BACKGROUND PAPER

Session 1: Unlocking Africa's Agricultural Potentials for Transformation to Scale

Climate Smart Agriculture in the African Context

Prepared by:
Timothy O. Williams, Marloes Mul & Olufunke Cofie, (IWMI)
James Kinyangi (ILRI), Robert Zougmore (ICRISAT), George Wamukoya (COMESA),
Mary Nyasimi (ILRI), Paul Mapfumo (University of Zimbabwe),
Chinwe Ifejika Speranza (University of Bonn),
Dorothy Amwata (ILRI), Snorre Frid-Nielsen (University of Copenhagen), Samuel Partey (ICRISAT), Evan Girvetz (CIAT),
Todd Rosenstock (ICRAF) and Bruce Campbell (CIAT)

With inputs and contributions from FAO and UNEP

EXECUTIVE SUMMARY

- Agriculture remains vital to the economy of most African countries and its development has significant implications for food security and poverty reduction in the region. Increase in agricultural production over the past decades has mainly been due to land area expansion, with very little change in production techniques and limited improvement in yields. Currently one in four people remains malnourished in Africa.

- Land tenure insecurity for millions of smallholder farmers, including women, declining soil fertility, degraded ecosystems, poor market access, inadequate funding and inadequate infrastructure development continue to hinder agricultural development in Africa. These challenges are expected to be further exacerbated by climate change which has emerged as one of the major threats to agricultural and economic development in Africa. The IPCC's Fifth Assessment report indicates that Africa's climate is already changing and the impacts are already been felt. Although the UNFCCC places great emphasis on mitigation efforts (reducing greenhouse gas emissions and creating carbon sinks) the impact on climate change will not be seen immediately even if the most effective emission reduction measures are implemented. Therefore, developing adaptation mechanisms to deal with the negative effects of climate change must be a high priority.

- With the SDGs, the world is committing to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture", "ensure availability and sustainable management of water" and at the same time as "take urgent action to combat climate change and its impacts". In agriculture, these challenges and aspirations must be addressed together and simultaneously. Agriculture in the coming decades must feed the continent, serve as the engine of growth and adapt to climate change. Climate-smart agriculture (CSA) puts these conditions at the heart of transformational change in agriculture by concurrently pursuing increased productivity and resilience for food security while fostering mitigation where possible.

- CSA integrates all three dimensions of sustainable development and is aimed at (1) sustainably increasing agricultural productivity and incomes; (2) adapting and building resilience to climate change from the farm to national levels; and (3) developing opportunities to reduce greenhouse gas emissions from agriculture compared with past trends. It is an approach to identify the most suitable strategies according to national and local priorities and conditions to meet these three objectives. There is no such thing as an agricultural practice that is climate smart per se. Whether or not a particular practice or production system is climate smart depends upon the particular local climatic, biophysical, socio-economic and development context, which determines how far a particular practice or system can deliver on productivity increase, resilience and mitigation benefits.

- Ecosystem functions, including biodiversity and water services, are key to increasing resource efficiency and productivity and ensuring resilience. They are even more critical under the new realities of climate change. Ecosystem Based Adaptation (EBA)-driven agriculture linked to viable supply and demand side value chains, has an important role to play in developing an agricultural sector that is well integrated to the broader landscape, is climate resilient and environmentally and socially sustainable.

- For Africa to reap the potential benefits CSA, concrete actions must be taken to: enhance the evidence base to underpin strategic choices, promote and facilitate wider adoption by farmers of appropriate technologies; develop institutional arrangements to support, apply and scale-out CSA from the farm level to the agricultural landscape level; manage trade-offs in perspectives of farmers and policymakers; strengthen technical, analytical and implementation capacities; ensure policy frameworks and public investments are supportive of CSA; develop and implement effective risk-sharing schemes.

- Information relating to the investment needs for agriculture and climate finance is limited, and may not include all related investment needs. Available literature provided an estimate of cumulated needs for agriculture investment in sub-Saharan Africa, North Africa, and the Near East over the period 2005/7-2050, amounting to approximately US$ 2.1 trillion, or USD 48.5 billion per year. The amount of annual investment needed to adapt agriculture to climate change is comparatively low, as the expenditure required to counteract the negative impacts of climate change on nutrition are estimated to be only USD 3 billion per year. For African countries, climate change adaptation is considered to be more important than mitigation, but agricultural mitigation practices can provide adaptation synergies, justifying investment in mitigation. In particular in the livestock sector, improved management practices can result in both increased productivity and substantial reductions in emissions. If the African mitigation potential of 265 million tCO_2 per year up to 2030 is to be harnessed (e.g. through cropland management, grazing land management and the restoration of degraded lands), it will require investments of USD 2.6-5.3 billion per year (at a carbon price of USD 10-20 per ton). An additional 812 million t CO_2/year can be mitigated through preventing deforestation driven by agricultural expansion, through forest conservation combined with sustainable intensification practices that are capable of achieving food security. Avoiding 75% of total deforestation in Africa has an additional cost of USD 8.1-16.2 billion per year. However, these estimates do not take into account additional costs, such as research and capacity building, which must be equally financed to ensure that research-based evidence informs decision making.

- Financing for CSA needs to be scaled up considerably. Climate financing mechanisms need to give more attention to agriculture and CSA and the sector's particular opportunity of combining adaptation and mitigation benefits while enhancing food security. Strengthening capacities of African countries to access these funds is also essential in this context. The main financing source for public investment in CSA, however, will be the regular agricultural development budget. CSA should not be treated as an "add on" approach. Rather, the approach adopted within the context of CAADP to screen agricultural investments in the National Agricultural Investment Plans (NAIPs) with a climate smart lens to strengthen the climate-smartness of investment plans and programmes and pursue resource mobilization for their implementation should be further strengthened.

- Actions are required from a broad range of stakeholders from government and the public sector, private sector, academia and research, NGOs and CSOs among others as implied in SDG 17, and a practical platform for their engagement and delivery of solutions. Some opportunities are emerging for promoting CSA approaches in Africa. At the 23rd ordinary session of the African Union held in June 2014 in Malabo, Equatorial Guinea, African leaders endorsed the inclusion of CSA in the NEPAD programme on agriculture and climate change. The session also led to the development of the African Climate Smart Agriculture Coordination Platform which is expected to collaborate with Regional Economic Communities (RECs) and Non-Governmental Organisations (NGOs) in targeting 25 million farm households by 2025. Moreover, The NEPAD Heads of State and Government Orientation Committee at its 31st session also welcomed the innovative partnership between NPCA and major global NGOs to strengthen grass-root adaptive capacity to climate change and boost agricultural productivity. The meeting requested NEPAD Planning and Coordinating Agency (NPCA) in collaboration with FAO to provide urgent technical assistance to AU Member States to implement the CSA programme and that the African Development Bank (AfDB) and partners should provide support to African countries on investments in CSA.

1. BACKGROUND

Agriculture in Africa must undergo a major transformation in the coming decades in order to meet the intertwined challenges of achieving food security, reducing poverty and responding to climate change without depletion of the natural resource base. Although agriculture looms large in the economy of Africa, employing more than 60% of the population and contributing 25-34% of the GDP, productivity is low and food insecurity is high. Reviewing the different dimensions of food insecurity around the world, FAO, IFAD & WFP (2014), reported that food availability remains low in SSA and slow progress has been achieved in improving access to food due to sluggish income growth, high poverty rates and poor rural infrastructure which hampers physical and distributional access. At the same time the stability of food supplies has deteriorated owing to political instability, civil wars and outbreaks of deadly diseases. As a result, one in four people remains malnourished. The region also faces challenges in food utilization as indicated by high prevalence of stunted and underweight children and in improving the dietary quality and diversity, particularly for the poor.

