Chapter

Modalities for Scaling up Implementation of Innovations and Best Practices for Resilient Agricultural Systems in Africa

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Abstract

Climate change is already impacting negatively on Africa's agriculture and threatens to significantly reverse the gains realized in food security as the 1.5 degC warming threshold set by the Paris Agreement fast approaches. This is happening at a time when a wide range of tested and viable technologies, innovations and best practices exist with the potential to scale up climate resilient food production across the region's diverse agricultural systems. A framework and modalities are proposed to support stakeholders in identifying and scaling up appropriate technologies, innovations and best practices for climate-resilient food production in different farming systems. These provide a much needed solution for Africa's policymakers who are currently grappling with options to meet their citizens' food security today even as they ponder over how they will feed their rapidly growing populations, expected to reach 2 billion by 2030 under worsened climate conditions.

Keywords: food security, climate change, technologies, innovations, best practices, scaling up

1. Introduction

Agriculture is the largest productive sector in Africa employing between 60 and 70% of the total labour force as well as supplying up to 50–70% of household incomes [1]. Over 80% of the food produced is from smallholders in a mainly rain-fed sector where women constitute 50–60% of the total workforce and which contributes to about 20–25% of the overall GDP of the continent [2]. Livestock production accounts for about 30% of the gross value of agricultural production, with 92% of that coming from the production of beef cattle, dairy cattle, goats, sheep and chickens [3]. Pastoralism is practiced in more than 75% of African countries by between 200 and 500 million people, including nomadic communities, transhumant herders, and agro-pastoralists [4]. The sector's output has increased since 2000, mainly due to expansion of agricultural land [1]. However, food production in sub-Saharan Africa needs to increase by at least 60% by 2030 to feed the growing population then [5]. To achieve this, the huge unexploited potential in the continent's agriculture sector needs to be exploited.

A number factors have for long stood in the way of Africa realizing the enormous potential inherent in the agricultural sector for poverty reduction and wealth creation. Two among these stand out. First, is the failure to scale up and out the many proven technologies, innovations and best practices for sustainable food production. These include failure to embed agricultural innovation within local socio-ecological structures and practices, political instability in some regions hindering engagement with farmers, unclear profitability of innovation to end-users, lack of participation by users in technology development and decision-making, and unfavorable policies and legislation such as that on land tenure and intellectual property ownership among others [6].

Secondly, government-led agricultural extension services on the continent have been ineffective owing largely to inadequate support from government. Yet these services should play a critical role of bringing the farming community information on new technologies, innovations and practices, which they can adopt to increase productivity, incomes and standards of living. Whereas technology and skills transfer has been more successful in programs driven by Africa's private sector--in export-oriented sub-sectors such as sugar, coffee and tea, this has remained lackluster or non-existent [7] when it comes to non-cash crop systems, where the smallholders belong [8].

As a consequence of not optimizing the continent's agricultural potential, there has been persistent poverty among its people, projected to prevail beyond 2030 while it is eliminated in other parts of the world. Similarly, the food security situation has been deteriorating in all sub-regions of Africa. Of the total undernourished population in 2018, 17 million were in Northern Africa and 239 million in sub-Saharan Africa [1] and is projected to reach 320 million by 2025 with no policy interventions [9]. This could however be an underestimate, considering additional stress on food systems recently brought about by the unprecedented locust outbreak that severely ravaged the Horn of Africa 2019 to 2020 with significant crop and livestock losses, compounded by the COVID-19 pandemic since early 2020.

The urgency of this chapter is driven by (a.) the Intergovernmental Panel on Climate Change (IPCC) Special Report on Impacts of 1.5degC Warming, predicted to commence towards the end of this decade, and (b.) the challenge to African policymakers produce enough to feed the 2 billion people in 2030 under the envisaged harsher climate then. The objective of this chapter, therefore, is to develop and promote a versatile framework for identifying and scaling up appropriate technologies, innovations and best practices for climate-resilient food production accessible to smallholders across diverse farming systems on the continent in the short to medium term.

2. Impacts of climate change on African agricultural systems

The Intergovernmental Panel on Climate Change (IPCC) Special Report on the Impacts of 1.5 degrees global warming above pre-industrial levels (SR1.5) released in October 2018 was categorical that warming in sub-Saharan Africa will be greater than the global average and that rainfall will decline in certain areas. There's general concurrence among most circulation models (GCMs) that temperatures are increasing across the region. However, many models vary widely regarding predicted precipitation changes. Climatic changes are not uniform across the region but temperatures are expected to increase in all locations.

The forecasts for Sub-Saharan Africa suggest that higher temperatures, increase in the number of heat waves and increasing aridity will affect the rain-fed agricultural systems [10]. Schlenker and Lobell [11] estimated that in sub-Saharan Africa, crop production may be reduced by 17–22% due to climate change by 2050.

Farmers in sub-Saharan Africa practice a wide range of crop and livestock production activities varying across and within the major agro-ecological zones by mainly smallholders who occupy 80% of all arable land in Africa with each owning less than 2 hectares [2]. **Table 1** below presents the major farming systems in sub-Saharan Africa. Smallholder farmers remain vulnerable to climate change. Not only do changes in temperature, rainfall and the frequency or intensity of extreme weather events affect their crop and animal productivity but also significantly degrades their household's food security, incomes and overall well-being [13].

