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IDRC GRANT / SUBVENTION DU CRDI : - USER DRIVEN APPROACHES TO MAKE GOVERNMENT AND FARMER LED SMALLHOLDER IRRIGATION IN MOZAMBIQUE MORE PRODUCTIVE (CULTIAF 2)

User Driven Approaches to make Government and Farmer-led Smallholder Irrigation Schemes in Mozambique more Productive, Self-sustaining and Equitable

Or

<u>FArmer led Smallholder Irrigation in MOzambique (FASIMO)</u>

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Research organisations	- Universidade Eduardo Mondlane (UEM); Faculdade de Agronomia e Engenharia Florestal (FAEF) – Leading institution - Instituto Nacional de Irrigação (INIR); Instituto Superior Politécnico de Gaza (ISPG), Instituto Superior Politécnico de Manica (ISPM), Penevy Services Pty, See4d (Strategy, evaluation & engagement for development) and Resilience BV
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Contents

1 Executive summary

The irrigation sector in Mozambique plays a major role in ensuring stable agriculture production yet is challenged by rapid degradation and underutilisation of infrastructure. Smallholder irrigation is composed of schemes developed by government and partners (government-led) and by the "vibrant" schemes developed by the farmers themselves (farmer-led). The farmer-led smallholder irrigation in Mozambique (FASIMO) project sought to better understand both types of irrigation development by documenting their successes and failures, and to identify irrigation development models that would transform irrigation into being more productive, self-sustaining, and equitable. Key project results and achievements are highlighted below.

Factors influencing success and failure of irrigations schemes. Research results show that in most of the irrigation schemes, smallholder farmers have limited knowledge on irrigation management techniques, and lack training and technical assistance. Also, there is poor performance of contractors who carry out design, construction, and supervision work; weak farmer organisations that are mostly promoted by external entities and thus not self-sustaining; limited coverage and technical capacity of extension services to deal with matters related to irrigation management. Furthermore, farmers have limited connection to markets, especially farmers focusing on subsistence agriculture.

Soil water monitoring tools. The greatest achievement of the project was the introduction, promotion, and use of the soil Water Monitoring Tools (WMT) as an efficient water use technology by farmers and other stakeholders. The tools led to positive impacts in the target irrigation schemes in both Gaza and Manica provinces and have been adopted by other development stakeholders. Using the WMTs, farmers cut water usage by half, reduced irrigation costs by 40% while increasing crop yields by 10% in two consecutive seasons (2020 and 2021). Sitoe, a horticultural farmer from a women dominated irrigation scheme explains, "*We used to water our fields every day and this was costly in terms of fuel for the pumps (34,889 Mozambique metical, CAD 700), time, and labour to cover 4 ha over one cropping season. Now, we are only irrigating twice a week based on the readings from the Chameleon, reducing the irrigation costs to about 14,354 Mozambique metical, CAD 288*." Farmers invested the money and time saved in other activities such as farming in dryland areas, household activities and income generating activities. A gendered analysis of these activities showed that women re-invested their save time in household activities while men tended to do heavy-duty activities such as land clearing for agriculture purposes. The soil water monitoring tools also have enormous potential for changes in practices and policies.

GIS models for mapping irrigated areas. The project also developed cost-effective models to identify and map irrigated areas in Mozambique using remote sensing. The models show that there is a lot of irrigated agriculture in the country, and that farmer led irrigation (FLI)systems are more abundant than government led irrigation (GLI) systems. The algorithms developed successfully identify irrigation hotspots where active water management is taking place. Such findings are very useful to the National Irrigation Institute (INIR) in identifying new sites/places where farmers are irrigating, monitoring existing irrigated areas and in planning targeted development interventions.

Gender differences and women empowerment. Women and men perceptions regarding selected Pro-WEAI empowerment domains indicated that: (i) male farmers exert greater control and autonomy over resources such as land, assets and income compared to women, however widows are entitled the same level of control and autonomy over these resources; (ii) there is a widespread acknowledgment of the existing imbalance in the workload between female and male farmers; (iii) within the study sites, men own more land (0.8-1.0 ha) compared to women (0.2 ha), and control irrigated land, in both farmer-led and government-led schemes.