Currently, about 48% of Africa’s population or approximately 450 million people live in extreme poverty, on less than US$1.25 per day, with 63% of the continent’s poor living in rural areas depending on agriculture for their livelihoods (World Bank, 2015). At the same time, the continent is experiencing rapid increase in population and urbanization. Half of the 2.4 billion increase in global population that will occur between 2013 and 2050 will occur in sub-Saharan Africa (SSA), and 56% of Africa’s population is projected to live in urban areas by 2025(UNDESA, 2013 and 2014). Meeting future demand for food would require a big increase in supply. Water and land are likely to present the greatest challenges on the food supply side, given the dwindling availability of arable land and water resources in some parts of Africa and because many of the smallholder farmers and pastoralists that form the backbone of agriculture in Africa are utilizing a degraded natural resource base. The ecosystems that provide healthy surface water and groundwater as well as food, fodder and fibre are deteriorating. With these challenges, agriculture on the African continent cannot proceed in a business-as-usual manner. There is evidence that growth in agriculture is the most effective and equitable strategy for reducing poverty and improving food security in developing countries. African agriculture therefore needs to transform itself to improve food and nutrition security of the growing population and to provide a basis for economic growth and poverty reduction.

However, climate change will make this transformation task more difficult. In North Africa annual rainfall is likely to decrease by 4–27% leading to droughts and increased salinity (Barkhordarian et al., 2013; Radhouane, 2013; IPCC, 2014). The IPCC estimates that crop and fodder growing periods in western and southern Africa may shorten by an average of 20% by 2050, causing a 40% decline in cereal yields and a reduction in cereal biomass for livestock (Thornton et al., 2009a, 2009b and 2009c; FAO, 2010a; Lobell et al., 2011).Western, central and southern Africa may experience a decline in mean annual rainfall of 4%, 5% and 5%, respectively (Hoerling et al., 2006; IPCC, 2007; IPCC, 2014). Only in East Africa is rainfall anticipated to increase. The other four regions are likely to experience drought conditions that will be more frequent, more intense and longer lasting. As a result, the area of arid and semiarid land is likely to increase by 5–8% by 2080 (IPCC, 2007; Elrafy, 2009). Considering the sensitivity of the prevailing farming systems to drought, crop yields are projected to decline by as much as 50% by 2020 across the continent. Moreover, crop net revenues may fall by up to

90% by 2100 (Jones and Thornton, 2008). Furthermore, livestock producers in agropastoral and pastoral systems, and mixed crop–livestock systems are likely to be affected by a drop in the availability of animal feed and water, as well as the changing severity and distribution of pests and diseases affecting both livestock and fodder (Thornton et al., 2007, Jones and Thornton, 2008). The IPCC's Fifth Assessment report states that "climate change will amplify existing stress on water availability for society and the natural environment in Africa and on agricultural systems, particularly in semi-arid environments. FAO (2014) noted that 'water mediates much of climate change impact on agriculture and increased water scarcity in many regions of the world present a major challenge for climate adaptation, food security and nutrition'.

Climate-smart agriculture (CSA), a concept developed by FAO, is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2013). It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing the food security, ecosystems management and climate change challenges. It is comprised of three main pillars:

- Sustainably increasing agricultural productivity and incomes;
- Adapting and building resilience to climate change;
- Reducing and/or removing greenhouse gases emissions, where possible.

CSA is not a prescribed practice or a specific technology that can be universally applied. It is an approach that requires site-specific assessments of the social, economic and environmental conditions to identify appropriate agricultural production technologies and practices. A key component of CSA is integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use.

At the farm level, CSA aims to strengthen livelihoods and food security, especially of smallholders, by improving the management and use of natural resources and adopting appropriate approaches and technologies for the production, processing and marketing of agricultural commodities. At the national level, CSA seeks to support countries in putting in place the necessary policy, technical and financial mechanisms to mainstream climate change adaptation and mitigation into agricultural sectors and provide a basis for operationalizing sustainable agricultural development under changing conditions.

Efforts to promote CSA in Africa are advancing at the policy level. At the 23rd ordinary session of the African Union (AU) held in June 2014 in Malabo, Equitorial Guinea, African leaders endorsed the inclusion of CSA in the NEPAD programme on agriculture and climate change. The session also led to the development of the African Climate Smart Agriculture Alliance which is expected to enable the NEPAD Planning and Coordinating Agency to collaborate with Regional Economic Communities (RECs) and Non-Governmental Organisations (NGOs) in targeting 25 million farm households by 2025. As a follow up action at the sub-continental level, ECOWAS, for instance, also put in place the West Africa CSA Alliance to support the mainstreaming of CSA into the ECOWAP/CAADP programmes (ECOWAS, 2015; Zougmoré et al., 2015). The NEPAD Heads of State and Government Orientation Committee at its 31st session also welcomed the innovative partnership between NPCA and major global NGOs to strengthen grass-root adaptive capacity to climate change and boost agricultural productivity.

The meeting requested NPCA in collaboration with FAO to provide urgent technical assistance to AU Member States to implement the CSA programme and that the African Development Bank (AfDB) and partners should provide support to African countries on investments in the CSA field (African Union, 2014). Several countries in Africa already screened their National Agriculture Investment Plans using a framework developed by FAO in consultation with NPCA and identified specific additional investment needs for CSA implementation and upscaling (FAO, 2012).

Although there has been a rapid uptake of CSA by national organizations and the international community, implementation of the approach is still in its infancy and equally challenging partly due to lack of tools, capacity and experience. This technical paper analyzes the challenges and opportunities and identifies the technical, policy and financial solutions to improve and sustain implementation of CSA across African countries.

2. CHALLENGES

CSA faces a number challenges related to the conceptual understanding, practice, policy environment and financing of the approach. Specific challenges that are considered as needing critical attention and intervention(s) are outlined below:

- **Lack of practical understanding of the approach.** CSA approach is obviously attractive and compelling in principle, but its application under Africa's diverse agro-ecologies and highly heterogeneous farming systems, socio-economic conditions and policies still requires concrete examples of success. The evidence of how such successes are measured and achieved is of critical importance (Neate, 2013). Gleaning clear empirical messages to inform farmers and policy makers and support any scaling up initiatives will depend on how the CSA concept is understood in practices, allowing for adaptations and continuous two-way feedback mechanisms between researchers and practitioners, farmers and policy makers.

- **Lack of data and information and appropriate analytical tools at local and national levels**. In many African countries, there are no long-term climatic and landscape level data. Where some data exist they are dispersed and difficult to access. Global models of climate change are at scale and resolution difficult for local, national or regional managers to work with (McCornick et al., 2013). Capacity and analytical tools to downscale the results of global models to regional, national and watershed scales are not readily available in most countries. As a result, decision makers lack knowledge of current and future projected effects of climate change in their country and the implications for agricultural practices, food security and natural resource management. The lack of information, limited human and institutional capacity as well as lack of research-based evidence impedes the ability of decision makers to target CSA implementation to areas most at risk and to implement adequate financing plans. Initiatives such as the EPIC programme[1] in Malawi and Zambia which focuses on building the evidence base to identify country specific climate smart agricultural practices; increasing policy and research capacity to integrate climate change issues into agricultural and food security planning and vice versa; and developing investment proposals for scaling up CSA activities that are linked to climate

[1] **Economics and Policy Innovations for Climate-Smart Agriculture (EPIC)** programme - http://www.fao.org/climatechange/epic/home/en/

financing sources as well as traditional agricultural investment finance sources, need to be scaled up.

