecological zones and farming systems, such as different grassland and cropland practices and systems

1) About Agriculture for Impact

Agriculture for Impact (A4I) is an independent advocacy initiative based at Imperial College London, supported by the Bill & Melinda Gates Foundation and led by Professor Sir Gordon Conway. A4I encourages better European government support for productive, sustainable, equitable and resilient agricultural development in Sub Saharan Africa (SSA), focusing in particular on the needs of smallholder farmers. A4I convenes the Montpellier Panel, a group of European and African experts in the fields of agriculture, trade, ecology and global development, which publishes regular high-impact reports on topics related to improved agricultural and economic development in SSA. The last report "The Farms of Change: African smallholders responding to an uncertain climate future" was published in September 2015.

2) Introduction

Agriculture and smallholder farmers are particularly vulnerable to climate change. In many regions of the world the first impacts of climate change can already be felt. Erratic rainfall, shorter growing seasons and prolonged droughts mean that crop growth suffers, as do the livelihoods of those smallholder farmers who depend on these crops for food, nutrition, and income. To meet the demands of an increasing global population for more nutritious food, agricultural productivity has to be increased. However, this will have to be achieved sustainably, with fewer resources and interventions that are climate-smart.

Sustainable Intensification (SI) integrates innovations and practices from the fields of ecology, genetics and socio-economics to build environmentally sustainable, equitable, productive and resilient ecosystems that improve the well-being of farms, farmers and families. SI offers a practical pathway towards the goal of producing more food whilst ensuring the natural resource base on which agriculture depends is sustained, and indeed improved, for future generations.

According to the Montpellier Panel reports "Sustainable Intensification: A New Paradigm for African Agriculture" and "Innovation for Sustainable Intensification in Africa," SI includes three mutually reinforcing pillars: Ecological Intensification, Genetic Intensification and Socio-Economic Intensification.

The following submission sets out examples of successful agricultural approaches and technologies falling under the framework of *Sustainable Intensification* that enhance productivity sustainably, helping to achieve food security and to increase farmers' resilience and capacity to adapt to climatic shocks and longer term changes.

3) Ecological Intensification:

Ecological Intensification involves using ecological processes more intensively in a sustainable manner. The aim is to use land, water, biodiversity and nutrients more efficiently and in ways that minimise negative environmental impacts.

Two approaches that fall under the heading of ecological intensification are precision agriculture and diversification.

3.1 Precision Agriculture

Precision agriculture aims to ensure that inputs – whether of nutrients, pesticides, seeds or water – are used in a precise and strategic way so ensuring that they are used sparingly and effectively with minimal environmental impact. Knowledge of sustainable farming practices that protect natural capital for smallholder farmers is limited, as is access to the right types of inputs in remote parts of sub-Saharan Africa. The prudent and targeted use of inputs such as fertilisers helps to improve soil quality and moisture whilst minimising the environmental impact that excessive use can cause. Precision farming can be achieved with methods such as microdosing, soil testing and seed spacing.

- Microdosing

Land degradation is particularly acute in parts of sub-Saharan Africa (SSA), where long-term overuse of soil and low, unpredictable rainfall are prime reasons for poor food production. In SSA an estimated 180 million people are affected, whilst the economic loss due to land degradation is estimated at US$68 billion per year.

Unless nutrients are replaced, soils become depleted, causing the yields and crop quality to decline. However, farmers are often unable to invest in soil nutrients because they are increasingly costly and often inaccessible. In many cases farmers lack access to the inputs that are appropriate for their soils. Knowledge amongst smallholder farmers about what inputs to use and how to apply them effectively is limited. Other farmers are unwilling to invest in inputs because they may not be guaranteed a return on their investment. For these reasons, farmers in SSA use a very small amount of fertiliser compared to all other regions, perpetuating significant soil nutrient deficiencies. SSA uses on average 7kg per hectare of fertiliser, accounting for only 3% of the global consumption. (In contrast, Asia uses an average of 150kg per hectare). In June 2006, the African Union adopted the

Abuja Declaration committing to increase fertiliser use to 50kg of

nutrients per hectare by 2015. Although 50kg per hectare may be excessive in some situations, no region of the world has been able to increase agricultural growth rates and reduce hunger without increasing fertiliser use. African farmers need to use more inorganic fertiliser, but they need to do it sustainably. Farmers must complement existing methods – manure applications and intercropping with nitrogen-fixing legumes or crop residues – with increased but targeted use of fertilisers to return nutrients to the soil, also known as *microdosing*.