Women have more access to rain-fed land, which is also controlled by men, but can own and control the land if they are widowed. They also have access to irrigated plots if they are members of an irrigation scheme. For example, in Gaza province, women participation in irrigation schemes is above 50% because men have migrated to South Africa for other jobs; while in Manica, women participation in irrigation is about 30%. Also, women participate actively and have greater opportunities to irrigate when irrigation systems are simple, e.g., using surface flow or gravity schemes, not complex such as those combining infrastructure and knowledge intensive technologies. If using motor pumps, for example, only 40% of women carry out irrigation with support from their family members, who run the pumps. Although soil water and nutrient monitoring tools contributed to reduce the burden and workload of both female and male farmers, we argue that the tool was more beneficial for women, compared to men, because they reduced women's burden at household level. For example, daily calendars showed that women spend time working with their husbands in the field, and there after shoulder all the household chores - fetch water and firewood, cook, clean, and take care of children. For instance, with the use of tools, Ms. Sofia Johane went from a 2-day irrigation interval, to a flexible and on demand irrigation schedule of 4-7 days on her cabbage plot. This gave her more time to take care of her 5 children and manage household chores.

Models for improving irrigation in Mozambique. The project tested and documented models with potential to improve the irrigation sector in Mozambique. Findings shows that key aspects of the models include:

1. Involve farmers as key decision-makers in the design, implementation, and management of the irrigation scheme.
2. Establish transparent and democratic governance structures such as the Water User Associations (WUA) or Farmer Associations.
3. Training of both irrigation leaders and ordinary farmers on management of the infrastructure and improved agronomic practices.
4. Duat increased the ownership of the investments in the irrigation scheme and triggered increase of cultivated land in some irrigation schemes.
5. Use of agricultural technologies and linkage to markets are important means to enhance sustainability of irrigation schemes.
6. Introduction of cash crops can increase resilience to climate impacts in smallholder farming.

2 The Research Problem

Agriculture is the main livelihood strategy in Mozambique; however, its productivity remains very low. The government invests in irrigation to boost food production, but the productivity of irrigated farming is also low. This is due to farmers' lack of financial resources and skills, and government's limited resources[1] and strategies to maintain the economic and institutional sustainability of irrigation schemes, which results in their rapid degradation and underutilisation. This challenge is even greater due to more frequent extreme natural disasters (i.e., floods, droughts, and cyclones) occurring because of climate change. In comparison, there are many productive areas of irrigation developed by smallholder farmers, with no or little support from third parties, including the government. This overall successful irrigation is farmer-led, i.e., it is established, improved, or expanded by the farmers themselves. Thus, FASIMO intended to better understand both types of irrigation development and the opportunities and challenges faced by each.

FASIMO built on the foundation that the revitalisation and expansion of smallholder irrigation in Mozambique is the key to improve agricultural productivity, safeguarding food security, while increasing resilience to climate variability and shocks. The project learnt from both types of irrigation development and worked with the farmers to identify, promote and/or pilot improved business plans, better farmer organisational models and improved water management practices at plot and scheme level. The main premise is that greater involvement of farmers in all aspects and stages of irrigation development will lead to better outcomes in terms of agricultural productivity and irrigation scheme sustainability.

Specifically, FASIMO intended to:

1. To conduct a comparative analysis of how the management, business models, and the formal and informal institutional arrangements in government and farmer led smallholder irrigation affect scheme functioning.
2. Improve crop productivity and water use efficiency through use of soil water and nutrient management tools.
3. Identify and test user-driven business and farmer organisational models including market linkages that improve profitability and equity for farmers engaged in Government funded and farmer led smallholder irrigation.
4. Use evidence to contribute to irrigation policy development and changes in practices for government and multilateral agencies.

The project team developed skills in participatory research techniques to engage properly with farmers, gaining insights and trust. Results towards addressing the research problem have already been documented as indicated in sections below.

[1] *Including availability of trained and qualified extension officers, or financial resources to provide for adequate farmers' assistance by allocation means of transport and others.*

3 Progress towards milestones

For the period from 1st of April 2019 to 31st December 2022, the Project has achieved milestones measured by different indicators as described below. Overall, the accomplishment of milestones, as stated in the proposal, was severely affected by the coronavirus pandemic, and the extreme weather events such as floods and tropical storms that happened in the beginning of the year 2021, destroying crops in the fields and cutting off road networks, thus affecting the outcomes of the project.