- **Lack of adequate investment at the national/regional level and high up-front cost of investment in CSA at the farm level**. Increasing climate adaptation and resilience of agriculture requires investments in infrastructure at different scales, from regional to national to river basin and farm levels. The Africa's Infrastructure Diagnostic Report (Foster and Briceño-Garmendia, 2010) reported a deficit in infrastructure investment (in roads, transportation, communication, power, agricultural water infrastructure and development and management of water resources that are germane to CSA. At the farm-level, farmers have limited assets that they can invest on their own and lack access to financial services that can allow them to invest in CSA. Also, few investors are on the market to offer loans leaving government agencies, donors and NGOs to subsidize famers' investment in CSA. It has been argued that there is a lack of clear business case for CSA practices to attract investors and the credit market sector to invest in CSA. There are few documented examples of CSA practices in Africa, and most of these are on conservation agriculture (CA) and agroforestry (AF) (Kassam et al., 2009; Garrity et al., 2011). However, the adoption of the two technological packages by the predominantly smallholder farmers in Africa has been generally poor and in some cases their applicability in smallholder systems contested (Giller et al., 2009; Sumberg and Thompson, 2012). A related point is the lack of investment in ecosystem-based adaptation (EBA) approaches. CSA accommodates EBA approaches so as to better understand the inter-linkages between and water use, agricultural production and ecosystems services within and external to agroecosystems. Sub-Saharan Africa's loss to agro-ecosystem degradation is estimated at 6.6million tonnes of grain annually, enough to meet annual calorific needs of approximately 31 million people (Munang et al., 2015). Although the effectiveness of the EBA approach as a component of CSA in optimizing Africa's agricultural productivity has been documented (Munang et al, 2015) the main policies to enhance agricultural productivity give minimal consideration to ecosystems that underpin food production.

- **Inadequate coordinated, supportive and enabling policy frameworks**. Implementing CSA requires the development of supportive policies and frameworks, as well as coordination across programs and institutions responsible for agriculture, climate change, food security, land use, water management and energy generation to avoid inconsistencies and promote harmonization of efforts. Existing policy frameworks, whose formulation were not informed by the need or demand for CSA, are likely to present compatibility challenges. The emerging evidence of the impact of climate change also point towards a need to clearly enumerate the major elements and effects of climate change in order to identify and inform CSA practices and innovations. Climate change will be mostly affecting agriculture through three main drivers: (i) temperature changes; (ii) atmosphere GHG concentration changes; and (iii) changes in rainy season regime in terms of length, total rainfall amount, and distribution. According to the IPCC, while it is very likely that temperature and CO_2 concentration will keep on increasing during the 21st century in SSA, low confidence exists in projections regarding length, total rainfall amount, or distribution of the rainy season (Christensen et al., 2013; IPCC, 2014). Moreover, coordination and integration of policies and plans have proved problematic in Africa. For instance, a recent review of the regional agricultural investment program (RAIP) and national agricultural investment programs (NAIPs) of 15 member states of the Economic Community of West African States (ECOWAS), revealed that only one country, Burkina Faso, explicit linked climate change adaptation to its NAIP. The remaining 14 countries failed to mainstream climate change adaptation into their NAIPs. But in all countries strategies for increasing climate resilience are captured in the National Adaptation Programs of Action (Mul et al., 2015). There is lack of institutional arrangements that are needed for CSA to upscale from the farm to the landscape

- **Socioeconomic constraints at the farm level**. Although farmers have always adapted and coped with climate variability manifested, for example, in delayed onset of rains, seasonal water deficit and increasing seasonal maximum temperature, they often lack knowledge about potential feasible options for adapting their production systems to increasing frequency and severity of extreme weather events (droughts and floods) and other climate changes. Another constraint concerns land tenure and access to land and water resources. Millions of poor farmers, including women hold tenuous and unsecured water and land rights in many parts of SSA. Existing customary and institutional factors as well new drivers, for example, large-scale foreign investment in agricultural land that leads to the displacement of current poor land users have exacerbated this state of affairs (Williams, et al., 2012; Williams, 2014).. At another level, lack of accurate and timely information and technical advisory services, unavailability and lack of access to inputs, including suitable crop varieties constrain their ability to assess the risks and benefits of CSA and make informed investment decisions. Competing resource use (e.g. labour, cash, biomass) at the farm scale have been a major constraining factor. Furthermore, smallholders in particular face obstacles in gaining access to domestic, regional and international markets.

- **Inadequate empowerment of women and youth.** Women contribute significantly to food production in Africa, yet remain marginalized and lack access to factors of production. Gender stereotypes on such issues as land and water rights, education, access to technologies, labour, capital, support services and credit, are some of the stumbling blocks to women's effective participation in the agricultural sector. Overlooking women means Africa is losing out on a great income and livelihood creating opportunity. The World Bank estimates that if women worldwide had equal access to productive resources (seeds, extension services, etc.), 100-150 million fewer people would go hungry every day. Empowering women is essential to unlocking Africa's agricultural productivity. On youth, 60% of Africa's population is in the 15-34 year bracket and this presents an opportunity to reap a demographic dividend on the continent. Youths and women should be empowered through education, access to affordable capital, appropriate mentorship programmmes to enable them play their role in the agricultural sector.

- **Lack of adequate and innovative financing mechanisms and effective risk-sharing schemes**. In many countries there are not yet in place financing plans to promote the uptake of CSA, yet the transition to climate-smart agricultural development pathways requires new investments. "As farmers in Africa face major risks arising from the effects of climatic hazards, they also face the challenge of managing risks associated with the high costs (at least initial costs) of adopting new technologies (e.g. conservation agriculture and agroforestry) whose benefits often only come after several years/seasons) of production. Most of the farmers have little or no access to credit, micro-financing and/or insurance." (Mapfumo et al., 2015: 41-43).

- **Difficulty in managing trade-offs from the farmers' and policymakers' perspectives.** There is often a disconnection between farmers and policy makers in the agricultural sector with respect to priorities for resource management. One of the underlying causes of this problem is the difference in objectives between the two groups. Prioritization of the three objectives of CSA (increased productivity, adaptation and reduction of greenhouse gaseous emissions where possible) is likely to differ among key stakeholders including farmers, government officers and policy makers. This has implications on how CSA practices are ultimately evaluated, and whether or not policy makers and practitioners at various levels will be attracted to the advocated CSA options for financial considerations.

3. OPPORTUNITIES

1. **Africa's natural and human resources.** Africa holds 65% of the world's arable land and 10% of internal renewable fresh water sources. With a growing middle class currently estimated at 300million people, the African food market alone is projected to grow to USD 150 billion by 2030. Properly harnessed, the entire agriculture and agri-business sector is projected to grow to be worth an estimated USD 1trillion by 2030. When optimized, growth in agriculture is at least two to four times more effective in reducing poverty than in other sectors. Agricultural growth also stimulates productivity in other sectors e.g. processing, transport etc. whose value chains link with the agro-chain, hence results in economy wide impacts. The World Bank reports that in Africa, a 10% increase in crop yields translates to approximately a 7% reduction in poverty. This potential in natural and human resources is an opportunity that can be grasped through the provision of policy and fiscal incentives for the promotion of sustainable CSA approaches.

2. **Evolving and increasing set of analytical tools and decision support models.** A number of new studies, analytical tools and decision support models are becoming available that can help to make informed decision about CSA. A few examples of decision support tools are highlighted below:

    a. FAO in consultation with NEPAD and the Worldbank developed a screening framework in the context of CAADP to identify priority areas for CSA financing based on existing NAIPS. This framework helps to identify potential activities or programs planned in the current NAIP that have high CSA potential, as well as those that could potentially have high CSA potential but need further refinement and clarification to determine CSA potential.(Table 1).

    b. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) leads capacity building of African farmers and up-scaling of CSA technologies through strategic partnership and using several decision support tools developed by the research team.

    c. UNEP works to support decision-makers in balancing the synergies and trade-offs that arise in the choices to be made on the potential paths to transformation of agriculture in Africa. It does so by developing tools and guidance to assess these synergies and trade-offs, and by implementing scenario development and analysis that help in clarifying the potential consequences of existing trends and alternative future policy and management options for food production under changing patterns of consumption and production and under a changing climate.