Microdosing of inputs such as fertiliser, pesticide, or water is a highly efficient technique that minimises the application of and over-reliance on inputs. Fertiliser microdosing involves the application of small, quantities of fertiliser onto or close to the seed. This can be done by filling a soda bottle cap with fertiliser and applying it directly to the root of the crop. The same principle can be applied to herbicides that, far too often, are sprayed indiscriminately, killing not only weeds but sometimes damaging the crops themselves. Drip irrigation is a method of water microdosing, applying a limited about of water directly to where it is most needed, reducing wastage and evaporation.

Case study: Conservation agriculture and microdosing in Zimbabwe

In Zimbabwe, an estimated 75%-90% of crops remain unfertilised each season and when used, farmers on average only apply 3kg of nitrogen fertiliser per hectare, compared to average rates of 9kg per hectare for all of SSA. The usage rates are low and variable due to limited knowledge of appropriate use, lack of availability and affordability as well as cultural and traditional beliefs that fertilisers 'burn' the crops.

Since 2004, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has been working in partnership with the UK Department for International Development (DFID), the national extension service and NGOs to promote conservation agriculture amongst smallholder farmers. Conservation agriculture consists of 3 principles: minimum soil disturbance, legume-based intercropping and application of organic mulch to improve soil fertility. In 2011, more than 150,000 smallholders practiced conservation agriculture, raising cereal yields 15% to 100% across different regions. When combined with microdosing farmers in Zimbabwe significantly improved household food security.

To increase the adoption of fertiliser use, ICRISAT provided training on microdosing for more than 650 lead farmers, 241 government extension officers and 119 extension officers from 16 local and international NGOs. Between 2003 and 2007, more than 160,000 households received 25kg bags of nitrogen fertiliser and flyers in local languages explaining how to apply the fertiliser. *Despite poorer than average rainfall during the 2006/07 cropping season, farmers experienced yield increases between 30% and 50%.* During the same season, more than 170,000 households increased cereal production by an estimated 40,000 tonnes, saving US$7 million in annual food imports and significantly improving food security. As of February 2013, close to 300,000 farmers are now using both technologies and have achieved productivity gains of up to 100%.

3.2 Diversification

Diversification is the number and relative abundance of different species – both flora and fauna – that are found at a given site, or field. Diversity is generally considered a key factor in maintaining stable and resilient agro-ecosystems.

Diverse agro-ecosystems can have multiple benefits when varieties or species are grown together with minimal competition or if there is a mutual beneficial relationship between them. Mixtures of crops can provide for a diverse and healthier diet, deter pests, and during times of crises such as drought or cyclone, can provide a form of insurance when at least one crop out of many survives. Diversification can be achieved with the use of multiple cropping, agroforestry and integrated pest management (IPM).

- Agroforestry

Agroforestry is a form of multiple cropping in which annual herbaceous crops are grown interspersed with perennial trees or shrubs. The deeper-rooted trees can often exploit water and nutrients otherwise unavailable to the crops. The trees may also provide shade and mulch, creating a microenvironment, whilst the ground cover of crops reduces weeds and prevents erosion. One main advantage of agroforestry is that it provides vegetative material that can be used as mulch, and protect the soil from erosion, desiccation and heat.[1] Agroforestry – land with greater than 10% tree cover – makes up 43% of more than 1 billion hectares of global agricultural land, 190 million hectares of which are located in sub-Saharan Africa.

Agroforestry systems can be classified in a variety of ways, most commonly by their structural characteristics, such as for the types of trees that are grown or the crops and animals with which they are integrated. Some of the most commonly used practices included alley cropping, forest farming, erecting buffer strips, windbreaks or shelterbelts. The type of agroforestry system used and trees grown depends on factors such as the location, soil type and crops native to the region. If an agroforestry system is to be successful, the tree species must be chosen carefully, depending on both environmental and social suitability factors.

Case study: Faidherbia

Faidherbia albida is a nitrogen-fixing Acacia tree that is widespread throughout Africa that grows in a variety of soils and climates. Faidherbia is able to make large quantities of nitrogen available to nearby crops and increase the storage of carbon above ground and in the soil. It sheds its leaves in the wet season and retains them in the dry season, allowing for light to pass through in the wet season whilst providing residue in the dry season. As a consequence it is possible to plant and grow maize under the trees. Yields can reach more than 3 tonnes per hectare without fertilisers, depending on the amount of nitrogen fixed by the trees. The trees also contribute 2 tonnes or more of carbon per hectare to the soil and mature trees can store more than 30 tonnes of carbon per hectare.

