CoSAI
Commission on Sustainable Agriculture Intensification

Investigating pathways for agricultural innovation at scale: Case studies from Kenya

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Resource Plan Ltd

February 2022

Mati, B.M.; Sijali, I.V.; Ngeera, K.A. 2022. *Investigating pathways for agricultural innovation at scale: Case studies from Kenya.* Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. 46p.

Acknowledgements

This report was commissioned by the Commission on Sustainable Agriculture Intensification (CoSAI). CoSAI brings together agricultural and food systems experts and decision-makers from the Global South and is collaborating with scientists, innovators and partner organizations from across the globe.

The authors gratefully acknowledge the support and inputs provided by the Secretariat of the Commission on Sustainable Agriculture Intensification (CoSAI) as well as all associated Commissioners who played an extensive role in reviewing the analysis and various drafts of the report as well as their support and inputs towards the approach for the study. The authors also thank Richard Kohl for his extensive support through the process.

The Oversight Committee for the study comprised CoSAI Commissioners Maurício Lopez (co-Chair), Rasheed Sulaiman V (co-Chair), Irene Annor-Frempong, Rodomiro Ortiz, Uduak Edem Igbeka, Vara Prasad and Varad Pande, and technical advisor, Julia Compton. Study management and administration was provided by David Shearer and Josefina Achaval-Torre from the CoSAI Secretariat.

Within Kenya, the study was led by Bancy Mati. The authors sincerely thank all the institutions and individuals who provided data, information and insights which helped to ground and enrich this report. Special thanks go to Caroline Kimweli, Emmanuel Kisangau, Francisca Kalungu, Amos Ndunda, Victor Oluteyo, Gapuzwa Kanzere, Carolyne Koech, Simon Kageche, Raphael Merin, Amos Mutunga, Charles Muasya, Fredrick Kihara, Colin Apse, Amos Karithi and Carolyne Nguru. We wish to thank the farmers, land users and communities visited during the field work and the Field Facilitators for their hard work and in facilitating logistical arrangements for site visits, providing information and useful insights. We thank all who contributed either directly or indirectly to the study and the knowledge that informed this report.

Donors

RESEARCH PROGRAM ON Water, Land and Ecosystems CGIAR

This research was carried out as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE) and supported by Funders contributing to the CGIAR Trust Fund (https://www.cgiar.org/funders/)

Contents

Acronyms and abbreviations

AC	Alternating current
ADRA	Adventist Development and Relief Agency
CBO	Community-based organization
CIDP	County Integrated Development Plan
CIM	Christian Impact Mission
CoSAI	Commission on Sustainable Agriculture Intensification
DC	Direct current
EX-ACT	EX-Ante Carbon Balance Tool
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross domestic product
GEF	Global Environment Facility
GoK	Government of Kenya
ICRAF	World Agroforestry
ICT	Information and communication technology
IFAD	International Fund for Agricultural Development
IWMI	International Water Management Institute
KES	Kenya Shilling
NGO	Non-governmental organization
NIA	National Irrigation Authority
SACDEP	Sustainable Agriculture Community Development Programme
SAI	Sustainable agriculture intensification
SDGs	Sustainable Development Goals
SPIS	Solar-powered irrigation system
TNC	The Nature Conservancy
WFP	World Food Programme

Executive summary

CoSAI Innovation Pathways Study: Kenya country study

This is one of three country studies on Innovation Pathways in Agri-food Systems, managed by the Commission for Sustainable Agriculture Intensification (CoSAI).[1] The three studies use a common analytical framework to generate lessons on factors leading to successful innovation pathways, to guide future investment.

Sustainable food systems in Kenya: Challenges and opportunities for innovation

This report focuses on Kenya. The studies sought to identify pathways for innovation in the agriculture sector in the country, with a view to providing practical, evidence-based lessons for managers and investors in innovation. 'Innovation' in this context includes not only science and technology but, importantly, innovations in policies, finance and social institutions. 'Transformative innovation' of agriculture for sustainable agriculture intensification (SAI) means "major change to farming system structures and functions" or "a fundamental shift in the way food is grown and supplied", moving agricultural systems significantly in the direction of SAI goals.

Kenya is an agricultural country where the sector has a broad spectrum of land holding sizes, activities, actors and various value chains. At the same time, Kenya's agricultural sector is among the most innovative in sub-Saharan Africa, driven in part by education, entrepreneurial environment, openness to international trade and ideas, the need to grow more food for a rapidly growing population, declining areas of good land for cultivation, weather-related limitations and highly competitive markets. The range of innovations is broad, ranging from farming technologies to approaches, to financial models and information technology platforms. A number of these innovations are documented, mostly by projects funded by international donors, but these often profile individual farmers and small groups, rather than the wider innovation processes and lessons.

Three innovations that culminate in SAI in Kenya were selected from a shortlist of seven. The methodology involved desk reviews of published papers, reports, records and other materials, and interviews (virtual and face-to-face) of key informants, including government entities, private sector, development partners, non-governmental organizations (NGOs), traders and farmers. Field verification visits were made to Kitui, Machakos, Makueni, Kajiado and Murang'a counties. The selected innovations were as follows:

1. Water harvesting and storage in farm ponds enhancing agriculture intensification in eastern Kenya. This is a technological innovation involving the construction of water-harvesting farm ponds for crop irrigation, improving agricultural intensification, food security and climate change resilience by small-scale farmers. Although some farm ponds previously existed in isolated farms, this innovation started around 2009 with an initiation phase in Yatta Sub-County of Machakos County, where dug-out farm ponds were actively promoted (2009–2014). The out-scaling phase started from around 2013 to the present (2021) in the three counties Kitui, Machakos and Makueni in

[1] All of the studies are available on the CoSAI website (https://wle.cgiar.org/cosai/pathways-for-innovation).

eastern Kenya. It is estimated that at least 10,000 farm ponds were excavated and actively used for irrigation in the three counties.

2. Solar-powered irrigation enhancing agricultural intensification in peri-urban Kajiado. This focuses on adoption of solar-powered irrigation in peri-urban areas of Kajiado County, which border the city of Nairobi, from 2005 to 2021. This is mostly a *technological innovation* driven by business pull through peri-urban agriculture to meet the demand for fresh produce in the nearby Nairobi city, along with *innovative financing models* to suit farmer needs. Since Kajiado has almost no rivers, this innovation is driven by the need to pump groundwater, the availability of affordable solar-powered irrigation systems kits, and free (solar) energy. Solar-powered irrigation equipment is sometimes marketed as complete kits (solar panels, pump and irrigation gear). This has enabled irrigated agriculture to thrive using clean energy and thus resulted in agricultural intensification.

3. Blended finance supporting agricultural intensification and watershed management in Upper Tana Catchments. This innovation presents a case of watershed management activities implemented by land users in upstream catchments of the Upper Tana River Basin from 2012 to 2021. Starting with a three-year proof of concept phase (2012–2015) a business case was developed, followed by an implementation phase (2015–2020). This was a blended finance innovation with technological, environmental and socio-economic components. It addressed the creation of a Water Fund through a platform for public–private partnerships, providing support and a delivery mechanism for SAI and watershed conservation. The downstream water users (in Nairobi) provide incentives (blended finance) for upstream communities (land users) to conserve the sources of water.

From the foregoing, the following were recommended:

1. **Centering end users in the innovation**

Recommendation

- Farmers should be engaged throughout the innovation process. It is emerging that innovation thrives when farmers and local communities are included as investors or stakeholders rather than as beneficiaries, for example, in the construction of water-harvesting structures. Support them contribute to the ideas shaping the innovation, and encourage them to drive it practically.

2. **Innovative financing is often as important as technology in driving innovation**

Recommendation

- Quite often, end users are resource poor small-scale farmers who may require some financial push. Thus, the financing models that have a cost-sharing element (e.g., water credits) have a greater chance of success. Interesting examples at different scales of innovation include mobile phone financing for solar pumps (‘pay-as-you-grow’) and conservation measures financed by public–private partnerships of the Upper Tana-Nairobi Water Fund.

3. **Innovations take time to reach 'at scale'**

Recommendation

- Innovations take time to be tested, implemented and upscaled – at least eight or more years in the cases covered in this report. It is therefore imperative for all partners to have patience and to plan long term, including in the financing of the initiative.

4. **Leadership**

Recommendation

- Innovations usually benefit from strong leadership. The identification and support of champions (both individual and institutional) facilitate a coordinated pathway for growing the innovation. As for example, the strong leadership by a respected entity, as was provided by The Nature Conservancy in Upper Tana, was instrumental in putting together the partners needed to build up the Water Fund.

5. **Role of government**

Recommendation

- Conducive government policies, their implementation and support through relevant institutions facilitate smooth operations and easier upscaling of innovations. One example is favorable import tariff policies for solar-powered equipment. Government policy is informed by innovation based on lessons learned. Innovations can lead to policy reform.

6. **Bundling**

Recommendation

- The bundling of innovations when introduced from the beginning gives the initiative an integrated approach for both problem solving and success, enabling targeting of incentives, upscaling, policy push and out-scaling of lessons learned. For example, the success of solar pumps required a bundle of innovations in finance, institutions, policy and technology.

7. **Partnerships**

Recommendations

- Partnerships facilitate a multiplier effect helping to reduce transaction costs, share responsibilities and provide support according to strengths and needs of stakeholders.
- Integrated approaches are necessary and require partnerships in order to meet the needs of various actors at the financing and policy side as well as those of land users at the implementation end.
- Partnerships (of government, NGOs, development partners, researchers, farmers and the private sector) enable pulling together resources, synergies and project implementation.

1. Introduction

The Commission on Sustainable Agriculture Intensification (CoSAI) promotes more and better investment in innovation for sustainable agriculture intensification (SAI) in the Global South, and works to support the United Nations Sustainable Development Goals (SDGs) and the climate goals of the Paris Agreement. For CoSAI, 'innovation' includes not only science and technology but, importantly, innovation in policies, finance and social institutions. 'Transformative innovation' of agriculture for SAI means "major change to farming system structures and functions" or "a fundamental shift in the way food is grown and supplied", moving agricultural systems significantly in the direction of SAI goals. The CoSAI's main target audiences are 'innovators' (research and development entities and the private sector) and 'investors in innovation' (e.g., Ministries of Agriculture and international funders) who invest directly in agricultural innovation and research. Thus, the term 'innovation' in this context includes SAI-related institutional, policy and financial innovations as well as scientific and technological innovations. SAI refers to the transformative changes required in agricultural systems to meet the United Nations SDGs and the climate goals of the Paris Agreement, including social and human objectives as well as environmental sustainability.

In lieu of this, it is important to identify pathways, approaches and partnerships that can address the complexity of innovation challenges within agricultural systems. However, many past innovations have taken a less planned and structured pathway to success, engaging with imperfect enabling environments, with needed policy and institutional changes brokered along the way. Learning from pathways of previous transformative innovations is important for future work in this area. The purpose was to produce practical, evidence-based lessons on factors that influence success in pathways for innovation for SAI.

This particular report refers to the country case study for Kenya. It is one of three country case studies (Brazil, India and Kenya) that used a common framework of analysis to draw out common lessons as well as context-specific findings. The study sought lessons in innovation for SAI, based on concrete examples, providing evidence for innovation practitioners, including research and development organizations and direct investors in innovation in SAI. The country-level evidence helps complement a global review of evidence being commissioned in this area by CoSAI on approaches and instruments to support innovation in SAI. It contributes to the evidence base for global advocacy by CoSAI and partners to increase funding for global innovation for sustainable agriculture and innovation to rapidly scale up SAI.