IWMI scientists have developed an analytical tool to evaluate the need for water storage and its likely effectiveness under existing and possible future climate conditions. This has been applied in the Volta Basin, and the Ethiopian part of the Blue Nile Basin. The tool considers reliability, resilience, and vulnerability, and the economic, social, and environmental aspects of water storage options for different areas. The results can be shown in a manner that illustrates the trade-off between the key characteristics of a storage option (Figure 1)

Table 1. Categories of climate-smart agriculture investments[2]

Analytical categories for climate-smart investments: resilience		
Adaptation	**Dimensions of system resilience**	**Elements of system resilience**
Reducing vulnerability related to slow onset climate change (increasing system resilience)	Increase physical resilience	Water quantity and quality, soil resource & soil fertility, seed resources, livestock
	Increase economic resilience	Income diversification, risk management, off-farm earnings, diversity of employment opportunities, health and social services, markets
	Increase human and social resilience	Extension and access to technical know-how, farmer organization, connection to social networks, education and training, information management
Reducing vulnerability to extreme events		
Analytical categories for climate-smartness: mitigation		
Mitigation : Comparison against a business-as-usual scenario		
• GHG emission reductions: GHG reduced (tCO_2/ha) (net balance)		
• GHG emission efficiency: GHG reduced from increased efficiency of production (tCO_2/unit of product) (net balance)		
• Removing emissions - Carbon sequestration: C sequestered (tCO_2/ha) (net balance)		

[2] Based upon FAO, 2012. Identifying opportunities for climate-smart agriculture investments in Africa. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/015/an112e/an112e00.pdf

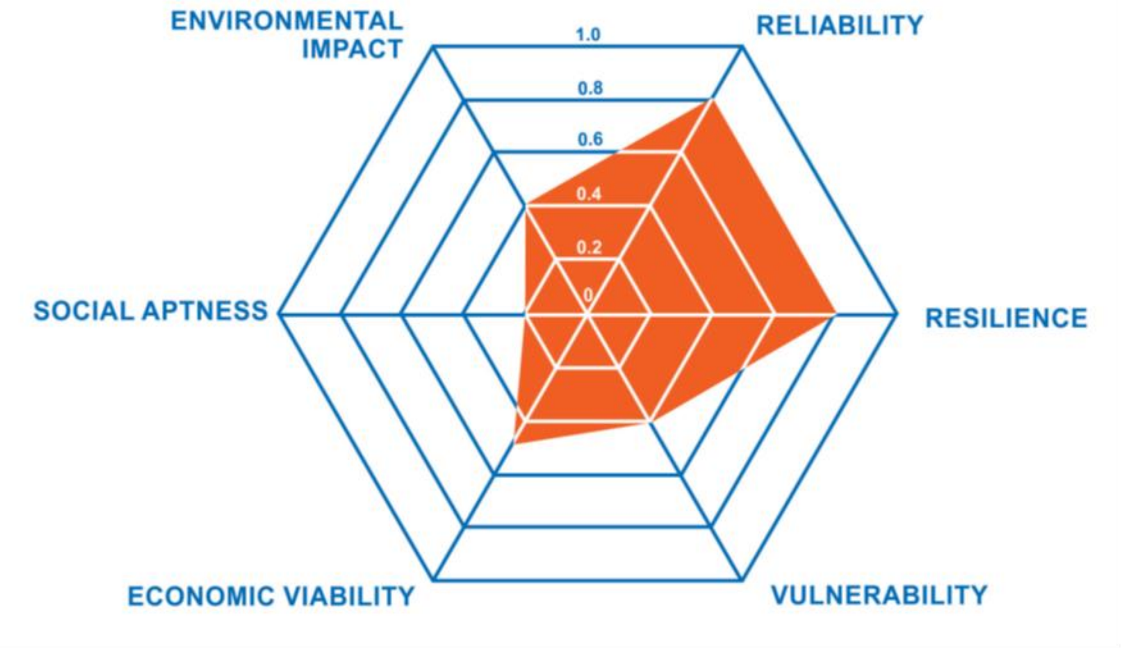

Fig 1. Analytical tool for evaluating water storage options (source: McCartney et al. 2013b)

Their analyses showed that throughout sub-Saharan Africa, the greatest need for storage was in the Sahelian zone, the Horn of Africa, and southern Africa, with local hot spots of need in southern Angola, Rwanda, Burundi, and Uganda, as well as in Malawi and Mozambique. In Ethiopia and Ghana, the greatest need was not in areas with the least rainfall as might have been anticipated, but rather in the areas with the highest population densities. Based on changes anticipated for a 'middle impact' climate change scenario, the effectiveness of storage will most likely decrease in both the Volta and Blue Nile basins. The analytical tool provides an initial step in more rigorous approaches to assessing investment in agricultural water storage (McCartney and Smakhtin 2010; McCartney et al. 2013b).

IWMI studies have also examined a wide range of options for storing water in different social and ecological circumstances and at different scales (Figure 2). Scientists investigated how much water a basin can store under current and increasing variability, types of storage for different situations, types of storage that will provide water when it is needed, and the advantages and disadvantages of different types and combinations of water storage.

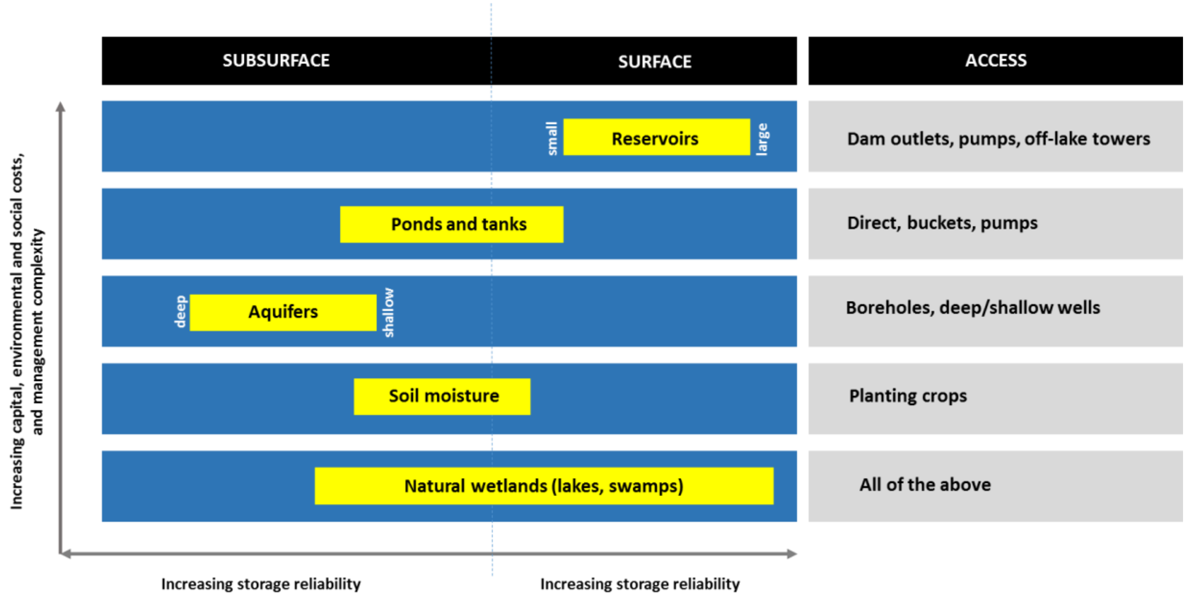

Fig 2.Options for storing water at various scales (Source: McCartney and Smakhtin, 2010

All storage options have costs as well as benefits and in any given location the extent to which a particular type will provide a reliable water supply will be different. Any water storage structure – from a small tank to a large dam – will have an effect on the natural system in which it lies. Arrangements that combine several kinds of water storage are likely to be more dependable than those based on a single type. There will rarely be an ideal combination and, in most instances, there will be tradeoffs. It is important to look for ways to store water across the continuum from small to large scales and to use complementary water-saving technologies and practices.