In Malawi, Faidherbia provided 300kg of fertiliser per hectare and boosted unfertilised maize yields from 2.5-4 tonnes per hectare, 200% to 400% more than national averages, when planted every 10 rows. In a survey of 300 farmers in the Dedza district of Malawi, those that grew Faidherbia did so in order to improve soil fertility on their farms (starting when the trees are 4 to 6 years old), did not use nitrogen fertiliser and were keen to grow more trees. In Niger, Faidherbia has been planted on almost 5 million hectares of land leading to similar benefits.

The climate change mitigation potential for systems incorporating trees with fertilising properties lies in their ability to sequester between 2 and 4 tonnes of carbon per hectare per year, compared with 0.2-0.4 tonnes of carbon per hectare per year under conventional conservation farming systems.

4) Genetic Intensification

Genetic Intensification includes 'conventional plant breeding,' 'biotechnology,' and also 'livestock breeding' which incorporates elements of both breeding technologies. Conventional plant breeding can occur through a variety of approaches and for a number of objectives such as with participatory plant breeding, improving seeds through hybridisation or enhancing their nutritional properties with biofortification.

Plant breeding aims to develop improved crop cultivars (deliberate cultivated varieties) to satisfy a range of needs and overcome a multitude of challenges. For example, breeders develop cultivars with improved yields and tolerance to drought or resistance to diseases in order to reduce the risks presented by increased food demand, diminishing supplies of good quality land and water, pest and disease outbreaks, and climate change. Soil quality can also be enhanced by varieties bred to enable nitrogen uptake and fixation or human nutrition can be improved through biofortification which adds or raises the levels of micronutrients present in a staple crop.

4.1 Conventional plant breeding

Through conventional plant breeding, beneficial genes have been preserved and brought into association with other complementary genes from close relatives.

- Biofortification

Billions of people around the world suffer from 'hidden hunger' or micronutrient malnutrition. Around 805 million people were considered chronically undernourished between 2012 and 2014. Whilst this has decreased by more than 100 million people compared to the previous decade and the prevalence of undernourishment has also fallen by 42%, micronutrient deficiencies affect an estimated 2 billion people.

Those that do not get enough micronutrients from the foods they eat such as Vitamin A, zinc and iron, face severe health complications and even death. Micronutrient malnutrition can cause stunting and blindness in children, lower resistance to disease in both children and adults, and increase risks for both mothers and infants during childbirth. Malnutrition is the underlying cause of 45% of child deaths under the age of 5.

The prevalence of and accessibility to super-markets and processed food products is growing in developing countries, but many rural poor communities, especially farming communities, often lack access or means to purchase processed foods. *Biofortification* – a process by which the nutritional quality of a food crop is enhanced through plant breeding – offers a way to reach these remote and resource-poor populations and effectively reduce malnutrition in rural areas.

Case study: Rwanda's high iron beans

In 2010, the Rwandan government introduced 4 high-iron biofortified varieties of bean. This was followed by a second wave in 2012, developed by the Rwanda Agriculture Board (RAB), the International Center for Tropical Agriculture (CIAT) and HarvestPlus. By 2014, more than 270,000 households or 15% of farmers were growing and eating the biofortified beans. These beans contain 14% more iron than commonly grown varieties. Given that Rwandans eat on average 200g of beans per day, the iron beans can provide 45% of their daily requirement of iron. HarvestPlus aims to continue to enrich their beans, with the goal of providing 60% of daily iron needs. The beans are also bred to be high yielding, virus resistant and heat tolerant.

Preliminary evidence shows that consumption of iron fortified beans can increase iron status in iron-depleted Rwandan women. For example, iron-depleted female university students showed a significant increase in haemoglobin levels (by 3.5g/L) and total body iron (up by 0.45mg/Kg) after consuming biofortified beans for 4.5 months. HarvestPlus also released iron beans in the Democratic Republic of Congo where they are being planted by 175,000 households and in Uganda, where vitamin A enriched orange-fleshed sweet potato is already widely produced and consumed.

4.2 Biotechnology

Biotechnology is any technological application that uses biological systems, living organisms, or their derivatives to make useful products or processes.

New cellular and molecular techniques open up a new world in which breeders can deliberately design and engineer new plant and animal types, speedily and with much less reliance on random processes. Under the general title of biotechnology, they are already having a significant impact on both medicine and plant and animal breeding, through three practical techniques:

Tissue cultures permit the growth of whole plants from a single cell or clump of cells in an artificial medium and, under certain circumstances, can stimulate mutation. It has become a powerful tool in the production of wide crosses, whereby wild relatives, often hosting desirable traits such as disease or drought resistance, are crossed with domestic varieties.