The milestones are:

1. How current institutions affect scheme functioning synthesized and documented.
2. Differences between farmers with water monitoring tools (WMT) and farmers without the tools regarding crop yields and water productivity documented and reported.
3. Differences between farmers with tools and farmers without tools regarding crop yields and water productivity analyzed.
4. Forums for participatory engagement among relevant stakeholders and value chain actors established within irrigation schemes.
5. Report/policy brief on policy lessons and reform options affecting women, men and youth farmers livelihoods, wellbeing, equity, food security and resilience to climate change developed for INIR.
6. The adoption level of project lessons and recommendations by policy makers, planners and key organizations assessed.

Milestone 1: How current institutions affect scheme functioning synthesized and documented.

Report and key recommendations on how current formal and informal institutions affect scheme performance in government led and farmer led irrigation.

Understanding the factors affecting scheme functioning was one of main objectives of FASIMO as this informs the policy and practice changes that the project influenced. Earlier project studies identified the reasons for failure of irrigation systems, which were grouped into two major categories, (i) factors requiring training and change in practices; and (ii) factors requiring changes in policy and regulation (details are captured in Annex 2).

For the first category, the following factors were identified: (a) smallholder farmers have limited knowledge on irrigation management techniques; (b) lack of training and technical assistance of smallholder farmers; (c) development of irrigation system without adequate involvement of farmers (from planning to construction), which leads to lack of ownership and willingness to undertake maintenance; (d) complex irrigation systems of huge water pumps, canals and pipes difficult for farmers to operate and maintain themselves; (e) poor performance of contractors carrying out design, construction and supervision works; (f) weak farmer organisations, mostly promoted by external entities and thus not self-sustaining; (g) limited coverage and technical capacity of extension services to deal with matters related to irrigation management, and (h) limited connection to markets, especially for farmers focusing on subsistence agriculture with lower use of improved agricultural inputs, lower yields and reduced surplus. For the second category related to changes in policy and regulation, the following factors have been identified, (a) supply of pumps and irrigation equipment to smallholder farmers without locally available spare parts and assistance for maintenance and repairs in case of breakdowns; (b) government and multilateral partners promoting mostly communally-owned irrigation infrastructures, sometimes without ensuring/fostering a common goal or mindset for farmers to work together; (c) limited access to credit at affordable interest rates, associated to lack of insurance and collateral for many smallholder farmers.

Milestone 2: **Differences between farmers with water monitoring tools (WMT) and farmers without the tools regarding crop yields and water productivity documented and reported.**

Report comparing crop yield and water productivity between farmers with tools and farmers without tools.

Overall, there were positive impacts resulting from use of WMT, which are backed up by evidence and testimonials. For instance, farmers in Rivoningo, a scheme using drip irrigation, reported to have halved the number of irrigation events, from applying water daily, to every 2 to 3 days. This resulted in saved money used to cater for fuel and labour, from 30,000 MZN/season/ha (~500 USD/season/ha) to 19,000 MZN/season/ha (~USD 300) (Annex 3). Moreover, farmers saved time spent to irrigate, and therefore used the saved time for extra activities. These activities include, women engaging more on household activities, men investing more time in land clearing for agriculture, more time for rainfed crops, fishing and other income generating activities. For example, one farmer reported that she earned 8,000 MZN (USD$ 127) in a season since she had spare time to dedicate to her rainfed crops. Similarly, some farmers used the saved time to expand the irrigated area. More importantly, farmers while they were able to reduce their water footprint, they managed to increase their yields, while reducing the applied water.

Report on water distribution measurement and the effects on overall water management in the scheme, including issues of gender-based allocation of water resources within the schemes.