3. **Opportunities specific to sub-regions:** several areas hold prospects for CSA in specific sub-regions of Africa. Some of these are highlighted below:

    a. *Integrated solutions for sustainable agricultural intensification in sub Saharan Africa*: Widespread soil fertility decline and land degradation in SSA necessitate a landscape approach to agricultural systems development and climate change adaptation in the region. The development of CSA best practices will need to focus on pathways to intensification of cropping systems, increasing efficiencies in livestock production systems, conservation of soil and water resources, and adaptive management of natural resources at both farm and landscape levels. However, this needs to be combined with the development of a supportive policy environment and the strengthening of advisory systems, including research and extension, to enable local producers to select and adopt practices that are climate smart in their particular context and location.

    b. *Recovery of forest based farming in Central Africa*: Opportunities for CSA in Central Africa arise from a growing but food-insecure population, and for which increasing agricultural productivity does not only enhance food security but also save forest resources. Depletion of forests in the forest-based farming systems will most likely lead to large greenhouse gas emissions and loss of ecosystems services. Required are CSA options that limit expansion of cultivated areas into forests or alternatively seek to establish new agricultural production systems that can at the least restore ecosystem services and values through alternative tree crops.

c. *Horticulture led growth in Northern Africa*: Increasing agriculture productivity and narrowing the current yield gaps for staple crops is a key priority. For example cereal yields in Algeria, Morocco, Tunisia and Egypt are still < 1.5 t ha-1 compared with > 2.5 t ha-1 in other regions of the Mediterranean (Alvarez-Coque, 2012). Increasing water scarcity (except in the highland agro-ecozones) and rising air temperatures coupled with diminishing soil fertility and accelerated soil erosion are already identified as major impediments to the goal for increasing productivity and enhancing resilience in North Africa. However, opportunities for increasing tree-based horticultural production are emerging. As investments in soil and water management and irrigation systems increase, opportunities also exist for employing CSA approaches centred on resource conserving technologies and management practices that enhance the efficiency with which key resources such as land, water, labour, nutrients and plant-based organic biomass are used

d. *Crop-livestock integration in Southern Africa:* Apart from the projected reduction in rainfall and an increase in frequency of drought for a region that is already largely semi-arid, Southern Africa has some of the most infertile and unproductive soils on the continent. As earlier discussed for East Africa, increasing crop productivity through intensification options is a priority for the region. The sub-region also has some of the least diversified cropping systems and a critical challenge in addressing chronic food and nutrient insecurity and land degradation is: "how to get the region's smallholder communities out of the 'Maize Poverty Trap" (Mapfumo, 2011). This entails ensuring household self-sufficiency in staple maize through production or alternative access mechanism before communities can invest and/or diversify into other agricultural and non-agricultural livelihood options.

e. *Rice and aquaculture systems supplement cereal and tuber staple crops in West Africa:* West Africa already has a high and fast growing population. There is therefore limited scope for increasing agricultural production through extensification. In recent years, the region has witnessed an expansion of the maize mixed farming system in the Sahelian and sub-humid zones. There is also growing emphasis on agroforestry and rangeland management in dry regions including Sahelian and Guinean zones and dominant pastoral systems where livestock feed resources will otherwise decline. On the other hand, the increasing prospects for both smallholder and large scale irrigated systems in these semi-arid zones are likely to change the 'landscape' for crop-livestock interactions and open new opportunities for CSA. Opportunities for employing CSA approaches to simultaneously increase crop productivity and reduce greenhouse gas emissions are also likely to emerge in irrigated rice and fisheries (including aquaculture) systems.

f. *Water-smart agriculture in East Africa*. Is an approach that is being used by a wide-range of farmer support organizations to support smallholders through four interrelated elements: a) making better use of green water (rainfall and soil moisture) to avoid reliance on abstraction of blue water (which already accounts for more than 70% of total global abstractions); b) where sensible and feasible, development of supplementary irrigation based on principles of good resource governance and water use efficiency; c) stronger linking of farmers to markets opportunities and value chains that can provide opportunities for substantial income enhancements, particularly through dry season production; and d) a stronger emphasis on combined soil and water management to enhance soil fertility, reduce degradation and increase capacity to deliver water to root systems during critical growing periods. [Nicol et al, 2015].

4. SUGGESTED ACTIONS/THE WAY FORWARD

Cognizant of the above development challenges and opportunities for transforming agriculture to underpin climate resilient livelihood systems and foster food and nutrition security as well as sustainable natural resources utilization, agricultural transformation through CSA will require the following necessary actions. These priority action-oriented solutions also capture the priorities highlighted in AGRA's 2014 Africa Agriculture Status Report for enhancing adaptation within Africa's agricultural sector.

A. **Promote climate-smart, context-driven approaches and solutions. This will require investing in ecosystem-based approaches, new technologies and an enabling environment to enhance and facilitate uptake of CSA.** "CSA builds on existing experience. Therefore, knowledge of sustainable agricultural development, and sustainable intensification founded on agro ecological approaches is central to CSA (Campbell, et al., 2014). Sustainable intensification fosters more efficient resource use, and contributes to adaptation and mitigation through effects on farm productivity and incomes, and reduced emissions per unit of product" (AGRA, 2014: 183-185). Equally needed are stress-tolerant crop varieties and livestock breeds, improved analytical tools and decision support models and small-scale irrigation technologies suitable for smallholder farmers (Giordano, et al., 2012). Moreover, it is necessary to promote sustainable consumption by reducing food loss and waste and promoting balanced dietary habits.

B. **Adapt water management to improve food security within the context of CSA.** Adapting water management to climate change entails four main pillars (McCornick et al., 2013). These include: 1) assessment of water resources and risk to agricultural production; 2) rethinking of water storage, including banking of ground water, managing aquifer recharge and retention and conservation of soil moisture; 3) producing more food per unit of water through boosting rainfed agriculture and managing climate-induced water variability through supplementary irrigation; and 4) boosting resilience through uptake of improved agricultural and water management technologies and income diversification strategies.

C. **Improve coordination of policies and strengthen local national and regional institutions to support the implementation of climate-smart agriculture: "**Without appropriate institutional structures in place, CSA-related innovations may overwhelm smallholder farmers. Strong institutional support is required to: promote inclusivity in decision making; improve the dissemination of information; provide financial support and access to markets; provide insurance to cope with risks associated with climate shocks and the adoption of new practices; and support farmers' collaborative actions. Many institutions and stakeholders, including farmers (and farmer organizations), private sector entities, public sector organizations, research institutes, educational institutions, and Civil Society Organizations can play important roles in supporting the adoption of climate-smart agriculture. In addition, national governments not only need to coordinate financing for

CSA technologies and practices, but also have the flexibility to plan and work across sectors. As markets become increasingly important, private sector players such as the smallholder farmers themselves become significant. There are growing opportunities for inclusive partnerships involving governments, private sector agribusinesses, and development organizations to collaborate on CSA issues such as carbon finance". (AGRA, 2014: 183-185)

D. **Develop innovative financing schemes to unlock both agriculture and climate finance to improve access of smallholders, governments and private sector entrepreneurs to capital needed to develop and implement CSA: "**Strengthening financing opportunities at all levels and for different risks is important, as is the bundling of insurance and agricultural credits. Mobilize AECF, cooperative banks, and national banks for support leading to a partnership-based approach to innovative financing. There is need to develop a programmatic approach to develop a pipeline of investments in support of climate-smart agriculture, which should be country driven. In assuming a leadership role, governments can better organize resource flows to avoid duplication, fill financing gaps and create synergies. In addition, development partners should agree on implementation arrangements for identified investments based on their comparative advantages; synergies should be identified and collaborative arrangements agreed upon. Directing climate finance to support institutional investments that can accelerate adoption of practices for increasing resource-use efficiency is an important step towards climate-resilient development in agriculture. Public sector finance for adaptation and mitigation is likely to provide the most important sources of climate finance for CSA in developing countries. Funding sources could include: bilateral donors; multilateral financial institutions; the Global Environment Facility (GEF); and the emerging Green Climate Fund that was established by the UNFCCC, which can channel funds through national policy instruments such as Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Programs (NAPs)." (AGRA, 2014: 183-185)

E. **Raise the level of national investments in agriculture but invest wisely and weigh up costs and benefits.** Rigorous analysis of proposed investments in infrastructure and technologies can help decision makers to invest wisely and avoid unintended consequences. Assessment and modeling approaches used by IWMI enable countries which have limited planning capacity to envision the likely outcomes of adaptation strategies under various scenarios and to consider alternatives and tradeoffs (McCornick et al., 2013). Moreover, "finite public resources can be more selectively targeted by using the following criteria: For technologies that generate significant private returns, grant funding or loans may be more suitable to overcoming adoption barriers. For technologies such as conservation agriculture that require specific machinery inputs and significant up-front costs, payment for an ecosystem services scheme could be used to support farmers, break the adoption barrier and support the development of a commercial market for small-scale mechanization. In some cases, relatively affordable technologies that generate quick and demonstrable benefits may warrant priority and potentially establish some of the channels through which more sophisticated technologies are dispersed in the future. Nationally owned climate-smart agricultural policies and action frameworks will increase adoption of technologies by farmers. There is also the potential for carbon finance to support farmers during the initial period before the trees in agroforestry systems generate an economic return. Larger and more coordinated investments in CSA interventions need to be harnessed and allocated appropriately in order to generate the highest returns for sustainable agricultural growth. Changes taking place in the agricultural sector need to be planned for, including adaptation and mitigation as essential part of developing CSA strategies, investments and financing plans. Increasing agricultural mechanization and investments in rural services for farm machinery should be encouraged in order to enhance food security. Governments should ensure that the Maputo Declaration calling for increasing budgets for agriculture is achieved" (AGRA, 2014: 183-185).