2. Country background

2.1 Kenya: Baseline Information

Administrative units: Kenya is divided into 47 counties in a devolved system of government, enshrined in the Constitution of Kenya (GoK 2010a). Kenya's devolution model has seen the national government transfer certain powers, functions and responsibilities to the 47 counties. Some of the functions devolved to counties that are relevant to SAI include agriculture, environment and natural resources (including forestry), lands, housing, urban development, health and social services. Thus, devolution requires that agricultural development must be factored in County Integrated Development Plans (CIDPs), which should be in line with the Kenya Vision 2030 and national government plans and strategies.

Population: According to the Kenya Population and Housing Census (KNBS 2019), Kenya had a population of 47.64 million in 2019, with annual growth rate averaging 2.2%. The household size averages 3.9 individuals, living in 12.1 million households. The country has a youthful population with 35.7 million (75.1%) below 35 years of age. A majority of the Kenyan population (68.9%) live in rural areas, but rural–urban migration has been increasing. Meanwhile, poverty is a major problem albeit incidences of poverty have been dropping, from 52.2% in 1997 to 38.7% in 2020. However, the country ranks 143 out of 189 countries and territories on the UNDP Human Development Index (UNDP 2020). Over 10 million people in Kenya suffer from chronic food insecurity and poor nutrition, while nearly 30% of Kenya's children are classified as undernourished (GoK 2011).

Economy: The economy of Kenya is largely dependent on agriculture and tourism. The per capita gross domestic product (GDP) of Kenya in 2019 was KES 204,783 (equivalent to USD 2,048) (KNBS 2020). Indeed Kenya has transformed from a Low Income Country to a Lower Middle Income Country, as declared by the World Bank in 2015, when the country's per capita GDP exceeded the USD 1,000 mark. The country had a GDP growth rate averaging 5.4% in 2019, but dropped to 1.4% in 2020, due to the COVID-19 pandemic. It was expected to recover after the COVID-19 restrictions are lifted in 2021.

Agriculture: Agriculture is the mainstay of Kenya's economy, contributing 34.1% of annual GDP in 2019 (KNBS 2020) and thus provides critical supportive linkages to other sectors. The sector employs about 57.5% of Kenya's population and over 70% of the rural population, the majority being small-scale farmers (KIPPRA 2020). Crop production accounts for 27.8% of total GDP (82% of agricultural GDP) according to 2019 data (KIPPRA 2020). The livestock sector accounts for 12% of agricultural GDP with the rest taken up by fisheries and forestry subsectors. There are over 8 million farmers in Kenya (4.5 million farming households) of which the majority are smallholders who produce 65% of the marketed produce in the country (GoK 2019).

Climate change threats: There is growing evidence of climate change in Kenya. The minimum temperature has risen generally by 0.7–2.0°C and the maximum by 0.2–1.3°C, depending on the season and the region (GoK 2010a). Temperatures are increasing and the six warmest years have all occurred since 1987. Also, the frequency of 'hot' days has increased dramatically, by 57 days per year while cold nights have declined by 42 days per year. Projections indicate increases of 1–3.5°C by the 2050s (GoK 2010b). About 6.5 million people (13%) per year are exposed to droughts in Kenya and this number is expected to increase to 34% (more than 25 million people) by 2050 in tandem with population growth. Drought particularly affects agriculture, which is mostly rainfed in Kenya.

2.2 Existence of Agricultural Innovations in Kenya

Kenya's agricultural sector is among the most innovative in sub-Saharan Africa, driven in part by the need to grow more food for a rapidly growing population, declining area of good land for cultivation, weather-related limitations, especially recurrent droughts, and highly competitive markets. In a study of agricultural innovations in Kenya (Makini et al. 2016), some 43 innovations were identified and categorized into eight domains – cropping, livestock, governance, marketing, finance, processing, natural resource management and value addition – of which 62% were crop-related innovations. The majority (61%) of the innovations were technical, 23% were organizational and 16% were institutional. Other projects have also identified innovations focused on land and water management in Kenya (Critchley et al. 1999). Indeed many agricultural innovations in Kenya remain undocumented, while others are still emerging, which offer lessons on factors that influence success in pathways for innovation for SAI.

3. Approach and methodology

This is one of three country case studies covering Brazil, India and Kenya, which utilized a common analytical framework to identify SAI innovations (Annex 1). In Kenya this involved a systematic and consultative process summarized as follows:

1) *Conducting Literature Review:* A review of literature was conducted to capture data, information and material content for the case studies. Information was gathered from reports, records, publications and other sources bearing on SAI in Kenya. Also reviewed were global, regional, national and local data sources from the internet, libraries and key contacts.

2) *Preliminary Identification of Candidate SAI Innovations:* From the literature review, the first round of seven candidate SAI innovations in Kenya (Annex 2) were selected. The selection criteria were common across the three country studies:

    a) Innovations that have been achieved recently, at least from 2000 to date
    b) Innovations that have impacted relatively large numbers of people, preferably targeted at groups or regions (excludes individual farmer innovations)
    c) Preferably home-grown innovations
    d) Transformative innovations
    e) Representing a variety of 'initiators', e.g., public sector, private sector, civil society and public–private partnerships
    f) Representing a variety of innovations in policy, social institutions and finance as well as science and technology (or ideally combined)
    g) Innovations that might affect different types of farmers.

3) *SAI Innovations Identified in Kenya:* Based on information gathered from literature, data analysis and consultations, the top three SAI innovations in Kenya identified were:
    (i) Water harvesting and storage in farm ponds for irrigation in eastern Kenya
    (ii) Solar-powered irrigation in peri-urban Kajiado
    (iii) Blended finance supporting agricultural intensification and watershed management in Upper Tana Catchments.

4) *Conducting Key Informant Interviews:* Using the contacts from the stakeholder mapping, respondents likely to provide further information and details on the selected SAI innovations were contacted as key informants. These were interviewed through ICT (information and communication technology) modes such as e-mail communications, telephone interviews, WhatsApp, Zoom meetings and face-to-face meetings with observance of all COVID-19 safety protocols.

5) *Verifying the Presence of the SAI Innovations at the Grassroots:* Field visits were made to five counties where the three SAI innovations had been identified: Kitui, Machakos, Makueni, Kajiado and Murang'a. During these visits, national and county government staff, non-governmental organizations (NGOs), community-based organizations (CBOs), private sector service providers, farmers and other stakeholders were interviewed and the innovations visited and verified (Annex 3).

6) *Limitations to the Analysis:* The scarcity of records and central databases meant that supporting data were not easy to find, with the exception of the blended finance case study. The information available from the Internet was descriptive, while due to COVID-19 pandemic, face-to-face interviews were at a minimum and data gathering relied on telephone and e-mail. Even then, field visits were made to verify realities on the ground and interviews conducted with key informants.

4. Case studies

4.1 Water Harvesting and Storage in Farm Ponds for Irrigation in Eastern Kenya

4.1.1 Background

Drought and prolonged dry spells have for years ravaged and continue to affect agriculture in the semi-arid counties of Kitui, Machakos and Makueni in eastern Kenya (Recha et al. 2016). Farming in the three counties is predominantly smallholder, rainfed crop production. The seasonal rainfall, when it falls, is highly variable, erratic and occurs in intense storms resulting in poor infiltration, excessive runoff and consequently massive soil erosion. Due to the erosion menace, between the 1970s and the 1990s, many donor-driven projects and government initiatives on soil conservation through terracing were implemented (Tiffen et al. 1994). However, soil conservation, much as it improved crop production marginally, could not bridge the yield gap caused by recurrent droughts, which have got worse over the years, to the point where farmers stopped planting maize during the long rains (Mati 2012). All these problems could be solved by making water available for farming, in all areas, even those lacking rivers or groundwater. It is this challenge which was turned into opportunity through water harvesting.

Water-harvesting farm ponds (water pans or on-farm small storages)[2] are water storage structures constructed below the ground surface to collect rainfall runoff from open surfaces such as home compounds, roads, grasslands and other areas (WFP 2018). A farm pond has an inlet to regulate inflow and an outlet to discharge excess water. It is usually surrounded by a small bund, which prevents erosion on the banks. A farm pond may be earthen (where the soil profile is self-sealing) or, in many cases, lined with dam plastic, concrete or other material to prevent water losses by seepage (Figure 1).

The field investigations showed that pond sizes vary depending on the farmer's water requirements, land availability, soil type, excavation costs and catchment characteristics. In Kenya, farm ponds are usually excavated by hand using simple hoe and shovel, but in a few cases, larger farm ponds are excavated by machinery. Water stored in the farm pond is extracted using buckets or pumps, the type depending on farmer's financial capacity (e.g., manual, petrol or solar-powered pumps). The water is usually used for irrigating part of the farm to grow high value/short season crops and, in some cases, for livestock watering. Due to high turbidity and other health concerns, most families do not drink water contained in farm ponds. Rather, they seek drinking water elsewhere, e.g., from boreholes, water kiosks or roof harvesting storage tanks. Thus, farm ponds are used mostly for crop intensification and to drought-proof agriculture in the dry zones.

[2] The terms '*farm pond*' and '*water pan*' are sometimes used interchangeably in Kenya, in reference to the structures dug in the ground for harnessing and storing rainfall runoff (whether earthen or lined). However, water pans tend to be larger and may not necessarily be located within a farm.

Figure 1. Water-harvesting farm ponds: (left) unlined earthen farm pond in Yatta, Machakos, and (right) plastic-lined farm pond in Mutomo, Kitui.

Photos: Bancy Mati

4.1.2 Description of the Case

Although farmers in eastern Kenya are used to drought and crop failures, the turning point came on the heels of the severe drought of 2005/2006 up to 2009. This period was marked by below-average rainfall for three consecutive years causing crop failures (van Steenbergen 2019). In that time, the few existing food stocks were depleted, livestock were sold in distress or just died and local people generally lost their assets and were impoverished. Seeing all this, Dr. Titus Masika, a retired teacher, encouraged local farmers to excavate water-harvesting farm ponds for use to grow food. With some assistance from an NGO, the Christian Impact Mission (CIM), farmers were trained on water harvesting and construction of farm ponds which were about around 4–5 meters deep (World Agroforestry 2020). This initiative encouraged many families to excavate their own ponds and within a short time, over 3,000 water-harvesting ponds had been constructed in the Yatta area alone (van Steenbergen 2019). This number continued to grow and by 2021 almost every household in Yatta owned at least one or more farm ponds. It should be noted that this success was partly enabled by the fact that the soils in Yatta are self-sealing. Hence the farm ponds are simply scooped (no need for lining) as they hold water adequately (Figure 1) without seepage issues. The technology is thus easy to replicate.

The water stored in the ponds was lifted to farmlands mostly using buckets or petrol pumps and used to irrigate food crops. The types of crops grown also changed, becoming more diverse, including marketable produce such as vegetables. Farmers could now grow kale, cabbage, tomato, onion, peppers and indigenous vegetables. It should be noted that farmers in Yatta cultivate on average 5 acres (2 ha) for field crops, mostly maize, pigeon pea, cow pea and green gram. The water from the farm pond is inadequate to irrigate such large areas. Rather, it is used to irrigate high value crops, especially vegetables and seedlings for sale. These types of crops do not cover the entire farm, but take up about a ¼ to ½ acre (0.1–0.2 ha) and rainfed crop production continues throughout the rest of the farm. Sometimes, when the rains fail, farmers 'top up' rainfed crops with the water from ponds, averting crop failure by using harvested water, hence agricultural intensification. The knowledge, attitude and behavior change components that were undertaken by the CIM included training on water harvesting techniques, utilization, agronomy and learning to grow crops with supplemental irrigation.