The research on water allocation and distribution within irrigation schemes aimed at finding out how farmers get access and allocate water amongst themselves, as well as the challenges men, women, and youth farmers face to access water for irrigation, especially looking at the most disadvantaged (Annex 4). In farmer-led schemes (FLI), farmers individually seek the means to access water and invest by themselves on equipment (be it pumps or pipes in pumped irrigation) or build their own irrigation canals (in gravity irrigation schemes fed by springs) or open drainage canals (in pit soils or wetlands) in order to irrigate. Therefore, in FLI, the access to irrigation water is subject to individual farmer's capacity to mobilize resources and have the skills to initiate irrigation. Whereas, in government-led schemes (GLI), both women and men have the 'same' access to water through the water membership as the irrigation infrastructure is supplied to them as a common asset and usually farmers in the GLI schemes expect the Government to give production factors such as improved seeds, fertilizers, insecticides and others, which somewhat negatively affect the management of the scheme. Differentiation in access to water occurs when fuel acquisition costs are individualized, whereby women tend to have limited access to financial resources to do so and therefore face difficulties to irrigate. This was observed in Chihozorio – a farmer-led schemed – with men owning irrigation equipment, while women have to depend on available borrowed pumps. In this scheme, women carrying out irrigation activities with support from their husbands and family members who own motor pumps represent only 40% (Table 1). Conversely, women participate actively and have greater opportunities to irrigate when irrigation systems do not involve infrastructure combined with technology, as it is the case of Chitsoguanine irrigation scheme with more than 75% of active women members (Table 1). In Chitsoguanine, farmers produce their crops in wetland (pit soils) and the irrigation is done managing water table through drainage system.

Another factor affecting water access and distribution was found in irrigation schemes using water pump, where the location of plots matters as it affects the quantity of fuel one needs to complete an irrigation event (Tiva Kurima Association in Gaza), while in drip irrigation the location of the plot was not a concern, since the water is distributed equally in the plots regardless the location (Rivoningo Association). Hence, plots located in the tail of the irrigation scheme are disadvantaged in gravity irrigation, since it affects duration of irrigation event, quality and the costs of the irrigation activity – being therefore a source of conflict between members. Drip irrigation on the other hand minimizes conflicts in the irrigation process, on the precondition that the system is well designed and maintained, leading to equal distribution of the water. It is worth mentioning, that no relationship was found between plot location within the scheme, with the gender of farmer allocated to that plot, that is, male, female and the youth farmers were 'randomly' distributed in the irrigation schemes.

Table 1: Description of farmers' association

Name of the irrigation scheme	Type of the irrigation scheme	Leadership (Male or Female)	Number of members (%)		
			Total	Male	Female
Makateco Association	Farmer-led	Male	29	6 (20.6%)	23 (79.3%)
Individual farmers of Chihozorio	Farmer-led	Not applicable	10	6 (60%)	4 (40%)
Group of farmers of Chitsoguanine	Farmer-led	Male	70	17 (24.2%)	53 (75.7%)
Rivoningo Association	Government-led	Female	40	2 (5%)	38 (95%)
Tiva Kurima Association	Goverment led	Male	60	9 (15%)	51 (85%)

Milestone 3: **Differences between farmers with tools and farmers without tools regarding crop yields and water productivity analysed.**

Report and draft of scientific journal manuscript comparing crop yield and water productivity between farmers with tools and farmers without tools.

The project has as one of its objectives to improve crop water productivity of farmers. For this, ten (10) farmers were selected in each of the four (4) irrigation schemes chosen for the study (7 de Abril A and 7 de Abril B in Manica, and Makateco and Rivoningo in Gaza). From the 10 farmers, five were attributed the tools and the remaining five did not receive the tools (acting as the control group). However, since farmers exchange ideas and share knowledge within and between schemes, unsurprisingly, as time went by, it was noticed that the farmers without tools (control) adopted the irrigation interval used by those with tools in almost all irrigation schemes in Gaza and Manica Provinces. This happened due to the benefits on the saving resources (mainly time, fuel- for those with pump, water and labour). This was corroborated by farmers' testimonials during sessions of end of season workshops held in October and November 2021 in the 4 selected irrigation schemes where farmers confirmed exchanging knowledge and ideas about soil water monitoring tools (Annex 5 and Annex 6).

Milestone 4: Forums for participatory engagement among relevant stakeholders and value chain actors established within irrigation schemes.

Report on the value addition of linkages/networks between farmers and other stakeholders, showing the benefits gained by men, women and youth farmers on production, productivity and strengthening the agricultural value chain.