Biotechnology is more than just genetic engineering. Some of the less controversial techniques are making significant advances in producing more tolerant and resistant crops to biotic and abiotic stresses, such as pests, diseases and water stress. To date, most of the products of biotechnology have been produced in developed countries, mainly for global commodity crops, with limited application in developing countries. Yet, this is changing and increasingly, biotechnologies designed to reduce hunger and malnutrition, adapt to climate change and protect scarce natural resources are being developed and adopted in developing countries themselves.

- Tissue Culture

All cells, except sperm and egg cells of a plant, contain the full complement of genes, therefore it is often possible to grow individual cells and pieces of tissue into full healthy plants. This process is called tissue culture or micro propagation when whole plants are grown under artificial controlled conditions (in vitro) from sections of plant tissue. The plants that result are clones of the original.

Under tissue culture, a single original shoot tip is heat-treated to destroy diseases and then used through as many as ten cycles of regeneration to produce up to 1,500 daughter plants. Tissue culture is used to create large amounts of plants or growing material in a sterile environment with the required water and nutrients to suit the plant species and a gelling agent such as agar. During the process, plant hormones that regulate growth can also be added to increase multiplication or to enable the development of roots. Because the tissues are isolated and raised in contained and sterile environments, tissue culture is a highly effectively method for producing pest- and disease-free planting material.

Although most commonly used for high value horticultural crops, today tissue culture propagation has also been very successful in producing improved subsistence crops widely used in developing countries. One major breakthrough made possible by tissue culture is the development of disease-free bananas in East Africa. Bananas are a major source of consumption, nutrition and income in Africa; Ugandans for example eat on average 1kg per person per day. Other notable examples include higher-yielding varieties of rice and a frog-skin disease resistant cassava variety.

Case Study: Tissue culture bananas in Kenya

Bananas are a major source of food and income throughout the tropics and especially in East Africa. Banana plants are susceptible to disease because new plants are grown directly from suckers from a "mother plant," thus transferring any disease present, even if it is not visible. The black Sigatoka fungus, a leaf spot disease, has been particularly devastating to banana crops worldwide. It arrived in East Africa in the 1970s, decreasing productivity by as much as 40%. The fungus can be controlled with fungicides, but it has developed increasing resistance over the years, making the option both expensive and damaging to the environment.

After a visit to the work on tissue culture bananas in South Africa, Kenyan agricultural scientist Florence Wambugu applied the same technique in Kenya and found she could quickly generate healthy new plants. She persuaded the Kenyan Agricultural Research Institute (KARI) to undertake field trials on local varieties in the mid-1990s, and a training programme was initiated.

During the last decade, more than 6 million tissue cultured banana stems have been planted in Kenya, producing additional income of around Ksh5.5 billion (US$64 million) to banana farmers. A business model known as Wangigi, piloted by Africa Harvest, has greatly increased access to tissue culture banana outlets for 3,500 farmers, with some farmers trained to teach others on how to use the technology. A farmer-owned marketing company, Tee Cee Banana Enterprises Limited (TBEL), has been established to handle everything from postharvest storage to setting industry standards.

5) Socio-economic intensification

Socio-economic Intensification involves a greater intensity, variety and range of involvement of farmers in social and economic processes and institutions on the farm, in the community and across regions and nations. Adoption of new practices and technologies by farmers will only happen and persist if an appropriate enabling environment is supported that favours not only agricultural intensification but also its sustainability.

5.2 Enabling Environments

An enabling environment combines macro-economic policies that favour markets and trade, the provision of inputs, related physical infrastructure (such as roads and irrigation) and social infrastructure (such as education and research), together with institutions and regulations.

Governments play a pivotal role in creating an enabling environment for agricultural development. By providing a stable policy environment and avoiding unpredictable policy shifts, poor regulatory transparency, weak contract enforcement or restrictive investment policies, farmers (amongst other actors) can be supported to productively and beneficially engage in trading activities. A supportive enabling environment depends not only on the presence of laws and regulation, but their implementation; in agriculture, this requires strong political support for the sector at the highest levels. For example, political leadership was found to be an essential element in the comparative success of African countries implementing the Comprehensive African Agriculture Development Programme (CAADP), Africa's policy framework for agricultural transformation.