Box 1. Short-, medium- and long-term action points

The Economic Community for West African States (ECOWAS) provide several recommendations which can help guide the time-scale of CSA action points.

In the short term, focus should be directed towards adding value to climate change adaptation actions. Adaptation measures that have been successfully tested for wide application within a given region should be scaled up, depending on the context of the country, while taking agro-ecological zones into account. Furthermore, the dialogue between stakeholders should be structured for better convergence and coordination of initiatives relating to climate change, in order to effectively mainstream the climate dimension. Key actions include establishing interdisciplinary, multi-stakeholder, and/or cross-sector working groups (ECOWAS, 2015: 2-3).

In the medium- and long-term, focus should be on leading research to generate more technological innovations across several thematic areas. This should include little-studied areas such as fisheries, bio-agents control in the conditions of climate change, and the economic behavioural adaptation of communities to climate change impacts and mitigation. More knowledge generation is needed for adapted germplasm breeding regarding plant and animal physiologies under water and heat stress conditions. Also, methodological approaches are needed, likely based on the combination of farm and capacity building activities with research outputs, for improving mass diffusion of research outputs and best practice (ECOWAS, 2014: 26). Finally, the development of advanced decision-making tools is to be encouraged, while simultaneously creating mechanisms to ensure their effective use.

Who should be involved and what roles would each partner play?

- National governments and relevant ministries and agencies, AfDB, sub-regional and national development banks, private sector organizations, and NGOs.
- Partnerships networks: including Africa CSA alliance, West Africa alliance, Global CSA alliance, EBAFOSA.
- International Agricultural Research Centers: The institutions convoked to develop this technical paper have mandates that will enable them to contribute technical knowledge and expertise to the implementation of CSA in African countries. CCAFS addresses 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. Led by the International Center for Tropical Agriculture (CIAT), CCAFS is a collaboration among all 15 CGIAR research centers and coordinates with the other CGIAR research programs. CCAFS brings together the world's best 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. Learn more about our partners. IWMI works as a think tank to provide science-based solutions, products and tools and to facilitate capacity strengthening and uptake of research findings. IWMI has offices in Eastern, Southern, North and West Africa and leads the CGIAR Research Program on Water, Land and Ecosystems which combines

the resources of 11 CGIAR centers, FAO and numerous national regional and international partners to provide an integrated approach to natural resource management research. WLE promotes an approach to sustainable intensification in which a healthy functioning ecosystem is seen as a prerequisite to agricultural development, resilience of food systems and human well-being.

- UN Agencies: UNEP focuses on supporting the adoption of CSA through ecological approaches to increasing food productivity in agriculturally dominated landscapes, whilst maintaining important services produced by natural habitats such as forests, wetlands and rangelands. Healthy ecosystems provide services, including for example water (quality and quantity), nutrients, energy, and pollinators that underpin agricultural productivity, particularly in smallholder dominated landscapes. The actual economic value of such ecosystem services is still underestimated. Recent economic valuation studies underline the importance of a better understanding and inclusion of Natural Capital and Ecosystem Services consideration when developing plans for a more sustainable productive sector. Examples of such emerging studies include the upcoming study on The Economics of Ecosystem Services and Biodiversity for Agriculture and Food production (TEEB-AgF) and the Economic of Land Degradation study (ELD). Resources can be found at: http://www.teebweb.org/agriculture-and-food/ and http://www.ese-valuation.org/index.php/ese-unit/vantage and http://www.ese-valuation.org/index.php/res/publication/22-food-and-ecological-security-identifying-synergy-and-trade-offs. UNEP was also instrumental in the formation of the Ecosystems Based Adaptation for Food Security Assembly (EBAFOSA)[3], a pan-African policy framework and implementation platform, a solutions space bringing together key stakeholders and actors along the entire EBA-driven agriculture value chain, to forge partnerships aimed at upscaling EBA-driven agriculture and its value chains into policy & implementation through a country driven process to ensure food security, climate adaptation, enhanced productivity of ecosystems and link to supply and demand side value chains

- **FAO** is committed to supporting CSA initiatives at all levels and scales. It implements a large portfolio of projects that is aimed at increasing agricultural productivity and adaptation to climate change in Africa. FAO is also continuing to develop methods, tools, approaches and information that assist in the adoption of CSA and the development of appropriate policy frameworks, and supports countries in their application. CSA is a major area of work under its current strategic programme. FAO also supported NEPAD to facilitate the establishment of the African CSA Alliance and at the regional level FAO is also supporting the regional alliances, including the West African CSA Alliance. FAO has supported linking the national, regional and continental CSA agendas to the National and Regional Agricultural Investment Programmes and the NEPAD Comprehensive African Agricultural Development Programme (CAADP). The FAO country representations are working with the relevant national authorities to facilitate these programmes, and

[3] Established during the 2nd Africa Ecosystems Based Adaptation for Food Security Conference (http://www.afsac2.aaknet.org/) at the UNEP, this platform is being rolled out across all African countries in a phased out process and to date, about 35 countries are involved in this rollout. More on this is available online at http://www.ebafosa.org/

particularly to promote integration of the CSA approach in the national agricultural development strategies and National Adaptation Plans (NAPs).

5. ESTIMATED COSTS AND POSSIBLE FINANCING SOURCES

5.1 Investment needs for agriculture in Africa

Generally, information relating to the investment needs for agriculture and climate finance is limited, and may not include all related investment needs (FAO, 2012: 20). Schmidhuber et al. (2009) provided an estimate of cumulated needs for agriculture investment in sub-Saharan Africa, North Africa, and the Near East over the period 2005/7-2050, amounting to approximately USD 2.1 trillion, or USD 48.5 billion per year (FAO, 2012: 20). The amount of annual investment needed to adapt agriculture to climate change is comparatively low, as the expenditure required to counteract the negative impacts of climate change on nutrition are estimated to be only USD 3 billion per year (FAO, 2012: 22). For African countries, climate change adaptation is considered to be more important than mitigation, but agricultural mitigation practices often provide adaptation synergies, justifying investment in mitigation (FAO, 2012: 23). If the African mitigation potential of 265 million tCO_2 per year up to 2030 is to be harnessed (e.g. through cropland management, grazing land management and the restoration of degraded lands), it will require investments of USD 2.6-5.3 billion per year, in addition to a carbon price of USD10-20 per ton (FAO, 2012: 23). An additional 812 million tCO2/year can be mitigated through preventing deforestation driven by agricultural expansion, through sustainable intensification practices and forest conservation, which are capable of achieving food security (FAO, 2012: 24). Avoiding 75% of total deforestation in Africa has an additional cost of USD 8.1-16.2 billion per year (FAO, 2012: 25). However, it should be noted that these estimations do not take into account additional costs, such as research, capacity building and planning.