As reported in the second interim technical report, forums for participatory engagement have not been established in irrigation schemes due to the coronavirus pandemic that greatly affected the fulfilment of this intervention in its original form. The restrictions imposed by COVID-19 did not allow gatherings of groups of people, in addition to the reduced number of visits by the project staff. However, since the pandemic situation improved between August to mid November 2021, the project has carried out the following:

- The FASIMO project, with the purpose of promoting reciprocal learning on organizational and management models, and fostering collaboration among farmers, organised an exchange visit between farmers from Makateco, Rivoningo and Tiva Kurima associations in Gaza (Annex 7). The exchange visit was held at Rivoningo association, with participation of 34 host farmers (32 women), 4 from Makateco association (2 women) and 4 from Tiva Kurima association (2 women). The local government represented by the director of District Agricultural Services (SDAE-Guijá) accompanied by the extension officers were present to the meeting. The meeting was also attended by President and the Head of the agricultural division of Gaza Works - the NGO that promoted the foundation of Rivoningo - and facilitated by FASIMO project staff from University Eduardo Mondlane, National Irrigation Institute and the Higher Polytechnic Institute of Gaza. The key highlight from the mutual learning meeting are, (i) Makateco farmers shared that the use of water monitoring tools helped them to cut back their costs with fuel to run the pump, which led to expansion of irrigated area from 1 to 2 ha; (ii) Rivoningo farmers explained how they manage to plan collectively what to grow and when, as well their collective marketing strategy and how the benefits are proportionally and transparently shared among farmers according to individual's output; (iii) farmers from Tiva Kurima spoke about their experience in producing seedlings in the greenhouse and sell to the neighbouring farmers, however, this activity was discontinued due to the pump breakdown; (iv) farmers from Rivoningo and Tiva Kurima jointly advised Makateco farmers on issues related to financial management and how to avoid its misuse by creating a dedicated bank account or mobile-money account for the associations to overcome the current practice whereby money is kept at a member's house.
- The project made follow ups to identify changes as a result from the exchange visit, especially in Makateco and Tiva Kurima schemes, where there still some organizational and management aspects to be improved. For instance, participant farmers from Tiva Kurima went back to their association and called for a meeting where new members of the governance structure were elected. In Makateco, farmers have taken up and implemented planning of agricultural seasons ahead, as well as the importance of allocating individual plots for farmers to grow whichever crop they choose, instead of only having a single common area. It was due to the planning of agricultural season that farmers were able to communicate to FASIMO staff their difficulty in finding agro-dealers to buy improved inputs. In response, the project together with the District Agricultural Services through the extension officer recommended farmers the appropriate varieties and agro-dealer shops. Farmers from Makateco purchased improved seeds with their own resources, and now feel confident to plan and carry out seasonal planning.

Milestone 5: Report/policy brief on policy lessons and reform options affecting women, men and youth farmers livelihoods, wellbeing, equity, food security and resilience to climate change developed for INIR.

Report on key policy lessons, including feedback gained on appropriateness from INIR

The soil water monitoring tools represent one of the greatest achievements by the Project, with enormous potential for changes in practices and policies. Smallholder farmers have gained a three-fold benefit of reducing by half the amount of water applied, while saving time and money spent on irrigation as mentioned in “Section 3. This evidence has been shared with three key stakeholders, namely, (i) the National Irrigation Institute’s (INIR) staff, including the General-Director, (ii) the staff from the Small-scale Irrigation and Market Access (IRRIGA) Project, and (iii) at a Workshop from the Water Productivity (WaPOR) Project[2]. INIR and IRRIGA Project[3] staff participated in a FASIMO results dissemination presentation about findings on using soil water monitoring tools held in November 2021 at INIR’s headquarters. Learning about the successes from using the tools in FASIMO, the IRRIGA Project purchased and introduced them in irrigation growing vegetables in Manica Province.

Written report/policy brief on preliminary results regarding mapping irrigated areas shared with over 120 individuals, from water managers, irrigation managers, and others local and national forums.

The project has made significant progress in pursuit to develop cost-effective models to identify and map irrigated areas in Mozambique using remote sensing and the models show that there is a lot of irrigated agriculture present already (mostly FLI), often more than the GLI systems. For instance, the algorithms developed successfully identify irrigation hotspots where active water management is taking place. Such findings will be very useful to the National Irrigation Institute (INIR) to monitor and find (new) sites/places where farmers are irrigating, and plan targeted interventions accordingly. Additionally, Two manuscripts discussing the different approaches for mapping irrigation using remote sensing were written, one has been published, and other submitted for revision.