FAO [14] reports that food and agriculture needs to produce 49% more food by 2050 yet climate impacts such as extreme weather events, spreading pests and diseases, loss of biodiversity, degrading ecosystems, and water scarcity will worsen as the planet warms. Climate change is very likely to have an overall negative effect on yields of major cereal crops across Africa, with strong regional variability in the degree of yield reduction [15]. Cereal production growth for a range of crops in SSA is projected to decline by a net of 3.2% in 2050 as a result of climate change, with the largest negative yield impacts projected for wheat, followed by sweet potatoes and yams [16]. Using an ensemble of GCMs and a crop model,

Farming systems	Land area (% of region)	Agric. Popn. (% of region)	Principal source of livelihood
Tree Crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work
Forest Based	11	7	Cassava, maize, beans, cocoyams
Rice-Tree Crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Highland Perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work
Highland Temperate Mixed	2	7	Wheat barley, tef, peas, lentils, broadbeans, rape, potatoes, sheep, goats, livestock, poultry, off-farm work
Root Crop	11	11	Yams, cassava, legumes, off-farm work
Cereal-Root Crop Mixed	13	16	Maize, sorghum, millet, cassava, yams, legumes, cattle
Maize Mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
Large Commercial and Smallholder	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances
Agro-Pastoral Millet/Sorghum	8	8	Sorghum, pearl millet, pulses. Sesame, cattle, sheep, goats, poultry, off-farm work
Pastoral	15	8	Cattle, camels, sheep, goats, remittances
Sparse (Arid)	17	1	Irrigated maize, vegetables, date palms, cattle, off-farm work
Coastal Artisanal Fishing	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work
Urban Based	<1	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work

Source: IPC [12].

Table 1.
Major farming systems of sub-Saharan Africa.

Thornton *et al.* [17] estimated the mean yield losses of 24% for maize and 71% for beans when global warming exceeded 4°C. If Nitrogen stress is considered, some studies [18] found yield decreases higher than 50% for maize in the Sahelian region and around 10–20% in other Sub-Saharan regions, and an overall negative trend of 5–50% not considering Nitrogen stress.

High-temperature sensitivity thresholds for important crops such as maize, wheat and sorghum have been observed, with large yield reductions once the threshold is exceeded [13]. Cassava, millet and sorghum yields are projected to be slightly higher under climate change, probably owing to their higher tolerance to high temperatures and drought stress. Cassava appears to be more resistant to high temperatures and unstable precipitation than cereal crops [19], while multiple-cropping systems appear to reduce the risk of crop failure compared to single-cropping systems [20]. Climate change extremes can alter the ecology of plant pathogens, and higher soil temperatures can promote fungal growth that kills seedlings [21].

World prices are a key indicator of the effects of climate change on agriculture and specifically on food affordability and security. Food prices will likely increase for all major staple crops, when maize, rice and wheat prices in 2050 are projected to be 4%, 7%, and 15% higher than under the historic climate scenario, respectively [16]. Consequently, the per capita calorie availability across sub-Saharan Africa is projected to decline by 1.3% or 37 kilocalories per capita per day.

Climate change also increases the number of malnourished children in 2030 and 2050 being higher by 1 million children in 2030 and still higher by 0.6 million children by 2050, respectively. With respect to trade, little change in net cereal imports is expected as a result of climate change but at sub-regional level, eastern Africa is projected to experience the largest increase (15%) in net cereal imports due to climate change as a result of declining maize yields [16].

The impacts of climate change on grazing systems include changes in herbage growth (due to carbon dioxide concentration, rainfall and temperature) and changes in composition of pasture and in herbage quality [22]. Increases in carbon dioxide concentrations and precipitation will tend to increase rangeland net primary production, though this increase in production will be modified positively or negatively by increased temperature leading to differences in production among species. The proportion of browse in rangelands may increase in combination with more competition if dry spells are more frequent [23]. For example, in a future East Africa with a warmer and wetter climate, tropical broadleaf growth may increase more than other grazing grass species and changes in net primary productivity in African rangelands will likely be mainly negative [22].

Over shorter time horizons, climate risk in pastoral landscapes will be affected by increased variability of rainfall—spatially and temporally [23]. Climate risk will also increase through increased frequency of extreme events such as drought, flooding and extreme highs and lows in temperature. According to [22] this may have negative effects on herd dynamics, stocking density and the productivity of pastoral production systems. Herrero et al. [24] reports that in Arid and Semi-Arid Lands (ASAL) of Kenya, the loss of animals and subsequent loss of milk and meat production to 2030 due to increased drought frequency would lead to over USD 630 million and outbreaks of rift valley fever associated with increased rainfall and flooding.

Incomes and food security for rangeland communities will also be affected. In much of Africa, livestock are an important risk management asset for millions of people. Ericksen et al. [25] also mapped out where the vulnerability of livestock keepers in the rangelands may change in the coming decades. This includes areas that are food insecure and vulnerable to the impacts of future climate change across the tropics and sub-tropics. Using length of growing period (LGP) as a proxy for the number of grazing days, Herrero et al. [22] project substantial reductions in

LGP across African rangeland systems, who also project an average maximum temperature flip above 35°C across Africa. This is a critical threshold for rangeland vegetation and heat tolerance in some livestock species.