4.1.3 Out-Scaling to Other Counties in Eastern Kenya

The water harvesting initiative evolved through two phases, with the starter phase (2009–2014) in Yatta Sub-County of Machakos County, where digging of farm ponds was actively promoted with assistance of CIM. The success of the Yatta water-harvesting farm ponds attracted many visitors to the area. A number of projects and programs were implemented to upscale water harvesting across Kenya based on the Yatta model. This triggered the second phase which was the out-scaling to other parts of Kenya, which occurred during 2014–2021. By this time, visitors were trooping to Yatta to learn from their experiences and see the farm ponds and agricultural activities. Indeed the training center located at Yatta and operated by CIM started charging fees for training or taking groups around, at a cost of KES 10,000 (USD 100) per day, when they realized that farmers were spending too much time hosting visitors. The groups visiting Yatta were mostly leaders, farmers, NGOs and individuals – a number of serious adopters resulted from this learning exercise. Beyond Yatta Sub-County, water harvesting was promoted by NGOs and county governments. By 2021, it was estimated (information from key informants) that about 10,000 farm ponds had been constructed in the three counties of Kitui, Machakos and Makueni (Figure 2).

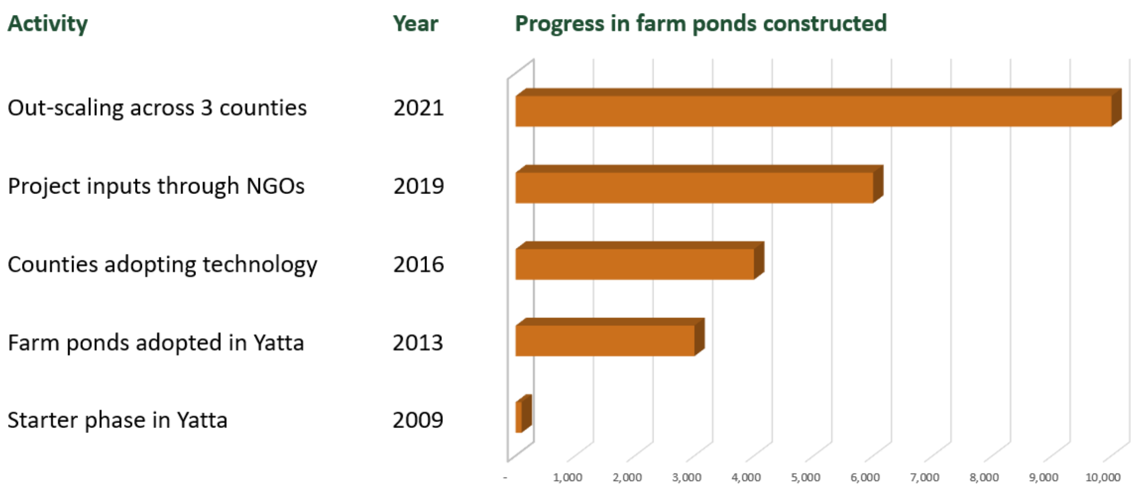

Figure 2. Progress of the adoption of farm ponds in Kitui, Machakos and Makueni.

The adoption of water-harvesting programs traceable to the Yatta interactions was more visible in the three neighboring counties of Kitui, Machakos and Makueni. The three counties have slightly different approaches in how they facilitated adoption of farm ponds, summarized here as follows (information gathered from interviews with staff and stakeholders during verification visits).

a) Machakos County (beyond Yatta): Although the over 4,000 farm ponds in Yatta are also within Machakos County, other areas in the county are not as advanced. The other sub-counties have adopted various versions of the farm ponds, based on local conditions. Since most areas suffer seepage water losses, the farm ponds require lining, usually with plastic dam-liners. During 2014–2019, a project known as DryDev (Dryland Development) was implemented in Machakos as a component of a larger Sahelian project. It was led by ICRAF (World Agroforestry) with partners who included World Vision Australia, Adventist Development and Relief Agency (ADRA), Caritas and SNV (ICRAF 2020). The DryDev report (Drydev 2019) indicates that the consortium excavated 80 farm ponds (average capacity 250 m^3). Another initiative by the National Irrigation Authority (NIA) was supporting the construction of water-harvesting farm ponds through mechanized excavation for free. The farmer's contribution is in purchase of dam liners, clearing the debris and doing all the finishing works. At the time of the field surveys, some 1,000 farm ponds had been excavated by NIA alone. Indeed the number of household farm ponds in Machakos is largely unknown albeit staff interviewed estimated 7,500 farm ponds in Machakos alone, including those in Yatta in 2021.

b) Kitui County: This is the most arid of the three counties where farm ponds were actively promoted. As a result, the county government funded the construction of larger ponds for community and livestock drinking water supplies. However, household water harvesting with storage in farm ponds was also promoted by the county government and various NGOs, including Caritas, Action Aid, World Vision Kenya, the Kenya Red Cross Society and international development partners, e.g., the World Food Programme (WFP) and the Food and Agricultural Organization of the United Nations (FAO) (ICRAF 2020). Others include CBOs and farmer common interest groups. For instance, Caritas excavated at least 120 farm ponds in Kitui over the last three years, while a Kwamikuyu CBO dug 100 farm ponds in the Kwavonza Ward alone (field staff interviews). The total number of farm ponds in Kitui could not be ascertained because farmers quite often excavate ponds on their own initiative. One major challenge in Kitui is severe drought which ravaged the county for two consecutive seasons (2020/2021) to the extent that some farm ponds were dry. Generally, the larger farm ponds still had water even after the prolonged drought. This implies that it is necessary to construct large ponds in the drier areas (farms are also larger in this area).

c) Makueni County out-scaling model: In Makueni County, the combined efforts of the national government, county government, NGOs and farmers' own initiatives facilitated faster and more visible evidence of adoption of farm ponds. The county government was at the forefront of coordinating the activities. Water-harvesting farm ponds have always existed in Makueni, mostly dug by individual farmers as well as through support by NGOs and donor-funded projects (e.g., WFP, FAO, European Union, United States Agency for International Development, Caritas and Action Aid), albeit data for quantification are hard to come by. The contemporary impetus for water harvesting started when the Makueni County Government officials and farmers made a series of trips to Yatta in 2016 to learn from their experiences. Following this, the county government took seriously the concepts of water harvesting with the slogan "*Kutwikania Kiuu Movement*" which simply translates to "*Water Conservation Movement".* The Makueni County Government using NIA's machinery provided services of mechanized farm pond excavation (free), thus lessening the initial cost. The farmers' contribution included completion of the pond (removing debris, smoothing, lining the pond and providing auxiliary infrastructure including pumping equipment). By September 2021, NIA had excavated some 500 additional farm ponds of capacity 500–1,000 m^3 in the county. Parallel to NIA's excavated farm ponds, the county government implemented a cost-sharing arrangement for excavation of ponds in Kathonzweni, Makindu and Kibwezi.

4.1.4 Drivers of the Innovation

Type of innovation: This is a technological innovation at the farm level, bearing components of a financing model. Water-harvesting farm ponds require some engineering/technical expertise for design and construction, as the technology is not truly indigenous. Farm ponds were introduced to most farmers in the recent past, as a new and innovative way of harnessing rainfall runoff in relatively large quantities, capable of supporting irrigation. In addition, the Makueni case study illustrates an innovative financing model that enables cost-sharing of the more expensive aspects of developing a farm pond, i.e., cost of rapid excavation and purchase of dam liners. Moreover, farmers sometimes work together in groups supporting each other in digging farm ponds, e.g., in Kitui.

An integrated approach: An integrated approach was adopted by the starter Yatta project and later by the adopters especially in Machakos and Makueni Counties in promoting water harvesting. In both cases, farmers (including both adopters and non-adopters) were trained on pond construction, operations and management, crop selection and agronomy, soil fertility management, water conservation, marketing of produce and linkages to microfinance and farming as a business. The integrated approach is best illustrated through a water harvesting project implemented in Mwala, Machakos County, through the Drydev initiative (Drydev 2019). They observed that: "*since installing farm ponds, the farmers have diversified their production, now including vegetables, fruits trees, poultry and bee keeping, allowing them to produce throughout the year and thus maximizing their income."* This facilitated opportunities for increased production of major staples, vegetables and fruits, thus contributing to improved household nutrition.

Adoptable by all farming scales: The adopters and users of farm ponds range from the poor or uneducated who mostly dig smaller farm ponds using family labor, to farmers with alternative sources of income, e.g., having wage employment elsewhere, who invest in larger farm ponds with substantial capital outlay (based on interviews and field observations). Regardless of wealth status, all farmers required technical advice and services such as proper siting, construction and lining of ponds (where necessary) or pump selection, thereby encouraging cross-learning within the community.

Subsidies and incentives: Each of the three counties provided some form of incentive or subsidies to cushion farmers against the high costs of construction and equipping of farm ponds. In Kitui, NGOs provided subsidized dam liners while farmers provided labor for the excavation. In Machakos and Makueni (where ponds are larger), they sought the help of NIA, which excavated the ponds for free but the farmer did the finishing, including dam lining. Also in Makueni, the county government implemented a financing model of the cost-sharing excavation of farm ponds as described in Box 1 (quoting the Makueni County Director of Agriculture).

Box 1: Cost-sharing for construction of water-harvesting farm ponds in Makueni

This initiative is led by the county government which had purchased some machinery (back-hoe excavators) specifically for the water harvesting program, leased out to farmers at a subsidized fee. Farmers prefer mechanized excavation as it is faster and more cost effective than manual digging. The farmer hires the excavator for one day, paying KES 4,000/hour (USD 40/hour). On average, the excavator takes 5–6 hours on good soil or about 8 hours on hard and stony soils to excavate a 500 m^3 capacity farm pond, meaning just one day is needed for excavation. Depending on site conditions, some farm ponds are earthen, while others are lined with dam plastic. Thus, the average cost of a farm pond starts from about KES 30,000 (USD 300) for unlined ponds. For farmers who require lining their ponds, dam liners are expensive as the average cost is about KES 90,000 (USD 900) for a 500 m^3 pond, resulting in a total cost of about KES 120,000 (about USD 1,200) for these large lined ponds. This is a substantive capital outlay, hence the need to support the poor through various credit or grant programs. Indeed poorer farmers excavate smaller ponds using manual labor. The NGOs and other funding streams normally subsidize the cost of dam liners.

Partnerships: In the earlier stages, during the promotion of water harvesting in Yatta (2009–2014), partnerships were formed under the leadership of CIM (Dr. Masika) to kick-start the process. These included farmer groups and extension workers. In the out-scaling years (2014–2021) another partnership led by ICRAF with partners who included international NGOs (ADRA, World Vision, SNV-Netherlands and Caritas) promoted water harvesting through the Drydev project in Machakos and Kitui. Thereafter, there were various partnerships led by respective county governments, e.g., in Makueni, the county government partners in promoting farm ponds for food security with organizations such as the WFP, Action Aid, International Fund for Agricultural Development (IFAD) and FAO.

Policy and institutional support: At the national level, water harvesting is well espoused in long-term plans such as Kenya Vision 2030 as well as the Irrigation Policy (GoK 2017). In addition*, c*ounties play an important role in implementation of water harvesting programs. Nearly all counties have included promotion of water harvesting for irrigation in their five-year CIDPs. Based on the CIDP, development funding is channeled to counties, including grants for projects by development partners. Thus, the policy and strategy support was a major factor in driving the scale that was reached. In the Agricultural Sector Transformation and Growth Strategy 2019–2029 (GoK 2019), farm ponds feature as a critical enabler to unlocking growth of investments in agriculture. Even the Water Act (Republic of Kenya 2016) recognizes water harvesting and storage as necessary for improving agricultural productivity and climate change resilience.

4.1.5 Major Challenges Faced

One of the greatest challenges is the high cost of construction of farm ponds, especially those requiring dam liners. Without support by relatives or subsidies by various projects, poor farmers find it difficult to afford excavation of farm ponds, especially as it is a labor-demanding activity. Older farmers in Yatta informed the researchers that it took them a number of years to excavate one pond by hand, as the work had to be done during the dry season when other farm work is low. For this reason there is the need to support the poor and female-headed households with subsidies to excavate ponds.