The other output was to build capacity on using remote sensing techniques at INIR and other relevant irrigation sector stakeholders. The process of embedding the skills on identifying and mapping irrigation had been initiated with a training conducted between 07 to 11 March, 2022 in Bilene, Gaza involving staff from INIR (06), UEM (04), ISPM (01) and ISPG (04) (Annex 8) and followed up between 15 and 18 June 2022. The purpose of the training was to learn how to identify, map and monitor irrigated agriculture using remote sensing. The participants were introduced to the Digital Earth Africa (DEA) platform, an online environment that allows carrying out several analyses using Landsat and Sentinel – 2 satellite images, with 30 meters and 10 meters resolution respectively. The results from the analysis can inform decision-making and formulating policies and interventions, such as, monitoring health crop, level of water stress, monitoring and forecasting agricultural seasons, map irrigation, and more. The benefits of using satellite were presented to the wide audience in the seminary carried out on December 2022.

Milestone 6: The adoption level of project lessons and recommendations by policy makers, planners and key organizations assessed.

Report on the extent to which lessons and findings from the project are being used and promoted by government officials, planners, key organisations and farmers.

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[2] WaPOR is a Project from the Food and Agriculture Organization from the United Nations (FAO) that has been launched for its second phase in March. WaPOR Project aims to monitor and improve water productivity through provision of open access and near to real time remotely sensed water productivity datasets at different spatial resolution (Continental, National and Sub-national)

[3] IRRIGA Project is a 6-year World Bank Group’s funded project supporting small-scale farmers to increase productivity and linkages to markets in Manica, Sofala, Zambézia and Nampula provinces. The project lifespan is 2018 to 2024.

In the course of FASIMO project different activities were planned to disseminate and influence police makers, planners and key stakeholders. These were done through guided field visit, scientific journeys, stands, workshops and public media.

- The guided field visits were done on August 2022 in Gaza (Rivoningo and Makateco) and Manica (7 de Abril Anexa) irrigation schemes with participation of UEM and INIR represented by the Deans, local partners, the local government represented by the Dean of District Agricultural Services (SDAE-Guijá) accompanied by the extension officers, National Television (TVM), CECOMA (Marketing and communication centre) from UEM and media from the Ministry of Agriculture and Rural Development. During the visit the deans and farmers gave testimonies about the benefit of using WMT in their fields. All these activities were disseminated through the media. Makateco and Rivoningo farmers shared that the use of water monitoring tools helped them to cut back their costs with fuel to run the pump and to have more time for other extra activities.
- Scientific journeys were held on September 2022 in the Faculty of Agronomy (UEM) and on October 2022 in the High Politecnic Institute of Gaza where the project presented the functionality of the WMT and poster with the main project results
- FASIMO was present through Resilience BV in FACIM (Maputo International Exhibition) from August 30 to September 5 in Marracuene District. FACIM promote business opportunities with various brand, services and product exhibitions for all over the world.
- The FASIMO project carried out workshops, first on November simultaneously with TISA project (annex 11) and second on December (annex 12). These workshops intended to share and disseminate the main results and lessons learned from farmers throughout the project lifespan (2019-2022) the first workshop was attended by representatives of MADER-INIR (Ministry of Agriculture and Rural Development-National Irrigation Institute), MADER-DPP (Dean of Planning and Policies), DPAP Maputo (Provincial Directorate of Agriculture and Fisheries), Resilience Mozambique, UEM-FAEF (Eduardo Mondlane University-Faculty of Agronomy and Forestry Engineering) and the second was attended by representatives of MADER-INIR (Ministry of Agriculture and Rural Development by the National Irrigation Institute), Private sector (Tecap, Green land, Sete agraria, Irrigations solutions and AQUI), representative of Resilience Bv Mozambique, Faculty of Agronomy and Forestry Engineering (UEM-FAEF), FAEF BSc students, CECOMA and Jornal Notícias, a newspaper company.