Increasing food availability and rural incomes through increased agricultural productivity is recommended by Ringler et al. [16] as the most potent solution for reducing malnutrition particularly in sub-Saharan Africa. This could include expansion of the production area and intensification on existing croplands [26, 27]. But rapid urbanization is emerging as a major challenge to intensification, despite the high potential in available technologies to increase farm output [28]. Sustainable intensification of small-scale farming is therefore a vital option towards climate resilient food production [27].

But given the highly diverse Sub-Saharan Africa's agro-ecology, there is no single universal agricultural technology or practice that can achieve climate resilience and agricultural sustainability in the region [29] and adaptation strategies will vary for different locations [30]. The solution lies in the adoption of climate smart agro-ecology principles and landscape approaches that enhance resilience of agro-ecosystems and diversify production through cultivating crops and raising livestock that are stress-tolerant [29, 31]. Such agricultural techniques include agroforestry, mulching, intercropping, crop rotations, integrated crop–livestock management, conservation agriculture, improved water management, adopting and using innovative practices such as weather forecasts and climate risk insurance, among others [32, 33].

The last 30 years have witnessed evolution in the development and promotion of low-cost agricultural technologies in sub-Saharan Africa that are suitable for small-scale agriculture [34]. Many of these technologies are meant to address challenges of decreasing productivity such as poor soil fertility, degrading farmlands and climate variability. The question then remains; what are the best modalities and strategies of scaling up these best innovations and technologies? This is the main purpose of the following section of this paper.

Future changes in temperature and precipitation in the different agricultural systems may render some of the innovations and practices more or less effective that the present day performance. Considering the considerable costs involved in adopting technologies, innovations and practices for scale up and out, it is important that location-specific screening of the options is carried out against certified future scenarios of temperature and rainfall and other considerations. This is elaborated in Section 5 on modalities for scaling up and out.

The April 2020 flooding in the Lake Victoria basin and the backflow of the lake that has led to thousands of people displaced and tens of villages submerged has wiped out many gains made through farming practices recently promoted by NGOs projects. Thiery *et al*. [35] predicted this phenomenon but which unfortunately was not considered by local development planners. Similarly, the IPCC SR1.5 predicts severe impacts on water availability and the beef industry in southern African countries of Namibia and Botswana when the 1.5-degree C threshold is reached within the decade (from 2028). Africa's low-lying deltas will not be affected until after 2040, and planning for scaling out and up for the transfer of any technologies, innovations and best practices in these areas should check details in the report.

3. Sustainable agricultural technologies, innovations and best practices

There is still little consensus around the term "climate smart agriculture" as controversy still exists among key sustainability actors including agricultural scientists and development practitioners. Hence for this chapter, the term "sustainable agricultural production" is preferred, and it embraces all practices—both adaptation and mitigation solutions. Practices that contribute to sustainable agricultural production and resilience of farming systems in a wide range of contexts include, but are not restricted to: agroforestry, improved soil management such as through conservation agriculture, improved water management such as water harvesting and drip irrigation, integrated livestock and grassland management, improved nutrient management such as micro-fertilization and improved crop varieties. These are elaborated in detail in the Climate-Smart Agriculture Source Book [31].

Adoption of improved integrated production management practices also depends strongly on other factors such as investment costs and returns on investment, availability of labor, access to machinery and priority value chains. As a basic indicator of success, food security has to increase during the shift to more integrated practices [36].

Changes in technologies and practices that favor resilience and sustainable agricultural production must also be supported by a supportive enabling environment. The next section on modalities for scaling up technologies, innovations and best practices elaborates the enabling environments supportive of scaling up and out. Barriers to scaling up and out climate resilient agricultural technologies and innovation differ between contexts and over time [37, 38].

Identifying the main barriers or drivers in any particular context from an array of contributing factors is a key first step and the scaling process should adapt to these. Scaling may also be challenging in particularly diverse or unique agro-ecosystems and socio-cultural settings where climate smart technologies and innovations have to be significantly adapted to work in each setting. Key barriers to scaling up and out include:

a. Lack of technical options for the specific need and context considered and/or awareness of these options by the beneficiaries;

b. Lack of adequate institutional, human and financial resources for capacity building and extension services;

c. Lack of finance at macro-and micro-level within public/government budgets, local organizations and individuals, and aversion of private sector investments for small holders;

d. Lack of political will to address problems mainly among the most vulnerable communities;

e. Lack of awareness of innovative climate-smart approaches such as payments for ecosystem services and insurances;

f. Insecure tenure and access to resources including land and water;

g. High investment risk associated with adoption of certain technologies in given locations; and

h. Loss or high turnover of individual "champions" that drive the interest and processes in specific situations.

4. Scaling up technologies, innovations and best practices

4.1 Conceptual framework for scaling up

Numerous modalities have been developed for effectively scaling up and out agricultural technologies and innovations by organizations working directly with farmers and other stakeholders in the innovation system. Designed to facilitate scaling up and out on the ground, these frameworks are informed more by experiential knowledge than academic theory, but resonate well with the theoretical literature. An evaluation of some of these by Thomas *et al* [38] and Neufelt *et al*. [39] reveals that, despite broad structural differences as well as the number of steps in each and the order in which they are presented, the different modalities or operational frameworks had much in common with each other and the theoretical literature. Using these lessons as building blocks for scaling up strategies for climate smart innovations in the widest possible range of African contexts, the conceptual framework in **Figure 1** is proposed as the consolidation of modalities for successfully scaling up technologies, innovations and best practices for sustainable agricultural production in the context of Africa.