Another field observation was that technical staff suggested that there is generally enough surface runoff to fill a pond at household level, even after a few storms. The size of ponds is thus limited more by cost/labor consideration than by availability of runoff.

There is usually a need for trained technical staff to design, layout and supervise the construction of farm ponds. The number of available technicians was reported to be low, calling for more capacity building in this highly specialized field.

Some of the more common problems associated with farms ponds include high evaporation rates and safety concerns, which can be resolved by fencing the pond area, covering with special nets as well as provision of pumps with water draw-off points positioned away from the pond. Sometimes these best practices are not adhered to.

The energy to lift water from the pond to the irrigated field is another challenge. Many farmers cannot afford solar powered or motorized pumps. Delivery of water to fields is sometimes manual and thus wasteful (of both energy and water). All these issues need to be addressed to make best economic use of the farm pond for agricultural intensification.

4.1.6 Outcomes and Impacts

Estimates by field staff indicated that at least 10,000 farm ponds had been excavated by 2021, and were being used for irrigation of food crops in the three counties, *facilitating agricultural intensification and food security for small-scale farmers*. This positively impacted on at least 100,000 people in the food value chains created, emanating from the presence of the farm ponds (as reported by county staff).

The impacts of water harvesting and storage ponds for *improving food production and climate change resilience* are substantive. Respondents interviewed stated that by using the stored water, farmers were able to bridge the dry season when rains fail, hence produce more food crops such as maize, pigeon pea, beans, fruits and vegetables. Moreover, a wider range of crops including marketable produce, especially fresh vegetables and fruits were being grown.

Farm ponds *advanced the commercialization of the rural economy* through increased participation of farmers in strengthened value chains of selected inputs and commodities, access to credit and financial mechanisms, while enhancing information exchange, knowledge and advocacy. In one example in of a youth group that adopted farm ponds in Mwala, Machakos County, it was observed that a net positive return on investment could be achieved within 2½ years (Drydev 2019). In regard to income benefits, for the same youth group, it was observed that farm ponds cost KES 158,000–319,000 (average of KES 207,066 or USD 2,071) to install, including auxiliary irrigation infrastructure. Farmers reported increased annual farm income of KES 179,200 (USD 1,790). Average monthly household expenditure on food has reduced by KES 1,840 (USD 18) attributable to irrigated produce using farm ponds (Drydev 2019).

Farm ponds provide *opportunity for creation of employment and increased livelihood options* and household incomes through sales of their produce, with subsequent enhanced living standards. Water harvesting supports nutrition as farmers are able to grow nutrient rich crops and kitchen gardens. The water is also used for livestock thus enhancing integrated agriculture. Furthermore, water harvesting was also a social innovation, meaning it enabled the design and implementation of new solutions that imply conceptual, process, product or organizational change, which ultimately improve the welfare and wellbeing of individuals and communities (https://www.oecd.org/regional/leed/social-innovation.htm). In essence it changed how farmers respond to drought, enhancing incomes and community resilience to climate change.

Another outcome was the opportunity for farmers in dry zones to have *access to water at farm level* throughout the year and to irrigate crops including on land without a river or ground water resources. This gave this innovation opportunity for wide adaptability. Other factors included (a) dynamic leadership by Dr. Masika through CIM that initiated wide adoption within Yatta and attracted adopters – both NGOs and county governments, (b) technology advances through availability of solar-resistant plastic dam-liners, (c) subsidized excavation and incentives made available to farmers to accommodate the high costs of construction and (d) capacity building provided by NGOs, county governments and various projects. This was especially evident in the eastern Kenya counties of Kitui, Machakos and Makueni, where farmers adopted construction of farm ponds, to solve the problem of food security in the face of recurrent droughts.

4.2 Solar-Powered Irrigation in Peri-Urban Kajiado

4.2.1 Background

Kajiado County borders Nairobi city to the north and stretches southward to the border with Tanzania at Loitokitok. The total population as per the 2019 national census was 1,117,840, with a large proportion (46%) living in peri-urban areas close to Nairobi (KNBS 2019). However, the county is mostly semi-arid with low rainfall and a generally dry climate (County Government of Kajiado 2018). In addition, most of Kajiado has few rivers and is too dry for rainfed agriculture. Luckily, the peri-urban areas of Kajiado lying on the Athi-Kapiti plains have good soils and appreciable groundwater resources, estimated to have a potential yield of up to 240 m^3/day (WRA 2020), which can be exploited for irrigation. In the past, groundwater resources remained largely underutilized due to the high cost of water pumping using conventional energy sources, thereby discouraging investment in irrigation. Water pumping for irrigation relied on conventional energy sources, such as petrol or diesel pumps (Muturi et al. 2019) and in a few cases, electric pumps powered from the grid.

Evolution of solar-powered irrigation systems (SPIS): Before the 1970s, use of solar power generation was negligible in Kenya. As a response to the oil crisis of the 1970s, use of renewable energy was encouraged and solar energy for heating water and lighting homes was popularized. Toward the late 1970s, solar photovoltaic (PV) systems were installed in remote areas and solar pumps started to make their way into the Kenyan market (Chandel et al. 2015). The early types of PV pumping systems used centrifugal pumps, usually driven by variable frequency alternating current (AC) motors. However, these pumps had low hydraulic efficiencies in the range of 25–35%. These early solar pumps were fraught with problems, as they were inefficient, expensive and easily failed. The power obtained from solar equipment was usually weak with short functional life, and local people did not know how to maintain batteries. These factors discouraged smallholder farmers from adopting solar-powered pumps. In the 1980s–1990s, efforts on solar PV went to lighting of schools, health centers and for pumping drinking water mostly funded by donors and NGOs.

Meanwhile, affordable energy to pump water from groundwater sources for irrigation in Kajiado was the missing link to agricultural intensification. This disconnect was resolved from around 2000, when the energy sector was liberalized in Kenya (EED Advisory 2018), a critical trigger of the innovation. The number of solar-energy and irrigation companies marketing solar water pumps increased, including in Kajiado peri-urban areas. Private sector marketers of solar products, sometimes doubling up as agents of various companies, promoted SPIS solutions to farmers through farm visits, shows and advertisements in the media. This knowledge push encouraged farmers in peri-urban Kajiado to adopt SPIS. More farmers were able to open up land for irrigation or to convert from use of fossil fuels or grid electricity into SPIS.

4.2.2 Description of the Case

This innovation involved enhancing agricultural intensification using green energy through adoption of SPIS in peri-urban areas of Kajiado bordering the city of Nairobi. Kajiado County has high insolation rates of about 4–6 kWh/m^2 with an average of 5–7 peak sunshine hours per day. Only 10–14% of this energy can be converted into electricity due to the conversion efficiency of solar PV modules (EED Advisory 2018). Since 2006–2007, the Ministry of Energy has actively promoted solar energy for off-grid electrification. It funded the Solar for Schools program, which it aims to extend to off-grid public institutions. In terms of solar power penetration, data from the 2019 Kenya Population and Housing

Census Volume IV show that just 15.5% of households in Kajiado County used solar as their main source of energy for lighting (KNBS 2019). Even then, the percentage of solar energy harnessed for water pumping or irrigation was not quantified.

Type of innovation: This is mostly a technological innovation driven by business pull through peri-urban agriculture, bundled with innovative financing models using mobile money platforms. SPIS is defined as *"an irrigation system where water pumping is powered by solar energy"* (FAO 2018). The SPIS adopted in Kajiado (Figure 3) typically consist of the following main components: (1) a PV array (solar panels), (2) a controller unit [either direct current (DC) or AC inverter], (3) an electric motor, (4) a water pump and (5) a water storage facility/tank (optional). The most common solar water pumping systems for irrigation range from low-head submersible pumps for shallow wells to heavy-duty submersibles for borehole pumping. Boreholes that yield from 20 to over 100 m^3/hour have adequate water for irrigation and may require large solar panels, which are available on the Kenyan market.

Interviews with key informants revealed that, in the peri-urban areas of Kajiado, adoption of solar-powered irrigation by farmers has rapidly expanded in response to close proximity of the market for irrigated produce in nearby Nairobi city, and availability of equipment through various sales agents. The private-sector-led solar PV industry provided affordable, durable, easy to operate solar water pumps, sometimes marketed as a complete kit (solar panels, pump and irrigation equipment) with innovative financing models to suit individual farmer needs. This facilitated expansion of agriculture and improved production of food, both for local and export markets. In the peri-urban areas, the average farm sizes were small, ranging from 0.5 ha to about 10 ha for the more commercial farming. The majority of SPIS farmers were small-scale.

Figure 3. (a) Solar-powered irrigation system and (b) a crop of spinach grown under irrigation in Kajiado.
Photos: Bancy Mati.

4.2.3 Drivers of the Innovation

a) Market penetration of SPIS: Within Kajiado, SPIS adoption started increasing from around the year 2000, mostly due to marketing and publicity by respective companies promoting the technology, and a policy push for green energy (Republic of Kenya 2012). Sales data are difficult to come by but one company, Sunculture, reported to have sold at least 200 SPIS kits in Kajiado alone (staff interviews). Indeed the true number of SPIS kits operating in Kajiado remains largely unknown as no relevant mapping has been done. Most farmers buy their solar kits directly from the private sector and there is little information flow to the county databases. Generally, the sales of both small- and large-scale solar powered pumping systems are reportedly growing steadily. The factors contributing to this are illustrated in Figure 4.

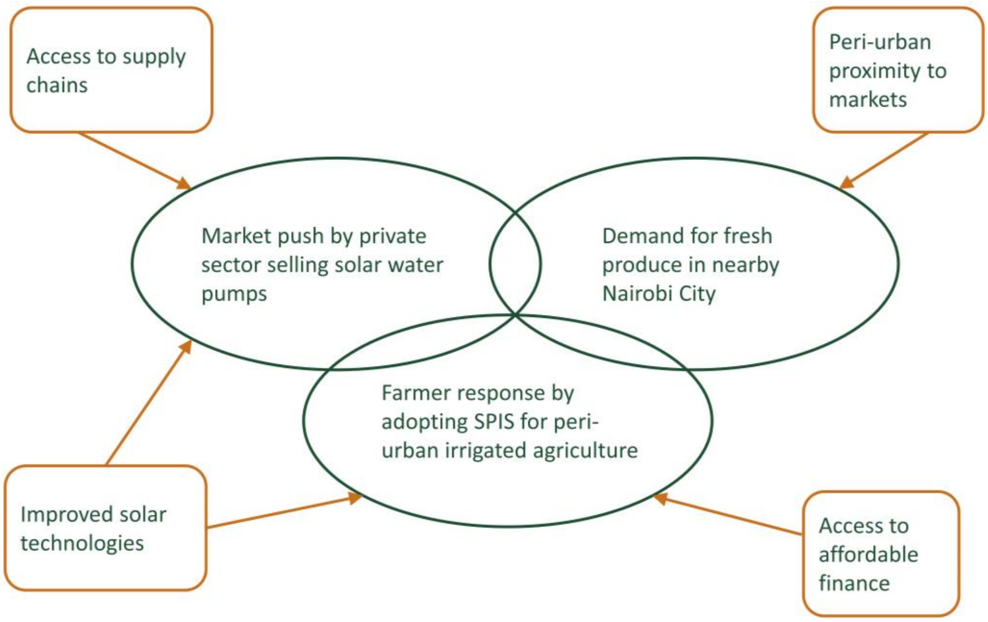

Figure 4. Schematic illustration of the drivers of success of solar-powered irrigation in Kajiado.