5.2 Other cost considerations

There are multiple issues and potential caveats along the pathway to transformational adaptation in the agricultural sector that can lead to additional direct or indirect costs. Critical factors and trade-offs must be considered, as the costs of change can be high if they are not properly taken into account. Transformational change can increase transaction costs, where additional economic or informational transactions are necessary to facilitate change. Opportunity costs should be considered in this context, as adaptation change runs the risk of creating path dependency, locking in choices and constraining future decision-making. Additionally, unintended consequences from current actions may result in additional costs in the long-term, due to narrow and short-term conceptualizations of value. Maladaptation is a potential risk, where adaptation interventions fail to reduce climate change impacts and instead increase adverse outcomes related to climate change, as well as present and future costs. Due to the high stakes and level of complexity compared to incremental forms of adaptation, adequate levels of adaptive capacity are critical for transformational adaptation.

5.3 Financing challenges

FAO (2012: 25-26) highlight several factors which limit the availability of financing for climate-smart agriculture. Most smallholder farmers are constrained in their ability to provide the necessarily levels of investment. Furthermore, private sector investment in smallholder agriculture is held back by low returns on investment. Investments in some climate-smart interventions entail upfront costs, while the benefits in productivity, resilience, and mitigation may not be realized for several years. To overcome these barriers to adoption, international climate finance has the capability to leverage additional private sector investments and public expenditures. Innovative mechanisms for delivering financial services, blending public and private finance will be key to accelerate climate action.

Although more financing schemes and funds are becoming available, a pipeline of investment-ready projects is lacking. More convincing project proposals are needed in order to make a sufficient business case for potential investors.

5.4 Directing investment

CSA is highly context specific, and at times involves trade-offs between productivity, adaptation and mitigation. As such, stakeholder consultation is important when deciding which CSA practice to implement, as factors such as labour availability and agro-ecological conditions may constrain CSA outcomes. Given this context specificity, CSA investment portfolios must be nationally and locally determined. Financing for CSA should be aligned with both national goals and priorities which are relevant to CSA. Providing consistent criteria to select projects and investment portfolios could provide guidance to project proponents and generate more results Depending on whether the project involves the public or private sector, different funding time frames and mechanisms should be utilized. Additionally, various actors need to be involved within both implementation and development of financing mechanisms, including: national governments, RECs, research entities, civil society, private sector, AUC-NEPAD, and the AfDB. Including these various actors will avoid duplication, promote buy-in, and grant increased legitimacy.

Stakeholder engagement mechanisms should be applied at various scales:

International level: via UNFCCC processes, donors, and global coalitions

Continential level: via AUC-NEPAD

Regional level: RECs

National level: as defined in NAIPs, and other relevant policies and programs.

Local level: on-the-ground coordination and implementation of CSA activities

The use of results-based financing for the public sector and civil society can provide accountability for donors and fund managers, where funding is contingent on outputs and outcomes. Up-front funding can be given to provide the training and inputs necessary to enable smallholder farmers to transform their practices. Operating funding is thus connected to specific project outputs, e.g. number of farmers that have been trained in a certain practice or supplied with a technology or input. Finally, residual funding can be provided contingent on the outcomes of the project, e.g. number of farmers who continue to utilize practices derived from training or technological dissemination. To operationalize this type of financing, closely-linked monitoring, reporting and verification frameworks are needed, e.g. GIS monitoring and tracking systems, hand-held/mobile survey tools. Reporting standards and independent verification institutions are critical to providing legitimacy.

5.5 Examples of short-, medium- and long-term financing mechanisms

Proposals for financing mechanisms are capable of addressing needs depending on the time window of the climate-smart actions at hand. These mechanisms can be categorized broadly, as follows:

- *National budgetary resources* are critical for addressing immediate climate-related risks in a given country. When these budgetary funds are mainstreamed into medium-term planning, they can be used as a sustainable funding mechanism for climate change action.
- *Private sector funds and bonds* derived from market mechanisms are needed in instances where the private sector is taking an active role in financing new CSA technologies. Different private sector financing mechanisms are needed that target different areas: e.g. large agri-business value chains, sustainability standards, national/regional suppliers, etc.
- *Concessionary mechanisms* have been instrumental in other build, operate and transfer schemes, and could be used to drive climate-related investment where concessionary agreements can be successfully negotiated.
- *Bilateral and multilateral funding* are development tools relied upon by many African countries. Funding can be negotiated to incorporate the additional need for climate change adaptation, bringing climate action into new borrowing and lending instruments.
- *Development banks* can provide grants, loans and other monetary instruments, e.g. the ClimDev Special Fund at the AfDB.
- *Global adaptation funds* have specific windows to provide support for countries and other relevant entities, e.g. Green Climate Fund and the Adaptation Funds.
- *Emerging markets and other investment funds* provide potential funding streams for innovative start-up ventures, e.g. renewable energy projects.
- *Other monetary instruments* include the NEPAD climate change fund, in additional to other mechanisms under consideration by regional economic commissions.
- EBAFOSA is modelled as a self-financing assembly that will run on membership fees and philanthropic, benevolent and other voluntary contributions.

6. REFERENCES

African Union (2014). Report of the chairperson of the NEPAD heads of state and government orientation committee. Assembly of the Union. Twenty-Third Ordinary Session. 26-27 June 2014. Malabo, Equitorial Guinea. http://africacsa.org/introducing-the-africa-csa-alliance-ascaa/. Accessed on 9th October, 2015.

Alliance for a Green Revolution in Africa (AGRA). 2014. Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa, Nairobi, Kenya.

Alvarez-Coque, J.M.G. 2012. Agriculture in North Africa: A Chance for Development. Policy Brief. Mediterranean Policy Program—Series on the Region and the Economic Crisis. The German Marshal Fund of the United States, Washington D.C. http://www.gmfus.org/wpcontent/blogs.dir/1/files_mf/1349356066Garc%C3%ADaAlvarezCoque_NorthAfricanAg_Oct12.pdf

Barkhordarian, A., von Storch, H., and Bhend, J. 2013. The expectation of future precipitation change over the Mediterranean region is different from what we observe. Climate Dynamics. 40: 225-244.

Campbell, B.M., Thornton, P., Zougmoré, R., van Asten, P. and Lipper, L. 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability 8: 39-43, http://dx.doi.org/10.1016/j.cosust.2014.07.002

Campbell, B.M., Thornton, P., Zougmoré, R., van Asten, P. and Lipper, L. 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability 8: 39-43, http://dx.doi.org/10.1016/j.cosust.2014.07.002

Christensen, J.H., Kumar, K.K., Aldrian, E., An, S.-I., Cavalcanti, I.F.A., Castro, M. de, Dong, W., Goswami, P., Hall, A., Kanyanga, J.K., Kitoh, A., Kossin, J., Lau, N.-C., Renwick, J., Stephenson, D.B., Xie, S.-P., Zhou, T., 2013. Climate Phenomena and their Relevance for Future Regional Climate Change. In: Stocker, T.F. Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA.

Cooper, P. J.M., S. Cappiello, S. J. Vermeulen, B. M. Campbell, R. Zougmoré and J. Kinyangi. 2013. Large-scale implementation of adaptation and mitigation actions in agriculture. CCAFS Working Paper no. 50. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

ECOWAS. 2015. A Thematic Roundup of Research, decision-making support and capitalization-extension of endogenous and scientific knowledge for the CSA in the ECOWAS/UEMOA/CILSS region. Paper prepared for the High Level Forum of Climate-Smart Agriculture (CSA) Stakeholders in West Africa, Bamako (Mali), June 15-18, 2015.

Elrafy, M. 2009. Impact of Climate Change: Vulnerability and Adaptation of Coastal Areas. Report of the Arab Forum for Environment and Development. Mostafa K.Tolba and Najib W. Saab Eds.

FAO (Food and Agriculture Organization of the United Nations). 2010a. Climate change implications for food security and natural resources management in Africa. Background paper prepared for the Twenty-sixth Regional Conference for Africa. Luanda, Angola, 3-7, May. ARC/10/8.

FAO. 2012. Identifying opportunities for climate-smart agriculture investments in Africa. http://www.fao.org/docrep/015/an112e/an112e00.pdf

FAO 2014a. Climate-Smart Agriculture: What is it? Why is it needed. http://www.fao.org/3/a-i4226e.pdf

FAO. 2014b. FAO Success stories on climate smart agriculture. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-i3817e.pdf. Accessed on 10th October, 2015.