4.2 Modalities for scaling up

The following seven steps lay out the modalities for effective scaling up and out highlighted in **Figure 1**. They are a culmination of the analysis of the wide range of published operational frameworks and modalities for scaling up climate smart innovations in diverse contexts discussed in previous sections.

4.2.1 Step 1: planning adaptively for the scaling process

The need to design scaling into mini-projects through proper planning from the outset is very important and approaches such as Logical Framework Analysis, Theory of Change and Impact Pathway planning may be used [39, 40]. Upscaling is typically considered when climate-smart technologies and innovations have been demonstrated to work at local levels ranging from villages to water basins and landscapes. By identifying barriers to scaling up, these approaches seek to mitigate these risks and overcome barriers as part of the design process from the outset. Furthermore, setting clear milestones that relate to scaling via a well-defined theory of change and impact pathway helps to bring divergent views and options together, cementing a joint understanding and vision of the rationale for scaling up and out.

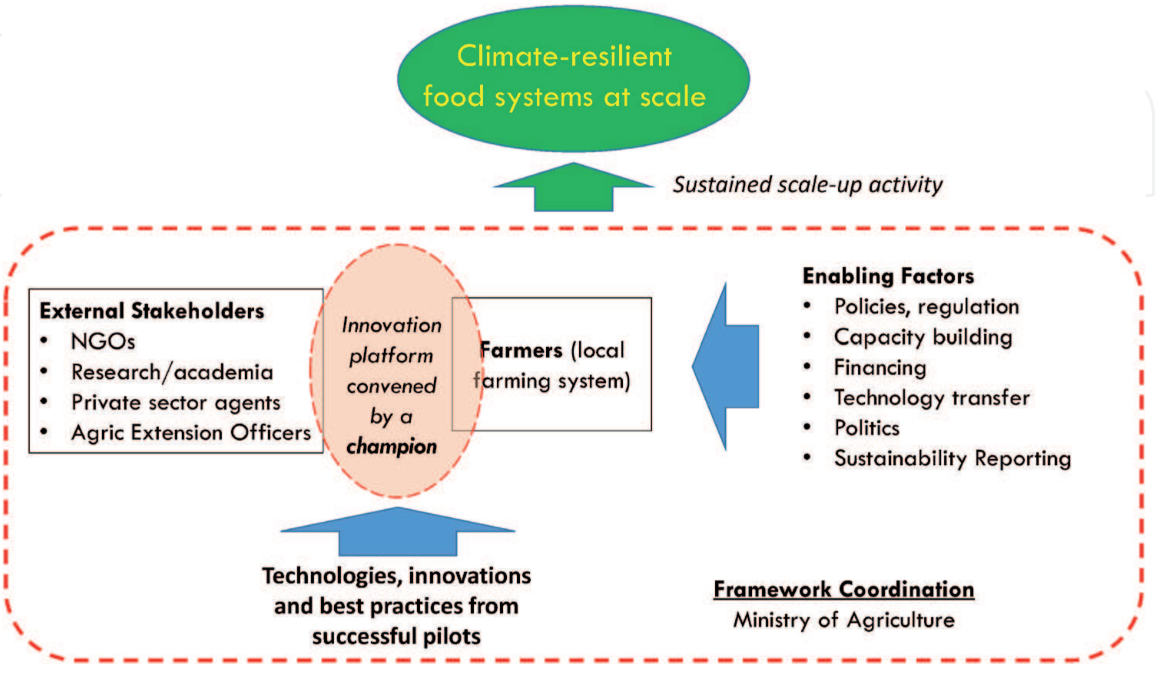

Figure 1.
Conceptual framework for scaling up agricultural practices, technologies and innovations.

4.2.2 Step 2: selection of technologies and innovations based on best-available evidence

Establishing the economic value of land for example can convince policymakers and land managers to invest and re-direct policy and practice towards financially viable climate smart options. However, while economics can drive key decisions, the social and cultural dimensions around changes in farming systems should not be overlooked when introducing new climate innovations [38] and participatory techniques for consider multiple perspectives and dimensions of value are available. Below are three stage process proposed for the identification of technologies, innovations and best practices for scaling up and out.

4.2.2.1 Identifying a portfolio of best practices, technologies and innovations

By the time one arrives to the scaling planning table, one already has a technology, innovation or best practice that has worked well at local scale and would like to disseminate it wider. At this point, it is important to understand that there is no "one-size-fits-all" solution for increasing resilience of a farming system. Instead, portfolios of credible, proven climate-smart best practices and technologies checked for scalability are more likely to realize goals of food security, resilience and increased productivity within a given agricultural system. It is critical that scalability assessment tools are employed in selecting the appropriate practice or a combination of them.