  FASIMO project presented the lessons on the factors of Successes or failure of irrigation systems in Mozambique; Results and lessons learned during the implementation of the Project (Mozambique experience); Project's social and Economic Impacts; Gender, Associativism and Sustainability in Irrigation Systems and Irrigation mapping using remote sensing. The workshops ended with open discussions about the acquisition and use of the WMT as described below:
    - Many participants recommended the exhibition of the WMT to traders and on TV, make them mandatory to use to the class of farmers as they also help farmers to know what irrigation is;
    - Dissemination to more new farmers in other places;
    - Sensitize the private farmer to use the WMT.

All the recommended action were taken by the Ministry of Agriculture and Rural Development through the National Irrigation Institute (INIR), which endorsed a private sector to import and sell WMT within the country and give the necessary assistance to the farmers. Also, among the INIR pojects it’s a practice nowadays to include WMT in there budget and allocation to the farmers.

4 Synthesis of research results and development outcomes

A. Objective 1. To conduct a participatory and comparative analysis of the management, business models, and the formal and informal institutional arrangements in government and farmer-led smallholder irrigation schemes

"In a nutshell, strong farmers' participation acting as decision-makers in irrigation planning, development and management is critical for the success of irrigation development, either farmer-led or government-led. Failing to do so leads to the rapid collapse of irrigation schemes"

FASIMO has carried out research and come up with two paper briefs discussing irrigation development in Mozambique. The Paper Brief I discusses and presents two preliminary successful models[4] (Annex 1) that have been identified, while Paper Brief II investigates the reasons behind the rapid collapse of irrigation schemes, and also adds some insights about the successes of farmer-led irrigation (Annex 2).

On Paper Brief I, the first successful model identified was an NGO funded irrigation scheme with strong farmers' participation, which has been replicated in 12 other locations in Gaza province. This model fully enabled farmers to act as key decision-makers in all or most of project activities from planning, implementation and management. This has been found to ensure sustainability of infrastructure, while enabling farmers to be profitable, considering that some of those schemes are more than 10 years old. For example, the Rivoningo scheme in Gaza province, was established in 2016 with support from Gaza Works[5]. In this scheme, like in the other 11, six factors were found to be contributing to increase the odds for success of irrigation schemes, namely: (i) farmers initiating and acknowledging the need to develop irrigation infrastructures; (ii) farmers providing in-kind and voluntary labour support during construction or co-sharing the irrigation development costs; (iii) farmers committed to repaying the initial investment; (iv) farmers establishing a transparent and democratic governance structure such as a functional Water User Association (WUA) or Farmer Associations, and (v) farmers (i.e. irrigation leaders and ordinary farmers) equipped with knowledge in operation and maintenance of irrigation infrastructure. Furthermore, the scheme is also arranged in such a way that part of the individual plots is dedicated for production of staple crops for household consumption, thus ensuring food security. The remaining plot area is used for production of cash crops, previously agreed by the Association. When harvested and sold, preferentially to an already identified set of merchants, the financial resources are used for three purposes. Firstly, part of the revenues is set aside to reinvest in the following production cycle; second, to maintain their irrigation infrastructure, and lastly, the balance is shared proportionally among the Association members based on their individual contribution. These resources are used on the benefit of their individual interests, thus becoming a secure source of income for the households. Since the shares are based on the proportion each farmer has contributed with, this system provides incentives for everyone to give their best toward higher productivity.

A second success story on Paper Brief I sheds light on sustainable irrigation development factors identified in Manica province, where contract-farming (also called outgrower schemes) were promoted through mutual agreements and partnerships between farmers and an agribusiness firm – The Vanduzi Company. In this model, smallholders are engaged in formal contract-farming with the Vanduzi Company, either by farming at irrigation infrastructure developed with government funds (Nhamadembe and 7 de Abril Principal irrigation schemes)

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[4] By successful models we refer to irrigation that is profitable, ensuring livelihoods, well connected to market and sustainable operation and maintenance of infrastructures.

[5] Gaza Works is a religious NGO assisting farmers in the acquisition and installation of irrigation systems, organizational aspects, business plan development, and technical assistance.

or through their own initiative (7 de Abril Anexa irrigation scheme[6]). Factors contributing for the success of this irrigation development associated to contract farming include: (i) farmers reduced risks due to market and price uncertainty (secure market at a price agreed beforehand); (ii) smallholder farmers receiving in-kind credit for agriculture inputs which suppresses farmers' lack of capital to invest in high-quality improved inputs; and (iii) permanent technical support to smallholder farmers on best agricultural practices. However, this "success" was entirely dependent upon the company supporting the farmers. When the company withdrew and no longer provided a secure market, farmers were not able to succeed by themselves and the situation deteriorated.