b) Solar-powered irrigation kits became affordable: Technological advances in the design of solar equipment saw prices go down generally, associated with the push for clean energy. For water pumping, invention of solar-powered pumps that operate with DC further simplified the technology, making it more efficient and affordable. In effect, contemporary SPIS kits offer an array of products ranging from small portable kits to large-scale installations for scheme-level irrigation or community-scale projects. For smallholder individual farms irrigating about 0.2–0.4 ha, an SPIS kit that includes a submersible pump and solar panels costs about USD 350–1,740 (KSSI 2017). Meanwhile, those for heavy-duty borehole pumping may cost about USD 30,000. As these are initial costs and there is low if any running costs, then the investment is worthwhile. Also, the cost of solar panels has reduced by 80% in the last 10 years. Furthermore, the cost recovery of solar pumping investments can be attained within 1–3 years (ALIN 2020). This shows that solar power has come of age to plug the energy needs for irrigation.

c) Access to markets for agricultural produce in Nairobi: The proximity of the county to Nairobi city and indeed location within the metropolitan area provides easy market targeting for fresh produce. The irrigated farms of Kajiado provide fresh vegetables (kale, cabbage, tomato and onion) for the local market and French bean for the export market, due to easy access to the international airport (Mati 2019).

e) Innovative financing and credit schemes for SPIS: There are a number of financial institutions providing grants, loans and credit for agriculture in Kenya including at village level. There are also private companies and NGOs offering innovative credit schemes targeting smallholder farmers engaged in irrigated agriculture. These include asset financing, such as providing in-kind soft loans for farmers to purchase SPIS equipment. The most common typologies of financing and credit models for SPIS include pay-as-you-grow, pay-as-you-go, microfinance credit schemes, mobile layaways, rent-to-own models, the leasing model, aggregator models and table-banking models (Mati 2019). Thus, a number of these credit schemes facilitate the poor to access SPIS through affordable financing (see Box 2).

Box 2. Innovative Financing with 'pay-as-you-grow' financial models for SPIS

This is a financing credit model for SPIS, designed for small-scale farmers, in which no collateral is required. The farmer shows evidence of access to land, irrigation water and being active in farming, but with a need for water pumping. Credit is allowed for farming on as little as ½ acre (0.2 ha) plot of land. The solar kits on offer vary with farmers' irrigation requirements. Some of the smaller ones comprise portable solar panels with a pumping kit (submersible pump and pipes). A solar pumping kit capable of a suction head of at least 15 m costs about USD 350. Farmers can take the pump on loan and pay through an M-Pesa[3] credit scheme which deducts 'water credits', in a credit scheme referred to as 'pay-as-you-grow'. This enables the farmer to pay for the cost of the solar pumping kit in small installments as he/she grows a crop. Once the credit is fully paid, the farmer fully owns the pump.

How it works

The solar panel is fitted with an electronic sensor linked to a dedicated SPIS M-Pesa loan account of the farmer and also to the bank. When the pump is operating, it triggers a connection to the computers in the offices of the company that sold the SPIS system, which reflect remotely that the pump is in operation (the company keeps a rich database of who is irrigating and when). At the same time, operating the solar pump also triggers a link to the loan account (in a bank) for that particular pump/farmer. As the water is pumped, it uses M-Pesa credit which in turn reflects as a deduction of the loan account in the bank – all this happens simultaneously. In essence, the loan reduces each time the pump is operated. When there is no money in the M-Pesa account, the pump stops and can operate again if the M-Pesa account is topped up. Some farmers pay a monthly rate while others pay on an as needed basis, i.e., they top up the M-Pesa account as necessary. This continues until the loan is fully paid, at which time the solar pump operates freely without the need for topping up with M-Pesa credit, and the pump becomes wholly owned by the farmer. Many farmers pay the loan by the second crop season of vegetables or within a year, as reported by key informants.

[3] M-Pesa is a mobile money system developed in Kenya which is the most popular money transfer platform accessed by nearly all Kenyans (https://www.safaricom.co.ke/personal/m-pesa/m-pesa-home).

e) Complete SPIS kits: Several SPIS service providers and companies provide the layout and design of the whole system, including planning of agronomic aspects, and act as holistic service providers. Examples include Sunculture, Kickstart International, Futurepump, Epicenter Africa and Irrico. In Kenya, there is a general trend toward suppliers planning and designing the entire SPIS (including pump and irrigation equipment), installing it and offering service contracts for its operation, thus being competitive. In that case, the company acts as a service provider but links the farmer to a financier for the purchase of the system.

f) Enabling policy: The Government of Kenya in 2012 zero-rated the import duty and removed Value Added Tax on renewable energy equipment and accessories (Republic of Kenya 2012). Moreover, the Finance Act - 2021 (Republic of Kenya 2021) upheld tax exceptions on specialized equipment for the development and generation of solar and wind energy, including PV modules, DC charge controllers, DC inverters and deep cycle batteries that use or store solar power. This helped to retain lower costs of solar panels and attachments. However, these tax exemptions do not cover peripheral equipment, such as mountings, pumps, pipes or irrigation equipment. If tax exemptions were expanded to all irrigation equipment, costs would be reduced leading to more adoption, and thus encouraging increased food production.

4.2.4 Actions and Actors Engaged

Value chain actors: There is a wide stakeholder base engaged in the SPIS value chain, as obtained in interviews with key informants. They include (i) users of solar products and equipment – mostly farmers, (ii) suppliers of either whole SPIS kits or components of solar-powered equipment and associated services, such as importers, wholesalers, retailers and re-sellers, manufacturers and service providers across a wide spectrum (private companies, technicians, extension workers, traders and transporters. There are also (iii) development partners supporting SPIS (UN, multilateral, international and local NGOs), (iv) banks and financial institutions, (v) marketing and farmer support organizations, including NGOs, (vi) institutions offering training on solar-powered systems and (vii) policy and regulatory institutions at national and county levels (government).

Service providers: There are many service providers active in Kajiado County in the SPIS space, some with offices there or simply operating from Nairobi. The most common ones include the following:

- Sunculture – have a wide range of small pumps including the RainMaker solar water pump systems, which consist of a solar pump, controller, battery bank, portable solar panel and sprinkler (http://sunculture.com/products)
- Epicenter Kenya – re-sellers of various types of pumps and also provide technical support for fixing pumps. Main types of pumps are those by Grundfos, Kenya Lorenz and others (http://epicenterafrica.com)
- Future Pump – have popularized their SF2 solar pump which is a reciprocating, positive displacement piston pump using a DC motor. It is simple in design – farmer fixable, and good for smallholder farms (https://futurepump.com)
- Kenya Lorentz – sells medium to large solar pumps including the PS2 solar pump which is of high efficiency with a wide power range from 150 W to 4 kW. They also sell a wide range of pumps (https://www.lorentz.de)

- Davis & Shirtliff – also a reseller of all types of pumps including Dayliff DDPS60 and Sun-Flos range, which are solar-powered pumps suitable for water transfer in small-scale applications and installation of equipment (https://www.davisandshirtliff.com)
- Other companies include Greenserve Agri-solutions, Chloride Exide, Grundfos, Wotech Kenya Ltd, Grekkon, Irrico International, Adritex Kenya and Generation Kenya Limited. Others offer various services from capacity building to extension services. For instance, Strathmore University does capacity building for technicians who may be self-sponsored or funded by companies, while the County Government of Kajiado provides policy support and extension staff on all aspects of agriculture including irrigation. Other stakeholders include transporters, traders and retailers who complete looping of an SPIS value chain.

4.2.5 Challenges Faced

A number of challenges face the sub-sector of solar-powered irrigation, cutting across technological, policy, economic and social issues, and they include the following:

#High initial costs: Although the prices of solar energy equipment have drastically dropped, making the technology affordable to medium-scale farmers and those with alternative incomes, the cost is still relatively high for smallholder farmers. For instance, a small solar pumping kit for irrigation costs about USD 350–800, which is still too expensive for poor farmers (Mati 2019). Moreover, most solar-powered pumping equipment is imported from China, India, USA, Germany and other countries and finding spare parts locally can be a challenge.

a) *Shortage of qualified technicians:* There are few qualified technical staff to handle design, installation, operation and maintenance of SPIS and this affects the quality of products, design, installation and maintenance services for SPIS (http://kerea.org/voluntary-accreditation-of-solar-pv-businesses-in-kenya).

b) *Shortage of land:* The peri-urban areas of Kajiado have been taken over by residential areas which occupy formerly fertile lands that could be irrigated. This means shrinking space for agriculture.

c) Limited publicly available information on renewable resources to support investment promotion, decision making and energy planning.

d) A limited local capacity to manufacture solar power components and equipment.

e) Limited information on appropriate credit and financing mechanisms, which causes delay in project implementation.

4.2.6 Outcomes and Impacts

a) *Reduced costs of pumping:* SPIS offers the opportunity to pump irrigation water without the running costs associated with fossil fuels or grid electricity. Although capital outlay required to purchase the equipment can be high (e.g., USD 800), in the long term SPIS are actually more economical since they have negligible running costs. Compared to diesel pumps, solar pumping reduces the cost of pumping by 40–90% over life of the system. The cost of solar modules has reduced by 80% in the last 10 years (Mati 2019).

b) SPIS offers good return on investment: Profits of at least 70% (Holthaus et al. 2017) have been recorded in Kenya. The turn-around time for this investment is usually 1–3 years, making these systems a worthwhile investment. They have a life span of about 5 years, in which time they could have paid back their cost. The important factor of solar pumping is not to over-work it, by exceeding 7 hours/day of pumping (depends on model, and can be less). Also, solar pumps provide clean energy (are green) and popular with donor-funded projects.

c) *Multiple use of solar energy generated:* SPIS are versatile and can be converted to other uses at farm level. They offer multiple use of energy which is especially important in areas not connected to an electricity grid. The solar energy is used for post-harvest processing of crops, lighting homes, charging mobile phones and other light industries. This eliminates the need to purchase fuels such as petrol and paraffin. Through improved access to energy and water, SPIS helps to stabilize, increase and diversify agricultural production (e.g., vegetables and fruits). The increased availability of food improves food and nutritional security, especially for smallholder farmers and their communities.

d) *Scalability:* Solar-powered irrigation is applicable across multiple scales as pumps come in a range of capacities and solar panels can be added if additional power as required. SPIS can be implemented at individual farmer or community levels. The County Government of Kajiado has conducted a mapping of the potential sites for solar energy installations, and is in the process of piloting a new smart-grid solar technology (ALIN 2020).

e) *Reduced labor and drudgery*: Solar pumping upscales farmers from using manual water-lifting devices such as bucket irrigation or treadle pumps. This is a major relief for women whose health is affected by manual irrigation methods. SPIS is low maintenance, easy to install, simple and reliable, and may operate unattended. Some smaller SPIS kits are portable, making them easy to share between farmers and for safe keeping.

f) *Environmentally friendly*: Solar water pumping is a climate-smart choice, especially when compared with petrol, diesel or other fossil fuels. Overall, SPIS can play an important role in climate change mitigation, reducing greenhouse gas (carbon dioxide) emissions in irrigated agriculture by replacing fossil fuels with a renewable energy source.

g) *Resilience against drought/climate change:* Farmers in dry zones regularly suffer crop losses due to droughts. Affordable pumping, especially with introduction of supplemental irrigation of crops, could cushion farmers against weather shocks. Being renewable, solar energy facilitates irrigation and thus attainment of SDGs that have a bearing on food security (SDG 2), water (SDG 6), energy (SDG 7) and climate change (SDG 13). The national government developed a roadmap for SDGs which is supportive of renewable energy including solar, as one way of climate change adaptation and resilience (Ministry of Devolution and Planning 2017).

h) *Gender and youth engagement in agriculture:* There are significant benefits of solar pumping solutions for women and youth. SPIS are often used for crops traditionally grown by women, such as fruits and vegetables. This could enable women farmers to engage in production of vegetables, improve household nutrition and incomes from sale of agricultural produce. Also, SPIS is a labor-saving technology which is attractive to youth. Although not quantified, key informants interviewed indicated that a large number of youth were engaged in SPIS in Kajiado.