4.2.2.2 Framing the context

The next step involves framing the context for scaling up and out in order to understand the circumstances under which the proposed innovation, technology or best practice worked at one level and the needs and limits of the level to which we are extending to through the process of scaling up and out. In particular, this step clarifies the geographical, historical and cultural contexts within which people's priorities and the possibilities for innovation are set and bounded [41]. There is also evidence that innovation may be suppressed if the dominant culture disapproves of departure from the "normal way of doing things" [42]. Scaling up and out of a technical innovation must comprehend the needs and limits of the level we are extending to and ensure that what is being scaled up is both relevant and possible at that level. For practical reasons, the boundaries for scaling up and out are determined by biophysical, institutional and economic considerations and may be modified to accommodate emerging practical issues such as costs of involving stakeholders across greater distances. Temporal limits also must be set to enable development of realistic work plans.

4.2.2.3 Matching best technologies and practices with farming systems

Once the geographical and social context as well as institutional, administrative boundaries have been determined, the portfolio of climate-smart technologies, innovations and best practices identified in earlier can now be assessed against these boundaries to determine their suitability of adoption. Agro-ecological zones and farming systems are extremely diverse, hence interventions need to be targeted to specific contexts and accommodate both indigenous and scientific knowledge. Heterogeneous qualities of the small-scale agricultural system as regards resource control and access and an array of socio-economic attributes should be considered while designing, delivering, and diffusing the technologies and practices in question. A decision support mechanism must be prioritized to match the practices and technologies with agro-ecological zones in which the farming systems lie. Whereas trade-offs and synergies among these goals are likely, the focus should ultimately be on maximizing synergies [43].

4.2.3 Step 3 mobilize innovation platform and built capacities

The agricultural innovation system is a network of individuals, organizations and enterprises (innovation platform), together with supporting institutions and policies in the agricultural and related sectors. The interactions in the system delivers new products, processes and forms of organization. The policies and institutions (formal and informal) shape the way that these actors interact, generate, share and use knowledge as well as jointly learn. The main actors in scaling up are local and non-local stakeholders.

4.2.3.1 Establishing innovation platform/s

Different stakeholder groups have unique incentives and abilities and will face specific challenges in scaling up climate smart innovations.

Local Stakeholders are the key beneficiaries in a scale-up undertaking. In the context of this paper, these are smallholder farmers (about 80% of sub-Saharan African population) and small and medium enterprises (SMEs) active within a given farming system [44]. These are the most vulnerable to the impacts of climate change and must be the focus of any resilience building programmes. For these farmers and SMEs, a successful agricultural and livelihood transformation depends on their effective integration in value chains [44]. They possess indigenous knowledge characteristic of their respective farming systems and Agro-Ecological Zones (AEZ), knowledge which forms a necessary base for successful climate change adaptation in crop farming, livestock and fisheries.

Non-local stakeholders include donors, government, researchers, civil society and private sector actors. Each of these possesses uniquely diverse roles within an innovation system. Researchers may for instance be interested in situational analyses to frame the context for the new site where new innovation is desired. Research must also be continuous in order to counter evolving climate change realities and contexts. Together with researchers, the civil society and donors may also be active in disseminating the experiences (local innovation and behavioral change) to facilitate further scale up [41].

Perspectives of donor agencies, governments and other non-local actors do not necessarily coincide with local people's perspectives of their own needs. Nyasimi *et al*. [37] emphasized the importance of advocacy in scaling agricultural technologies. By bringing diverse stakeholders together through the innovation platform, an opportunity is availed for exchanging ideas and building mutual understanding and trust. This is a critical ingredient for the innovation process. Similarly, inter-level collaboration is particularly important where local actors may interact with those at regional, national and international levels. It is important to eliminate barriers which may hinder local stakeholders from freely participating and sharing information that is considered culturally sensitive or private to them. Fostering meaningful participation calls for capacity building of the disadvantaged groups, fostering trust among all stakeholders and convincing powerful stakeholders to open the space for the disadvantaged groups to influence the agenda and nominate their own representatives.

4.2.3.2 Capacity building

Capacity-building in the UNFCCC process encompasses activities at the level of individuals, institutions and systems. Scaling up climate smart practices therefore requires capacity building across all levels from farmers, the private sector to national and international policy makers. The intervention selected for scaling up will help define the capacity building needs as well as the boundaries—such as a watershed, national or international scale—within which climate resilient development outcomes are expected. The Subsidiary Body for Implementation (SBI) regularly monitors and reviews progress on the implementation of the frameworks for capacity-building in developing countries.

Quality training coupled with appropriate incentives is an essential component of scaling up and out. The pilot phase develops an effective and efficient programme design. Lessons learnt from this need to be consistently applied during scaling up and out. Training therefore helps to transmit procedural and technical expertise as well as organizational values to new staff joining the ever-expanding innovation system. Similarly, staff of non-local stakeholder agencies needs to learn how to support local stakeholders [43].

Similarly, as scaling up can take significant time (often greater than 10 years) it is important that institutional capacity and incentives are built to maintain scaling beyond the tenure of any individual within an organizations. Training and development of staff responsible for implementing scaling up and out initiatives are critical, as is institutional capacity building, leadership, political support and incentives. As interventions are highly context-dependent, disseminating the principles of scaling may be more important than a specific option thought to fit a particular context. For example, capacity building at grass roots level via farmer-to-farmer visits, peer-to-peer training, training of trainers, development of community-based institutions and best practice competitions [37]. Multi-institutional projects and programs are also a means to ensure capacity is built across the range of actors involved.