FAO. 2015. Learning tools on nationally appropriate mitigation actions in agriculture, forestry and land use sector. http://www.fao.org/3/a-i4642e.pdf

FAO, IFAD and WFP. 2012. *The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition*. Rome: FAO.

FAO, IFAD, & WFP. 2014. *The State of Food Insecurity in the World 2014. Strengthening the enabling environment for food security and nutrition*. Rome: FAO.

Foster, V. and Briceño-Garmendia, C. 2010. *Africa's Infrastructure. A Time for Transformation*. A copublication of the Agence Française de Développement and the World Bank. Washington, D.C., World Bank.

Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., Larwanou, M. and Bayala, J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security 2: 197-214.

Giller, K.E., Witter, E., Corbeels, M., and Tittonell, P. 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. Field Crops Research 114:: 23–34.

Giordano, M.; de Fraiture, C.; Weight, E.; van der Bliek, J. (Eds.). 2012. Water for wealth and food security: supporting farmer-driven investments in agricultural water management. Synthesis report of the AgWater Solutions Project. Colombo, Sri Lanka: International Water Management Institute (IWMI). 48p. doi:10.5337/2012.207

Hoerling, M., Hurrel,l J., Eischeid, J. and Phillips, A. 2006. Detection and Attribution of Twentieth-Century Northern and Southern African Rainfall Change. Journal of Climate, 19: 3989–4008.

IFAD 2013. Smallholders, food security, and the environment International Fund for Agricultural Development (IFAD), Rome, Italy. 52 pp.

Intergovernmental Panel on Climate Change. 2007. Summary for Policymakers', in M. L. Parry et al. (eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability – Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. University Press Cambridge, Cambridge and New York.

Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. IPCCWGIIAR5 Technical Summary. Accessed on August 19 2014. Available at: http://ipccwg2.gov/AR5/images/uploads/WGIIAR5-TS_FGDall.pdf

Jones, P.G. and Thornton, P.K. 2008. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. Environmental Science and Policy.

Kassam, A., Friedrich, T., Shaxson, F. and Pretty, J. 2009. The spread of Conservation Agriculture: justification, sustainability and uptake. International Journal of Agricultural Sustainability 7: 292-320.

Lobell, D.B., Bänziger, M., Magorokosho, C. and Vivek, B. 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change 1: 42-45.

Mapfumo, P. 2011. Comparative analysis of the current and potential role of legumes in integrated soil fertility management in southern Africa. In *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management* (pp. 175-200). Springer Netherlands.

Mapfumo, P., Jalloh A. and Hachigonta, S. 2014. Review of Research and Policies for Climate Change Adaptation in the Agriculture Sector in Southern Africa. Future Agricultures Working Paper 100. Future Agriculture Consortium, Sussex, UK. 59 pp.

Mapfumo, P., Onyango, M., Honkponou, S. K., El Mzouri, E. H., Githeko, A., Rabeharisoa, L. & Agrawal, A. 2015. Pathways to transformational change in the face of climate impacts: an analytical framework. *Climate and Development*, 1-13.

McCartney, M.; Smakhtin, V. 2010. Water storage in an era of climate change: addressing the challenge of increasing rainfall variability. Blue Paper. Colombo, Sri Lanka: International Water Management Institute (IWMI). 14p.

McCartney, M.; Rebelo, L-M.; Xenarios, S.; Smakhtin, V. 2013. Agricultural water storage in an era of climate change: Assessing need and effectiveness in Africa. Colombo, Sri Lanka: International Water Management Institute (IWMI). 37p. (IWMI Research Report 152).

McCornick, P.; Smakhtin, V.; Bharati, L.; Johnston, R.; McCartney, M.; Sugden, F.; Clement, F.; McIntyre, B. 2013. Tackling change: Future-proofing water, agriculture, and food security in an era of climate uncertainty. Colombo, Sri Lanka: International Water Management Institute (IWMI). 36p. doi: 10.5337/2013.213.

Mul, M. L., T. O. Williams and O. Cofie. 2015. Overview of the scientific, political and financial landscapes of climate-smart agriculture in West Africa: sector of water resources. In Robert Zougmoré, Alain Sy Traoré, Yamar Mbodj (Eds.). Overview of the Scientific, Political and Financial Landscape of Climate-Smart Agriculture in West Africa. Working Paper No 118. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). pp 47-59.

Munang R, Mgendi R, Alverson K, O'Brien-Onyeka M, Ochieng C, et al (2015). Ecosystem Based Adaptation (EBA) for food security in Africa –Towards a comprehensive Strategic Framework to Upscale and Out-scale EbA-driven agriculture in Africa. United Nations Environment Programme (UNEP), Nairobi. Available online at: http://www.afsac2.aaknet.org/index.php/downloads/publications/item/69-towards-a-comprehensive-strategic-framework-to-upscale-and-out-scale-eba-driven-agriculture-in-africa

Neate P. 2013. Climate-smart agriculture success stories from farming communities around the world. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Technical Centre for Agricultural and Rural Cooperation (CTA).

Nicol, A.; Langan, S.; Victor, M.; Gonsalves, J. (Eds.) 2015. Water-smart agriculture in East Africa. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE); Kampala, Uganda: Global Water Initiative East Africa (GWI EA).

Radhouane, L. 2013. Climate change impacts on North African countries and on some Tunisian economic sectors. Journal of Agriculture and Environment for International Development, 107: 101 – 113.

Schmidhuber, J., Bruinsma, J., & Boedeker, G. 2009. Capital requirements for agriculture in developing countries to 2050. In *FAO Expert Meeting on "How to Feed the World in* (Vol. 2050, pp. 24-26).

Sumberg, J., and Thompson, J. (Eds). 2012. Contested Agronomy: Agricultural Research in a Changing World. Routledge, London.Sylla, M.B., A.T. Gaye, and G.S. Jenkins, 2012: On the fine-scale topography regulating changes in atmospheric hydrological cycle and extreme rainfall over West Africa in a regional climate model projections. International Journal of Geophysics, 2012, 981649, doi:10.1155/2012/981649.

Thornton, P, Herrero, M, Freeman, A, Mwai O, Rege E, Jones P and McDermott J. 2007. SATeJournal, ejournal.icrisat.org, Volume 4(1): 1-23. Accessed on July 14, 2014. Available at: http://www.icrisat.org/journal/SpecialProject/sp7.pdf

Thornton, P.K., Jones, P.G., Alagarswamy, G. and Andresen, J. 2009a. Spatial variation of crop yield response to climate change in East Africa. Global Environmental Change 19: 54-65.

Thornton, P.K., van de Steeg J., Notenbaert, A. and Herrero, M. 2009b. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems 101: 113-127.

UNDESA (United Nations Department of Economic and Social Affairs). 2013. World Population Prospects. The 2012 Revision. Volume 1: Comprehensive Tables. United Nations, New York.

UNDESA. 2014. Urbanization Prospects. The 2014 Revision. Highlights. United Nations, New York.

Williams, T.O., Gyampoh, B., Kizito, F. and Namara, R. 2012. Water implications of large-scale land acquisitions in Ghana. *Water Alternatives* 5(2): 243-265.

Williams, T.O. 2014. Accessing and putting water to productive use in sub-Saharan Africa. In: J. van de Bliek, P. McCornick and J. Clarke (Eds.). 2014. *On Target for People and Planet: Setting and Achieving Water-Related Sustainable Development Goals*. Colombo, Sri Lanka. IWMI. pp 42-45. doi: 10.5337/2014.226.

World Bank 2015. World Development Indicators 2015. Washington, D.C., World Bank.

Zougmoré, Robert, Alain Sy Traoré and Yamar Mbodj (Eds.), 2015. Overview of the Scientific, Political and Financial Landscape of Climate-Smart Agriculture in West Africa. Working Paper No. 118. CGIAR Research Program on Climate Change, Agriculture and Food Security. Available online at: www.ccafs.cgiar.org