4.3 Blended Finance Supporting Agricultural Intensification and Watershed Management in Upper Tana

4.3.1 Background

The city of Nairobi has a growing population, numbering 4,397,073 in 2019 (KNBS 2019). It is a thirsty city, suffering huge water deficits. The water demand in Nairobi city averages 750,000 m^3/day against a delivery capacity of 525,000 m^3/day (Gichuki 2015). The Upper Tana catchments supply the bulk of the water used in Nairobi through the Sasumua and Ndakaini dams, which draw their water from the Chania and Thika rivers, respectively. Nairobi being a major industrial hub in Kenya, its consumption includes both industrial and household water. However, increasing suspended sediment in the rivers has become a major issue as it increases the maintenance and water treatment costs. Indeed the water treatment costs often increase more than 33% during the rainy season, as sediment runoff fills and disrupts treatment equipment causing supply interruptions. Without intervention, this problem is likely to escalate, as climate change causes more intense rainfall events and population growth leads to more farming on steep watershed slopes. In addition, Nairobi's water treatment and distribution facilities are under pressure and face a deficit of 30% of water when the system is operating at full capacity. It is becoming clear that sorting this out requires interventions at the source, i.e., in the catchments where the resource managers are local farmers. Such efforts require supporting community actions in the areas where the water originates.

Meanwhile, in the upstream catchments of the Upper Tana, the land owners/users who live upstream cultivate the steep, fragile lands prone to erosion, soil degradation and are generally resource poor. It is essential that downstream users support upstream actors to better manage the watershed and promote conservation. Residing on top of water catchment areas, these land users constitute 'unpaid watershed managers' of the natural resources, including the water collected in dams and taken to the city of Nairobi downstream.

The city of Nairobi on its part has, among its residents and clients, large water users comprising companies with generous corporate social responsibility funds. Some of these companies and water utilities such as the Nairobi City Water and Sewerage Company are willing to support conservation and other beneficial activities in upstream areas where the resource comes from. Moreover, the city entities and land users would also like to see ecosystems preserved, agriculture practiced in a sustainable manner and watershed conservation that translates into cleaner water flows from the catchments. As opposed to previous approaches of one-off projects, this innovation brought together the water users downstream (Nairobi-based private and public institutions) who set up a long-term sustainable blended financing mechanism, the Upper Tana-Nairobi Water Fund which has since graduated into a fully incorporated trust in Kenya. It is a long-term financing model for watershed management combined with governance and having legal basis as a charitable public trust. The Water Fund created a platform for participation of public, private and development actors and communities, providing support and a delivery mechanism for SAI and watershed conservation, where downstream water users (at the tap) provide incentives (blended finance) for upstream communities (at the top) to conserve the sources of water.

4.3.2 Description of the Case

Type of innovation: This is a blended financing innovation with technological, environmental and socio-economic components. The Water Fund was the first of its kind in Kenya, and indeed in Africa.

Following a successful proof of concept, a five-year project phase from 2015 to 2020 actualized to create the Water Fund as an enduring institution and implement various activities out of which successful outcomes were achieved: reduced erosion, increased tree cover, rainwater harvesting, crop diversification, increased incomes for farmers and investment flows from partners. This phase was implemented with funding support from the Global Environment Facility (GEF) through IFAD (IFAD 2015) and implemented by TNC in collaboration with partners. It entailed the following:

Timelines: This innovation has a timeline of nine years (2012–2021) in two phases: (i) the first three years (2012–2015), implemented as a proof of concept phase, when baseline studies and partnerships building were done to test the business case for setting up a Water Fund modeled on experiences in other parts of the world but anchored in local realities and (ii) the second phase of five years (2015–2020) was the setting up of the Water Fund through a GEF-funded project culminating in the transition into a fully independent trust under Kenya law in September 2021.

Proving a business case for the Water Fund: The Water Fund was initiated in 2012 through a three-year proof of concept phase which was used mostly for gathering baseline data, hydrological and economic modeling and developing a stakeholder base. This stage was meant to determine the 'business case' for establishment of a Water Fund for Nairobi (TNC 2015). This entailed a series of studies over a three-year period meant to assess the economic viability of a Water Fund for the Upper Tana River basin. The studies were commissioned by a public–private steering committee comprising TNC and its partners. This coming together of the large companies led to financial commitments and goodwill for the Water Fund's establishment in Nairobi.

How the Water Fund works: A water fund is a governance and financial mechanism focused on science-based implementation of upstream land and water conservation measures necessary to meet water quality and/or quantity goals (Figure 5). It features a public–private partnership of government, public and private donors and private sector institutions – some of which are major water consumers 'at the tap' that contribute to the water fund operations and implementation fund and/or endowment. The endowment fund is a long-term financing mechanism to which the partners make contributions. Whether endowment or general implementation funds, they are used to support water and soil conservation measures 'at the top' (TNC 2015). These measures benefit local farmers through increasing agricultural yields by reducing soil erosion, improving crop production sustainably, taking care of water quality and catchment conservation.

Identifying the benefits and costs: The Water Fund business case study focused on the benefits that would arise given a USD 10 million investment in priority sub-watersheds disbursed over a period of 10 years as a preferred scenario. Investment planning and watershed modeling were performed using economic analysis and a coupled SWAT-InVEST modeling framework. Subsequently, FAO's EX-Ante Carbon Balance Tool (EX-ACT) tool (FAO 2017) was used to estimate carbon savings and climate mitigation impacts. The business case identified various interventions for targeted sub-watersheds: vegetation buffer zones along riverbanks, agroforestry, terracing of steep and very steep farmlands, reforestation for degraded lands at forest edges, grass buffer strips in farmlands and mitigation of erosion from dirt roads. The economic impact of these interventions was modeled for three key stakeholder groups, especially farmers in the sub-watersheds. It also delineated three priority sub-watersheds of the Upper Tana Basin as areas of critical importance for improving water quality and quantity in the basin: Sagana-Gura, Maragua and Thika-Chania rivers. The modeling results were used a proof of concept of the impacts of different conservation interventions to demonstrate what success would look like in the Upper Tana watershed.

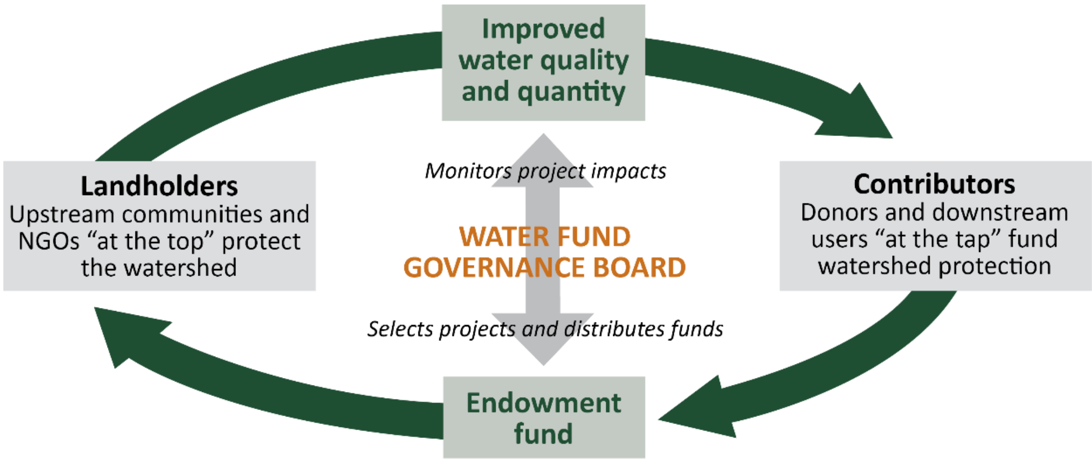

Figure 5. Illustration of how water funds work.

Source: TNC 2015.

Box 3. Why the Water Fund works

The financial support for water funds is used to promote sustainable land and water management practices upstream that filter and regulate water flow. These management practices can include strategically-sited tree planting and land terracing, natural water holding features and on-farm soil and water management practices. Funding is also used to support economic opportunities that enhance livelihoods and the quality of life for upstream communities that further incentivize farmers and landowners to implement sustainable management practices. Indeed, many of the interventions that improve water quality and quantity also lead to increased agricultural yields. Water funds can also enhance communities' ability to adapt to climate change, by building in resilience to fluctuating water supplies and temperatures.

Implementation of water funds is a proven model founded on the principle that it is less expensive to prevent water problems at the source than it is to address them further downstream. The results of the Water Fund business case demonstrated a clear economic basis for the establishment of the Water Fund. It proposed a USD 10 million investment in Water Fund interventions showing that this is likely to return USD 21.5 million in economic benefits over a 30-year timeframe. The study projected that for every USD 1 invested by the Water Fund, stakeholders in the basin and Nairobi would see over USD 2 worth of benefits accrued (Schmitz and Kihara 2021). The payback period for the investment is calculated at approximately 20 years. The Water Fund provides a secure and transparent program through which public and private donors and partners who depend on clean water supplies from the Upper Tana watershed can direct resources to conservation strategies that will yield the greatest returns for the common good and the economy.

Financial outlay: From a financial perspective, the business case recommended that to achieve the results required in the Upper Tana, an annual expenditure of some USD 1 million would be required over a 10-year period, impacting on some 50,000 farms and adjacent forests whereby most farms would be engaged to change their land management and soil management practices. This meant collective action by partners downstream and in the international community, who would mobilize at least USD 1 million annually, to try to achieve the target of USD 10 million that constituted the initial budget of the Water Fund (for a 10-year period).

Theory of change: The function of water funds is premised on the principle that it is cheaper to prevent water problems at the source than to address them further downstream (TNC 2015). Investments in green infrastructure using natural systems to trap sediment and regulate water often provide a more cost-effective approach than relying solely on gray (built) infrastructure such as reservoirs and water treatment systems. The idea of a Water Fund for Nairobi was based on findings from other successful water funds that TNC had implemented elsewhere in the world. Examples include the cities of Quito in Ecuador and Rio de Janeiro, Brazil. By the time of its formulation in 2012, the Water Fund relied on experiences gained in addressing similar issues in Latin America, where over 30 water funds had been developed (TNC 2015). The Water Fund was thus planned with these concepts (Figure 6) of sharing the benefits of watershed conservation by upstream land owners/users through investments by downstream beneficiaries of accruing water resources protection and ecosystem services.

Developing a blended finance system or 'water fund': This entailed mobilizing sustainable financing from donors, private sector and water users in the downstream city of Nairobi and in the international community to support agricultural intensification and watershed conservation activities in Upper Tana River catchments. Blended finance is defined as the strategic use of development finance for the mobilization of additional finance toward sustainable development in developing countries (OECD 2021). The problem addressed was the disconnect in availing a sustainable financing mechanism to support watershed management and SAI in the upstream catchments of the Upper Tana River Basin. The innovation started with a 'proof of concept' phase.

Setting up the institutional structures: This entailed creation of a public–private partnership or steering committee. Grassroots activities were implemented in partnerships with county governments (Murang'a, Nyandarua and Nyeri) and some specific activities and deliverables contracted out to NGOs, such as the Sustainable Agriculture Community Development Programme (SACDEP) and the Green Belt Movement. The day-to-day activities were coordinated by staff in the secretariat with oversight by the Board of Management, which represents the managerial expertise responsible for the technical matters of the Water Fund. The overall direction of the Water Fund was entrusted to a board of trustees, the apex body responsible for delivery of the Water Fund and resource mobilization.