Unlike 'traditional' extension services that have transferred *outside* solutions to farmers, new approaches need to be farmer-based, driven by local needs, participatory and considerate of groups such as women, young people and the very poor. Several other extension approaches such as farmer-to-farmer extension, community nurseries and farmer field schools, and rural resource centres can help spread innovation when technical solutions are found to be insufficient [39].

4.2.4 Step 4 create the enabling environment for successful scaling up and out

An enabling environment is necessary for successful innovation and scaling up and out. In additional to adequate finance, appealing to the motives of policy makers at all relevant scales as well as youth and women at the grassroots is particularly important in the context of Africa.

4.2.4.1 Secure a consistent funding mechanism

How well Africa's agriculture deals with climate impacts now and in the future will largely depend on the funding it receives or sets aside for adaptation measures. Meeting this financial challenge in Africa would require innovations, cooperative actions and political will to urgently and adequately address current and projected shortfalls for climate action targeting multiple funding sources. Financing to support up scaling adaptation to climate change could be obtained from public, private and other innovative sources such as crowd-funding and bank guarantees. The approach to scaling up and out will typically need to be adapted to the funding model. For example, international donors each have different priorities, which will influence the selection of climate smart technologies and approaches likely to be promoted in upscaling. Similarly, de-risking investments remains a key concern for the private sector no matter what their objectives are [45].

Financing options could include international sources such as UNFCCC-related funding sources including Adaptation Fund (AF) that finances climate adaptation and resilience activities, the Global Environment Facility (GEF) which finances environment-related projects or programs while supervising the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LCDF). The SCCF gives financial support to vulnerable countries for adaptation and technology transfer while the LDCF supports LDCs in financing their efforts to adapt to climate change. The Green Climate Fund (GCF) was also established to finance projects or programs for adaptation to and/or mitigation of climate change. African countries could enlist technical support from Climate Technology Centre and Network (CTCN) to prepare bankable proposals to tap into the GEF/GCF controlled funds.

Regional funds in Africa such as from the Africa Development Bank (AfDB) also provide an additional source of climate finance. However, experience from recent implementation of agriculture-related National Adaptation Plans of Action (NAPAs) of the Least Developed Countries (LDCs) that have largely remained underfunded should be a pointer to the need to intensify the search for innovative local financing mechanisms affordable by most African countries. Accessing climate finance from global sources such as Global Environment Facility (GEF), Special Climate Change Fund and Least Developing Country Fund has largely remained elusive. This is mainly due to the stringent and bureaucratic nature of these funds that local actors need capacity enhancement on how to apply for these funds.

This chapter encourages African countries to source much of their funding from domestic sources. These include from: national budgets through parliamentary appropriation; remittances from the diaspora, which have fast gained a leading position as key foreign exchange earner for most sub-Saharan African countries; NGO funds—this sector controls a significant chunk of donor funds towards climate action; and the private sector, most of whose members in the region are still struggling to understand their clear role in climate resilient development. Given the key role played by SMEs in the critical agricultural value chains, there's need to innovatively target them through awareness-raising on how they may invest in sustainable agriculture practices.

Microfinance institutions, merry-go-round and credit groups may also provide the much-needed alternative particular to smallholders in sub-Saharan Africa. Public and private investment programmes in African countries must be structured in ways that support climate technologies and actions. Such actions can be financed through climate programmes or alternatively climate change considerations can be incorporated into sectoral funding sources or through a special window for inter-sectoral funding of activities that demonstrate climate co-benefits. Decentralized Climate Finance (DCF) is becoming increasingly important, examples being the County Climate Change Fund (CCCF) in Kenya that is currently being scaled up to more regions in Kenya by the National Drought Management Authority (NDMA) after institutionalizing the pilot phase.

4.2.4.2 Gender and youth considerations in planning

Climate change impacts are not gender-neutral. Women in poor countries are vulnerable to the effects of climate change as a result of their critical and differentiated roles and responsibilities in food crop production and dependence on natural resources in their livelihood strategies. In Africa, the main economic sector, agriculture, is highly vulnerable. Women provide more that 60% of the labor force engaged in agriculture, and with increasing impacts of climate change this makes women at greater risk of livelihood insecurity. Women, children, the youth and the poor are particularly more vulnerable as they often have limited resources, receive less education and are not involved in political and household decision-making processes at different levels. Gender transformative adaptation measures will make sure that women, men and youth benefit from actions by increasing participation and identification of potential implementation bottlenecks. Various opportunities exist for removing such bottlenecks. For example, active engagement of women in designing adaptation measures and decision-making processes at different scales (from farm to national level) will improve adoption, thus increasing their adaptive capacity and resilience. Digitizing agriculture has also been found to attract the youth back to agriculture.

4.2.4.3 Public policies and political support

The policy framework, laws, regulations and norms in a given country and region have to be supportive if scaling up of sustainable land and water management options is to succeed [46]. Similarly, scaling up productive technologies can be severely constrained or rapidly advanced by the policy environment [47]. These could be treaties, laws, regulations, statements, administrative actions and funding priorities. Examples of policies that could constrain or advance scaling are those related to farm inputs, regulations regarding food safety and product quality, output markets and trade [6]. For example, a systematic review of published research suggests tenure reform in Africa produces relatively modest agricultural productivity gains.