- Micro-insurance

Agriculture is inherently an uncertain business. This is especially true in developing countries, where smallholder farmers often have less capacity to deal with shocks and stresses produced by climate change or market price fluctuations. Insurance is one tool that farmers can use to manage risk. With insurance, part of that risk – from weather, pest, disease or the market – is transferred to another party, who absorbs a share of the risk in return for a fee. When farmers suffer a loss, they claim for financial support from their insurer to mitigate part of the loss. Agricultural insurance is not a complete solution, but rather one component of a risk management strategy where constraints such as the lack of access to finance, improved seed and markets can also be addressed. For example where drought is a severe problem, the construction of irrigation schemes maybe a more cost effective approach.

In developed countries agricultural insurance schemes are often large in scale covering thousands if not millions of mostly large-scale farmers. A critical factor is the cost of insurance provision. Insurers have to accurately assess the risks and measure the damage while at the same time providing farmers with affordable insurance premiums. Unless these conditions are met, the insurance scheme is likely to be unsustainable. Recently a number of pilot projects that offer 'micro-insurance' have emerged. Generally, micro-insurance targets low-income smallholder farmers, with limited or no previous exposure to insurance and is based on an observable index.

Index-based insurance measures meteorological station readings, satellite data, or regional-level yield data. The general characteristics of index-based livestock insurance programmes are similar to those for weather and area yield. In 2008, fewer than 80,000 farmers benefitted from agricultural (crop and livestock) micro-insurance in Africa. By 2011, the number of agricultural policies has tripled, now reaching almost 240,000 farmers in 14 countries, representing US$6.61 million in premiums. For example, the CGIAR Index-Based Livestock Insurance (IBLI) project uses forage measurements taken from satellites to identify seasonal forage availability. If forage falls below a certain level, pastoralists can use the pay-outs to buy extra feed, medicine for their livestock, or take other livelihood protection measures.

Case study: R4 Rural Resilience Initiative, Senegal & Ethiopia

The R4 Rural Resilience Initiative (previously the Horn of Africa Risk Transfer for Adaptation (HARITA) project) is a joint programme led by Swiss Re and Oxfam. Farmers are given the option to work on projects designed to reduce agricultural risk, such as improving their soils and reducing water run-off, in order to purchase weather-based index insurance. It gives farmers the option to pay for their premiums with labour, engaging them in community-led and locally designed climate adaptation initiatives such as reforestation and crop irrigation projects in return for insurance. This programme has reached 29% of Tigray's population.

"R4" refers to 4 strategies for managing risk: risk reduction, risk reserves, risk transfer, and prudent risk taking. Building 'risk reserves' means that farmers build a financial base, either individually or as a group, which can provide a buffer for short-term needs in a response to shocks, aiding a farmer's ability to cope with risk. Prudent risk taking allows the savings to be used as microcredit, allowing farmers to create an asset base.

The programme has since been scaled-up from 200 Ethiopian farmers in the original 2009 HARITA pilot in Tigray, to more than 24,000 farmers across 81 villages by 2014. From 2009-2012, insured farmers increased their savings by an average of 123% more than their uninsured counterparts. In some districts farmers with insurance were able to increase their number of oxen, while others enjoyed increased reserves of grain. For example, in Kola Tembien, farmers who bought insurance in both 2010 and 2012 increased their grain reserves by 254% compared to those who never bought insurance. Farmers who bought insurance also displayed a greater ability to diversify their income sources.

An additional 2,000 farmers in Senegal also benefitted from the R4 initiative in 2014, following the 2013 Senegalese launch of the scheme. Farmers report that they see insurance as a form of saving which helps them survive the inevitable droughts. One farmer said "it saves your money in time of good harvest and compensates you when the rains are not good. On the other hand, you benefit from increased yields as a result of the inputs and knowledge when the harvest is good."

6) Conclusion

Ignoring the connection between dangerous levels of climate change, food insecurity and malnutrition will exacerbate challenges to economic growth and development of poor countries. To prevent the most serious consequences of climate change on agricultural systems, food production, nutrition security and farmers' livelihoods, combined efforts of national governments, donors and the private sector are needed.

Investments need to be targeted at technologies and farming practices that enhance productivity sustainably. This submission has set out examples and case studies of such approaches, falling under the wider context of Sustainable Intensification.

Investments need to be made in all three areas of SI: ecological genetic and socio-economic intensification and include: precision agriculture, diversification, conventional plant breeding, biotechnology and providing enabling environments, including the provision of micro-insurances to farmers.

Further examples and case studies are available at:
http://ag4impact.org/database/