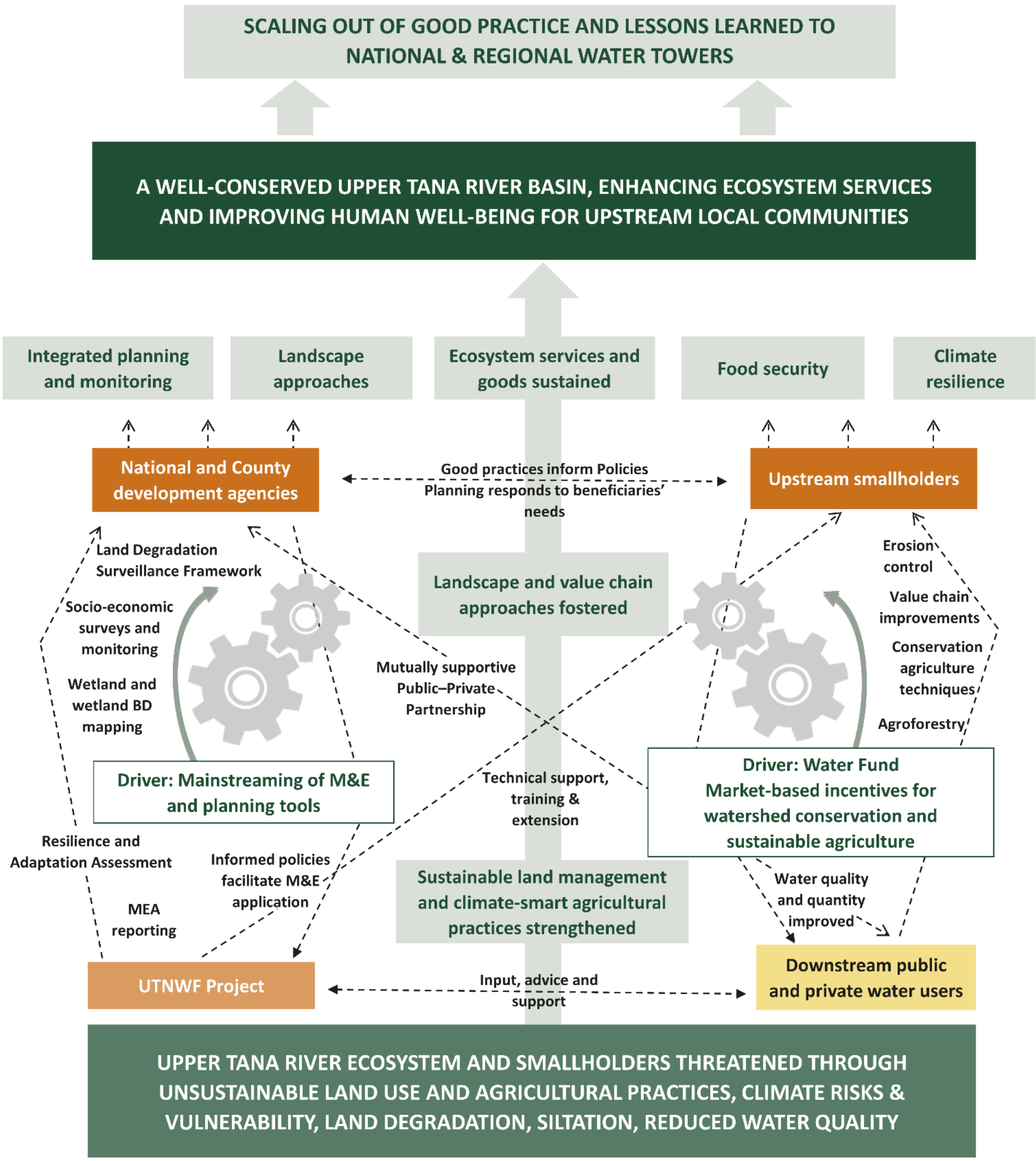

Figure 6. Theory of change for the Water Fund model.

Source: TNC 2015.

4.3.3 Drivers of the Innovation

A number of factors and activities contributed to the success of this innovation, such as the following:

- Establishment and institutionalization of the Water Fund management platform. This involved identification of at private sector companies in Nairobi, and linking them with public sector institutions to create a public–private partnership to establish the Water Fund as a charitable trust incorporated under Kenyan law and governed by a board of trustees. The board of trustees was charged with overall implementation of the Water Fund, which worked through a set of advisory committees and a technical secretariat, responsible for the day-to-day management of its activities.

- Mobilization of funds from both public and private sector institutions to support tangible activities in the upstream catchments. This included support from international stakeholders including the Swedish International Development Agency, GEF, IFAD, Frigoken Limited and Coca-Cola.
- Investment flows to upstream catchment land users/land owners that supported sustainable land management and integrated natural resources management implemented by farmers and other land users in the Upper Tana catchments. The farmers in the identified priority conservation areas were rewarded in-kind through training, provision of free tree seedlings and nutritious fodder grasses, subsidized dam liners for water harvesting, subsidized seeds and linkages to markets.
- Capacity building of farmers, farmer groups, community, county and national institutions was done using extension services from NGOs in collaboration with county governments (Murang'a, Nyeri, Laikipia and Nyandarua). Farmers were trained on best practices in crop agronomy, soil conservation, water harvesting and farming as a business.
- Establishment of robust knowledge capture, management and learning systems so as to track progress made and share lessons both at local and national levels. Strong emphasis was placed on monitoring and evaluation frameworks to support the Water Fund in decision making and allowing for an adaptive management approach to the targeted incentive schemes, and also to allow for upscaling, policy integration and replication of lessons learned.

4.3.4 Leadership and Partnerships

The Water Fund had strong leadership from The Nature Conservancy (TNC) which hosted the secretariat and convened all the partners. The main partners included the Nairobi City Water and Sewerage Company, Kenya Electricity Generating Company, the International Centre for Tropical Agriculture, Tana and Athi Rivers Development Authority, Water Resources Authority, East Africa Breweries Limited, Coca-Cola, Frigoken Limited and the water technology company Pentair. Other than the funding partners described above, there are other partnerships with local NGOs that cover the three priority sub-watersheds of Thika-Chania, Maragua and Sagana-Gura. These included the Thika-based SACDEP, the Greenbelt Movement and Caritas. Partnerships with expert institutions (ICRAF, National Museums of Kenya and Jomo Kenyatta University of Agriculture and Technology) were also established to support scientific baseline studies, training and impact monitoring. The Water Fund is now an incorporated charitable trust in Kenya, with dedicated leaders and a growing partnership base and own financial and governance systems.

4.3.5 Challenges Faced

A number of challenges have faced the implementation of the Water Fund. For instance, although at the beginning, water harvesting farm ponds had not been planned for, it became evident that water shortages during the dry season would result in direct over-abstraction of the rivers, and excess flooding during the rainy season still caused sedimentation. To solve these problems, rainwater harvesting and storage in lined farm ponds were added to the activities supported by the Water Fund. These farm ponds became popular but the cost of UV-treated dam-liners is high for farmers, hence the Water Fund provided them while the farmers bore the cost of excavation. The fact that dam liners were provided at a great subsidy (which is the largest cost) enabled the high adoption of water harvesting in the target areas. Landslides (considered a geological form of erosion) continue to occur in the most upstream parts of the catchment causing erosion damage and sedimentation of rivers, even in some steep forested areas. Some of the locations were totally inaccessible and took a long time to rehabilitate.

Climate change and erratic weather has seen extreme events of rainfall and drought, which hamper both crop intensification and watershed protection. Although hydrological studies have proved improved water quality over the short term, there is still a need for long-term data collection to be able to advise policy on the scientific outputs emanating from Water Fund activities. The COVID-19 pandemic starting March 2020 curtailed a number of planned field activities that could not be adapted to a virtual support and implementation system thereby derailing the pace of advancement of the Water Fund deliverables.

4.3.6 Outcomes and Impacts

The Water Fund has generated measurable benefits over the past six years for people living in the watershed, for the residents of Nairobi and for watershed functions: over 44,000 farming households (about 220,000 people) are on record as having adopted improved soil conservation and water-saving technologies. The Water Fund focuses on the most at-risk areas of the watershed and helps farmers take simple steps to increase water and food security. Strategies included tree planting for agroforestry and reforestation (Figure 7), terracing, water harvesting and planting vegetated buffer zones along river banks. Generally, the Water Fund generated a wide range of benefits enumerated as follows:

- 44,725 farmers have implemented land and water conservation measures
- 44,000 farmers receive weekly extension support through mobile SMS messaging
- 3.4 million trees planted, of which 1.2 million are avocado trees for improved food and income
- 163 ha of public forest in national parks within the Upper Tana rehabilitated
- 15,131 farm ponds (referred to as micro water pans in project documents) developed. These harvest 1.9 billion liters of runoff annually, thereby reducing erosion and keeping rivers healthy from over-abstraction during the dry season
- 298 km of riparian buffer conserved (on banks on both sides of rivers)
- 36 biological monitoring sites have recorded 1,900 species, with three new species under scientific documentation
- 92 secondary schools established environmental programs, bringing 35,000 youth into conservation
- River baseflow improved by an estimated 15% in targeted rivers
- Improvement in water quality rose by an estimated 11% due to reduced suspended sediments.

Figure 7. Tree planting exercise in the Upper Tana supported by the Water Fund.

Photos: Bancy Mati.

By fostering multi-stakeholder alliances and partnerships, while also being a broad-based public–private partnership, the Water Fund facilitated alliances incorporating beneficiary groups, NGOs and private sector and public service providers along an innovative implementation strategy, and partnerships can be formed in the future. This is the underlying concept of water funds in providing financial sustainability; through payments for ecosystem services which require both a market for suppliers and the demand of recipients.

The tools for the economic monitoring of return on private sector investment were integrated into the Water Fund management structure. The success of the Water Fund was measured against its efficiency in disbursing funds and to provide incentives for catchment management and to improve downstream water quality and quantity. Particular attention was paid to good targeting, i.e., the extent to which the most vulnerable beneficiaries such as poor and food insecure women, youth and female-headed households (now standing at 38% of total) benefited from Water Fund incentives and whether the incentive schemes employed were appropriate to the needs of beneficiaries. As a result, a conservative assessment of the results predicted by the science-based business case demonstrates a viable return on investment in the implementation of the Water Fund while direct community benefits have grown several fold from the initial estimates (key informant interviews).

Scaling out: Beyond the Water Fund, the rolling out of similar activities inside Kenya and across the African continent is a testimony to the encouraging results of this initiative. Some areas of uncertainty that remain include the degree to which biodiversity in the region is protected, the degree to which the project will reduce the risk of flooding events in the longer term and the sustained levels of sediment reduction being attributed to the project. However, the Water Fund is most certainly making encouraging strides toward climate resilience, nature-based solutions in the water sector, livelihood improvement and evidence-based policy making in the region.

5. Conclusions and recommendations

5.1 Conclusions

The Kenya case study on pathways to innovation for SAI includes three case studies, across different agro-ecologies and contexts, that can be considered successful cases of SAI. The first case of water harvesting and storage in constructed farm ponds to provide water for supplemental irrigation of food crops is set in semi-arid agro-ecologies of eastern Kenya (Kitui, Machakos and Makueni). It started with a passionate champion and resource poor, food insecure small-scale farmers in a dry environment who learn and are supported to construct farm ponds. The technological innovation is pushed by financing models and capacity building for it to work.

The second case of solar-powered irrigation in peri-urban areas of Kajiado County – which has grown mostly through a private enterprise push – is solar water pumping for irrigation and entrepreneurial farmers in a market-responsive initiative. Whereas a conducive policy environment facilitates this innovation, the role of the public sector in extension or capacity building is negligible, pointing to a possible future where innovation tends to be demand driven with the private sector at its core.