Climate change adaptation requires decentralized governance where local stakeholders determine key planning decisions and can incorporate local needs and priorities into the local level planning processes. Control of resources by local institutions and organizations as well as secure tenure allows land managers to look towards a future where they can build profitable and climate resilient systems. On the contrary, insecure property rights could hinder the adoption of climate-smart innovations, as there is little incentive to invest time and money into transition management practices. Protection of intellectual property by way of legislation is crucial to private sector engagement, which is fundamental to scalability. Such protection has been found to be responsible for the success of the seed industry across Africa [6].

One key way to ensure that leaders and institutions continue to pay attention to scaling up is to create an effective demand for it through the political system. Social change needs to be embedded in a society and supported by political constituencies which must be created and nurtured. Furthermore, these constituencies must be constantly reminded of the significance of the scaling up process to their political agenda. African leaders in particular will need to deliver on their commitments such as those under the Comprehensive Africa Agriculture Development Programme (CAADP) and the Malabo Declaration on Accelerated Agricultural Growth of the African Union (AU), and the Nationally Determined Contributions under the Paris Agreements, just to name a few.

4.2.5 Step 5 provide tangible early benefits and incentives to stakeholders

Scaling up and out processes can require sustained inputs from both internal and external stakeholders to an innovation platform who can facilitate or hinder attempts to scale up. It is necessary to provide tangible, early benefits to the stakeholders to trigger early support [40]. For example, ensuring contracted horticultural farmers are paid promptly upon delivery of their produce at the end of each season will retain them and win new additional farmers in the area into the programme. Other than incentivizing through sharing early benefits, it is also important to identify disincentives that may slow the pace at which innovations may be scaled and lead to disengagement from stakeholders. To retain stakeholder engagement, it is important to constantly manage expectations during the process of scaling up and out.

4.2.6 Step 6 monitor, evaluate, learn and communicate

Successful scaling up requires regular feedback from monitoring and evaluation systems. It is essential to learn from success and failure alike in order to develop best-practice in scaling up and out [38]. It requires a "learning by doing" culture, one that values adaptation, flexibility and openness to change. While a solid process needs to be laid out, scaling processes need to be adjusted regularly. Therefore, regular monitoring and evaluation as well as feedback from beneficiaries, communities, and field-based staff are important for learning and adjustment to take place. Two types of evaluation are relevant to scaling up. First is the evaluation of the pilot programme to establish whether or not the innovation tested has been successful and what lessons can be gleaned from it. Second, is M&E of the scaling up process [48]. It is necessary to monitor progress towards agreed sustainability targets and evaluate the impacts of climate smart technologies and innovations against measures of sustainability, including sustainable livelihoods [38]. Facilitating learning between different stakeholder groups across scales is critical—designed and implemented in collaboration with stakeholders to enable continuous learning—will improve climate- smart practices and ensure effective scaling up and out.

Local stakeholders require building of their confidence and skills to enable them to share, learn, develop, adapt and apply appropriate knowledge, ideas, methods and tools within a given context. On the other hand, non-local stakeholders need to learn how to support the local stakeholders by pursuing the necessary interdisciplinary research, training and opportunities for knowledge sharing. Scaling up also implies **learning** practically how to facilitate multi-stakeholder processes on a larger scale. Similarly, it implies learning by local stakeholders about the complexities and interconnectivities among the systems on which they depend for their livelihoods. It is this knowledge gained that will enable them modify issues of their concern or meet their priorities effectively. Where good practices and successes are identified, these need to be demonstrated and communicated widely to not only convince non-local stakeholders to learn from these experiences but also to build expertise in scaling up across different contexts.

4.2.7 Step 7 foster institutional leadership to support the scaling process

Scaling up cannot happen in a vacuum and requires leadership and process facilitation. Such leadership can be achieved by engaging a champion from one or more of the stakeholder groups (internal or external) who can lead and link different interests. This champion could be an enthusiastic NGO leader, a member of a farmer group, politician, financier, or a research team leader [38]. Key roles of the champions include inter-level coordination, [6] mobilizing key stakeholders involved in the scale-up and out program, coordination of the decentralized scale up governance framework and can also serve as an intermediary organization between the innovation "originating" and the innovation "adopting" organization to drive the scaling up process [49].

Within a scaling up arrangement for SLWM-related solutions, organizational leadership is provided by the process facilitator by mobilizing participation by different stakeholders through the agricultural innovation system/platform. This strengthens the institutional arrangements linking non-local to local stakeholders [41], which promotes not only local-level innovation involving both scientific and indigenous knowledge but also inter-level coordination [6]. This happens with new groups in new locations as scaling up advances. This task is best performed by the process facilitator (coordinating organization) responsible for the planning and facilitation of the scale up undertaking [49], who strongly recommend an intermediary organization between the originating organization and the adopting organization to effectively drive such a process.

The role of innovation intermediaries is also recognized in the literature. They facilitate interaction among isolated innovation networks, and between farmers and researchers, policy makers and other industry actors. They are also referred to as innovation "brokers" in other literature. Intermediation is presented as a formal professional role in development where intermediaries are hired consultants or web-based platforms for brokering exchange among actors in agriculture and food systems. Examples include AFIDEP which specializes in knowledge translation in the health sector—linking health researchers and ministries of health across Africa. Key partners in scaling up must always be mobilized and brought on board [50]. In most scaling up initiatives, partners were instrumental in helping to keep the momentum and focus [51].

4.3 Incentives and opportunities for scaling up

Incentives aimed at scaling up and out climate smart technologies and innovations need to be designed based on a thorough assessment of stakeholder needs, their local or traditional knowledge and a critical appraisal of existing incentives and their impacts.

4.3.1 Private sector incentives

A number of opportunities exist which the private sector could exploit towards climate resilient smallholder production with the right incentives in place. To realize these opportunities, the private sector needs incentives and co-financing for large-scale public-private partnerships [38]. These could include de-risking investments in land-based projects via state guarantees if projects fail and tax allowances for investing in restoration projects [45]. Secondly, these futuristic opportunities will require innovative partnerships, greater collaboration and connectivity among stakeholders riding on technological innovations along agricultural value chains. Considering the generally low profit margins in agriculture, the increasing interest from the private sector to scale up and out innovations can significantly stimulate such partnerships.

4.3.2 Incentives for farmers and communities

Incentives to encourage farmers should be designed in ways that encourage innovation and testing of interventions. Examples include Farmer Field Schools [52] and farmer competitions which bring prestige to farmers and can strengthen cultural identities enabling knowledge greater exchange and learning. Secondly, resource-poor farmers are unlikely to switch land management practices if there are no rapid returns to their investments—usually within one growing season. It therefore important that any climate smart interventions introduced add tangible value in order to be attractive and adopted. Finally, governments need to provide or improve provision of basic services such as infrastructure, health and education to boost the enabling environment for climate smart technology adoption by farming communities.

4.3.3 Incentives for policymakers

Policymakers will likely respond more readily to evidence that the implementation and scaling up and out of a climate smart option will contribute to current burning agendas such as unemployment, migration from drylands of Africa and Asia to Europe, food security in fragile states among others. Equally important to policymakers is evidence that lack of intervention would lead to increased scarcity of food, water and employment among the youth. Evidence expressed in terms of the indicators required for SDGs, national development and action plans and associated reporting for UNFCCC is likely to receive greater attention than data on areas of land degraded. Sound business cases or proposals for implementing climate smart solutions must demonstrate the multiple benefits obtainable in form of jobs, income creation, improved productivity and provision of other ecosystem services.

4.3.4 Opportunity to implement the Paris agreement

Of all major interventions proposed for promoting the contribution of agriculture to the Sustainable Development Goals (SDGs), scaling up and out of proven technologies, innovations and best practices promises the highest impact in Africa's context. The crucial entry point for agriculture-orientated interventions to improve food and nutrition security on a large scale should be smallholder farmers (over 80% own less than 2 ha) since majority of the food in sub-Saharan Africa (SSA) is produced by smallholder farmers while they are the most vulnerable to food insecurity and poverty [53]. Furthermore, most of the Nationally Determined Contributions (NDCs) submitted at the end of 2020 by African countries to the UNFCCC have identified agriculture as one of the priority areas for intervention towards climate change mitigation and adaptation, with some countries having already developed National Agricultural Action Plans. With the continent having the highest population growth rate, rapid urbanization trends and rising GDP in many countries, which are known to drive changing food consumption patterns, African agricultural systems will need to become resilient and adapt in order to meet growing demand, contribute to the achievement of the SDG-2 in particular, whose goals include ending hunger, achieving food security and improved nutrition by 2030, and promoting sustainable agriculture. It is imperative that those responsible for planning climate actions in different countries consider these agriculture priorities embedded in their NDCs to fast-track in scaling up and out.

5. Conclusion and recommendations

The threat by climate change on agricultural systems is real and calls for urgent interventions to rapidly build resilience among vulnerable communities in Africa. Considering that the smallholder farming community is responsible for almost 80% of the agricultural production, where only 10% is optimally used, greater impact at scale will be realized by targeting smallholder farmers with scale-up interventions. Similarly, considering that over 60% of the actual farmers are women and only 30% of them may access credit, it is imperative that gender-driven approaches be adopted when rolling out the scale-up modalities in order to catalyze transformation to inclusive and climate resilient agricultural systems on a large scale. The Chapter recommends consideration of the following steps by decision makers in any such scale up process:

a. Planning adaptively before rolling out any scaling up activity;

b. Selecting technologies and innovations based on best-available evidence recognizing there is no "one-size-fits-all";

c. Mobilizing innovation platforms by bringing together all stakeholders (local and non-local) and building their capacities to better engage in the scaling process;

d. Creating the enabling environment for successful scale-up/out by *inter alia*, securing consistent funding, integrating gender and youth considerations in planning, pursuing supportive public policies and securing local political support;

e. Providing tangible early benefits and incentives to stakeholders to ensure their sustained engagement and support through seasons of executing the strategies at their respective locations;

f. Consistently monitoring, evaluating, promoting learning and communicating widely the impact of adopting the strategies; and

g. Fostering institutional leadership to support the scaling up and out process.

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