The third innovation on blended finance unveils the possibility of raising sustainable financing for agricultural intensification, driven from a watershed management perspective in the Upper Tana catchment, with blended finance from institutions based in the city of Nairobi, located downstream. The concept of the Water Fund, although not new internationally, was tested and by building credible evidence that it works was able to attract funding. The three cases have certain common features that describe the pathways. These include strong and focused leadership especially at the beginning, bundling of innovations, partnerships through which initiatives share synergies and responsive farmers willing to try new things. Financing of the innovation through various innovative modes, new knowledge and learning were at the core of each innovation.

Some key challenges were observed, including scarcity of data, particularly on financial issues, with much information being provided verbally from interviews. In addition, where private sector engagement is strong, e.g., in solar-powered irrigation, the partnerships are difficult to pin down as there is competition and lack of central databases concerning what has happened. The field verification of each SAI case revealed much more information than use of the Internet, especially as so much remains unrecorded. In addition, the scaling process can be slow (in terms of reaching critical numbers of adopters), such as impacts on food security, climate change resilience and poverty reduction, which can be long term. The Kenya case study therefore shows that the pathways differ depending on local conditions and expected goals.

5.2 Recommendations

1) *Centering end users in the innovation:* Farmers should be engaged throughout the innovation process. It is emerging that innovation thrives when farmers and local communities are included as investors or stakeholders rather than as beneficiaries: for example, in the construction of water-harvesting structures. They contribute to the ideas shaping the innovation, and are encouraged

to drive it practically. In addition, end-user needs should be included through stakeholder engagement and development of tailored context-specific solutions.

2) *Financing:* Innovative financing is often as important as technology in driving innovations. Quite often, end users are resource poor small-scale farmers who may require some financial push without creating a dependency syndrome. Thus, the financing models that have a cost-sharing element, especially in-kind (e.g., water credits), have a greater chance of success. Interesting examples at different scales of innovation include mobile phone financing for solar pumps ('pay-as-you-grow') and conservation measures financed by the public–private partnerships through the Water Fund.

3) *Innovations take time to reach 'at scale':* Innovations take time to be tested, implemented and upscaled – at least eight or more years in the cases covered in this report. It is therefore imperative for all partners to have patience and to plan long term, including in the financing of the initiative.

4) *Leadership:* Innovations usually benefit from strong leadership, which should be identified and supported from the very beginning. The identification and support of champions (both individual and institutional) facilitates a coordinated pathway for growing the innovation. For example, strong leadership by a respected entity, the TNC in Upper Tana, was instrumental in putting together the partners needed to build up the Water Fund.

5) *Role of government:* Conducive government policies, their implementation and support through relevant institutions facilitate smooth operations and easier upscaling of innovations. One example is favorable import tariff policies for solar-powered equipment. Government policy gets informed by innovation based on lessons learned. Innovations can lead to policy reform.

6) *Bundling:* The bundling of innovations when introduced from the beginning gives the initiative an integrated approach for both problem solving and success, enabling targeting of incentive, upscaling, policy push and out-scaling of lessons learned. For example, the success of solar pumps required a bundle of innovations in finance, institutions, policy and technology. Identification of the root cause of problems and what should be changed by a minimum number of actions offers a pathway to innovation.

7) *Partnerships:* Partnerships facilitate a multiplier effect helping to reduce transaction costs, share responsibilities and provide support according to strengths and needs of stakeholders. Integrated approaches are necessary and require partnerships in order to meet the needs of various actors at the financing and policy side as well as those of land users at the implementation end. Partnerships (of government, NGOs, development partners, researchers, farmers and private sector) enable pulling together resources, synergies and project implementation.

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Annex 1: Common analytical framework

1. Description of the case

1. Construct a timeline of key events, such as innovation development, piloting, early scaling and ongoing growth.
2. What type of innovation is it? Technology, policy/regulation, social institutions, financing, other services?
3. The innovation was a solution to what problem?
4. What are the key components of the innovation? Core innovation? Complementary innovations? Delivery model?
5. What was the business or funding model? When and how did it become sustainable?
6. How was the process of scaling funded?
7. How was the innovation funded for users?
8. How was the innovation developed and tested?
9. Where was the innovation introduced and scaled? How did this evolve? Why evolution?
10. Who were the users of the innovation (demographics)? How did this evolve? Why evolution?
11. How did the context (where and who) affect the design and adaptation of the innovation? Scaling strategy?
12. What was the scaling pathway and strategy? Public, private, civil society, PPP, some other combination?
13. To the extent scaling was a partnership or collaboration, how was coordination managed?

2. Outcomes

1. What changes, outcomes or impact did the innovation produce at scale? Did impact change over time? At scale?
2. What evidence is there on outcomes at scale? Effects on different SAI objectives (environmental, social, human, productivity, profitability)?
3. What were the costs and benefits?
4. Who were the winners and losers of innovation?
5. What happened to different groups?
6. Any compensation or mitigation measures?
7. Any spin-offs or unexpected benefits?
8. As best you can, is the innovation sustainable for users? For any organization involved in the production, delivery, funding, etc. (if relevant)?

3. Actions and actors

1. Who were the key players and their roles through time?
2. What were the relevant characteristics of these players in terms of leadership, skills, competencies, resources or organizational culture?
3. Who initiated and led the innovation process, and their motivation? The scaling process, and their motivation?

4. What challenges or opportunities arose, and how was the innovation and/or scaling strategy adapted in response?
5. How was the innovation process designed? Was this a deliberate strategy, make it up as you go along, or a mix?
6. How was the scaling strategy designed and developed? Was this a deliberate strategy, make it up as you go along, or a mix?
7. Were different phases of innovation and scaling led by different groups? Why? How did the handover take place?
8. What partners were brought in, why, and how?
9. What roles did they play (or contribute) in innovation and scaling?
10. Why were they willing to play these roles? How were they persuaded?
11. How were intended users involved in the innovation and scaling process? At what points? What mechanisms?
12. Did demand exist in advance, or was it developed or created? If the latter, how was demand generated?
13. Did the scaling process include other complementary systems changes such as policy, laws, regulations, strengthening parts of the value chain, market system or public sector organizations, e.g. capacity building?

4. Analysis

In your opinion, justified by evidence, what role did the following factors play in explaining the outcome at scale?

1. The innovation processes.
2. Innovation characteristics, including business/delivery/funding models.
3. Relevance to demand, needs and priorities of users, other stakeholders.
4. Characteristics of the users or places, e.g. infrastructure, education.
5. Context, e.g. policy enabling environment, public sector organizations and capacity, value chain or market system actors.
6. Choice of scaling pathway and strategy.
7. Specific scaling activities, e.g. evidence generation, advocacy/marketing, community engagement, pricing, risk mitigation, use of champions.
8. Characteristics of organizations/actors leading or driving the innovation and scaling process.
9. Characteristics of partnerships and the organizations/actors that served as partners in the innovation and scaling process.

Annex 2: Initially identified long-list of SAI innovations in Kenya

1. Water-harvesting farm ponds enhancing agricultural intensification and climate change resilience in eastern Kenya
2. Improved availability and access to agri-inputs in Meru
3. Solar-powered irrigation enhancing agricultural intensification in peri-urban areas of Kajiado
4. Blended finance from downstream Nairobi city supporting agriculture and watershed management upstream
5. Innovative access to finance supporting agricultural intensification
6. Smallholder dairy supporting agricultural intensification
7. Combating striga in maize production in western Kenya

Annex 3: Key informants interviewed

1: Water-harvesting farm ponds in eastern Kenya

No.	Name of respondent	Responsibility	Area/county
1.	Caroline Kimweli	Liaison Officer	Machakos County
2.	Nicodemus Nzombe	Monitoring and Evaluation Officer	Machakos County
3.	Mutinde Kyalo	County Agricultural Engineer – Irrigation	Machakos County
4.	Josphat Kioko	County Director of Agriculture	Machakos County
5.	Joseph Nzioka	Extension Officer, Ikombe Ward	Yatta, Machakos
6.	Joseph Tuva Kilonzo	Chairman, Makutano Dairy	Yatta, Machakos
7.	Gideon Mbithi	Extension officer, Ikombe Ward	Yatta, Machakos
8.	Jackson Mutiso	Farmer	Yatta, Machakos
9.	Stephen Mubeli	Farmer	Yatta, Machakos
10.	Benjamin Kiambi	Head Teacher, Katoroni Primary School	Yatta, Machakos
11.	Emmanuel Kisangau	County Executive Council Member	Kitui County
12.	Titus Saidi	Water Superintendent	Kitui County
13.	Thomas Musangi	Project Manager, Caritas	Kitui County
14.	Francisca M. Kalungu	Chairperson, Kwamikuyu CBO	Kitui County
15.	Munyange Kilonzi	Farmer	Kwavonza, Kitui
16.	Muova Musyoka	Farmer	Isalala, Kitui
17.	Joyce Muasya	Farmer	Kwavonza, Kitui
18.	Agnes Musangi Mulwa	Farmer	Kwavonza, Kitui
19.	Martin Mboloi	County Officer, Agriculture	Makueni County
20.	Mary Muteti	County Director of Agriculture	Makueni County
21.	Amos Ndunda	County Horticultural Development Officer	Makueni County
22.	Gapuzwa Kanzere	Land Development & Management Officer	Makueni County
23.	Victor Oluteyo	Agricultural Mechanization Manager	Makueni County
24.	Pascal Ndambuki	Farmer	Nziu, Makueni
25.	Leonard Ndambuki	Farmer	Nziu, Makueni
26.	Raphael Mutisya	Farmer	Nziu, Makueni
27.	John Mutua Mbithi	Farmer	Nziu, Makueni
28.	Francis Maithya	Farmer	Kathonzweni, Makueni
29.	Obadiah Nzioki	Agriculture Officer	Makindu, Makueni
30.	Daniel Kimuyu	Farmer	Makindu, Makueni
31.	Agnes Waema	Farmer	Makindu, Makueni

2: Solar-powered irrigation in peri-urban Kajiado

No.	Name of respondent	Organization/role	Area/county
1.	Carolyne Koech	Sunculture	Kajiado North
2.	Magdalene	Sunculture	Kajiado South
3.	Milcah	Sunculture	Mitunguu, Meru
4.	Amos Mutunga	Davis and Shirtliff	Kajiado
5.	Simon Kageche	Irrigation Officer	Kajiado County
6.	Raphael Merin	Extension Officer	Kajiado County
7.	Boniface	Epicenter Africa	Nairobi
8.	Maurice Opondo	Ministry of Water, Sanitation & Irrigation	Nairobi
9.	Charles Muasya	National Irrigation Authority	Nairobi

3: Blended finance for watershed management in Upper Tana

No.	Name of respondent	Role/position	Area/county
1.	Carolyne Nguru	Extension Officer	Murang'a County
2.	James K. Karaya	Farmer	Mungetho, Maragua
3.	Stanley Kaminju	Farmer	Ngaaini, Maragua
4.	Eusebius Njoroge	Farmer	Kongoini, Kiharu
5.	Stephen Macharia	Water Resources Users Association Chairman	Sasumua
6.	Fred Kihara	Water Fund Manager	TNC, Nairobi
7.	Colin Apse	Manager	TNC
8.	Boniface Mwaniki	CEO, Water Fund	Water Fund, Nairobi
9.	Job Kihamba	Dam Manager	Ndakaini

CoSAI
Commission on Sustainable Agriculture Intensification

The Commission on Sustainable Agriculture Intensification (CoSAI) brings together 21 Commissioners to influence public and private support to innovation in order to rapidly scale up sustainable agricultural intensification (SAI) in the Global South.

For CoSAI, innovation means the development and uptake of new ways of doing things – in policy, social institutions and finance, as well as in science and technology.

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