Comparing the two models documented in Paper Brief I, the first has been able to empower farmers and create a higher degree of resilience as they have had to set up for themselves and have created a lot of social capital amongst themselves. The second model does not create resilience. Therefore, farmers may do well when the company is present, but when the company withdraws, farmers have not developed their own capital enough to continue their businesses. These two models indicate that there are multiple models for successful irrigation development in Mozambique. Both Government and farmer-led schemes, for instance, are likely to be successful and sustainable if connected to assured markets, whereby farmers could easily sell their produce at stable and fair prices. However, the development of farmer-led schemes in informal settings influences their recognition as an alternative model of irrigation development as they produce to respond certain market demand, despite their contribution for food security and livelihoods.

The promotion of a hybrid model (i.e., Irrigation that could be developed in partnership between farmers and the Government or NGOs with farmers repaying the investment in infrastructure) for irrigation development is also a strong possibility. However, its success will strongly depend on how the initial investments are brought to farmers, as it is essential to avoid the common pitfalls of Government investments being considered donations by the beneficiaries. A possible example for introducing these initial funds would be by promoting public-private-partnership. Under this arrangement, the government would provide the funding, while the private sector or NGOs would channelize the funds at a low or negative interest rates to farmers, inspired by the Rivoningo model where farmers are required to return up to 80% of capital costs. In addition, a long-term technical assistance focusing on production organization, overall scheme management, stronger institutions/governing bodies within the associations, and access to markets should be ensured through public-private partnerships.

The project documented reasons for rapid collapse of irrigation schemes, where nearly 50% of irrigation infrastructures developed by the government and partners are reportedly not functional, into two categories, (i) factors requiring training and change in practices; and (ii) factors requiring changes in policy and regulation. For the first category, the following factors were identified, (a) smallholder farmers have limited knowledge on irrigation management techniques; (b) lack of training and assistance of smallholder farmers; (c) development of irrigation system without adequate involvement of farmers (from planning to construction), which leads to lack of ownership and willingness to undertake maintenance; (d) complex irrigation systems difficult for farmers to operate and maintain themselves; (e) poor performance of contractors carrying out design, construction and supervision works; (f) weak farmer organisations, mostly promoted by external entities and thus not self-sustaining; (g) limited coverage and technical capacity of extension services to deal with matters related to irrigation management, and (h) limited connection to markets, especially for farmers focusing

[6] The 7 de Abril Irrigation Scheme is (used to be) a typical farmer-led irrigation scheme that has been upgraded with lined canals by a World Bank Group funded irrigation project. This corroborates the understanding FASIMO learned in the first year of project implementation that sometimes it is not "black and white" the distinction of what can be called farmer-led irrigation and government-led irrigation.

on subsistence agriculture with lower use of improved agricultural inputs, lower yields and reduced surplus.

In sum, both paper briefs provide important insights decision-makers and key irrigation stakeholders such as development partners, non-governmental organizations and others supporting irrigation development should take into consideration to promote productive, profitable and sustainable irrigated agriculture.

"In a nutshell, market participation seems to be the major determinant for technology adoption to improve crop productivity, as well as stimulate farmers' to increase their cultivated land."

The socio-economic study revealed that the share of farmers participating in the output market is 91% in GLI and 87% in FLI schemes in Manica province; compared to 55% in GLI and 34% in FLI schemes in Gaza province. Regarding the input market participation, a similar pattern was found across provinces and irrigation scheme type. The existence of the Vandúzi Company and NGOs interacting with farmers through contract-farming schemes seems to explain the higher portion of farmers participating in both output and input markets in Manica province. Reasons for differences between FLI and GLI will be further investigated.

The relative importance of produced crops differs across irrigation scheme types (GLI and FLI) and provinces. Chili and onion are important crops in the GLI schemes in Manica, but they are not in the FLI schemes in the same province. Undoubtedly, maize, a staple crop in Mozambique, stood out as the most important crop.

Findings also reveal that the average cultivated area of the farmers was considerably larger when compared to the average irrigated land across irrigation scheme types and provinces, suggesting that, there was room for increasing irrigated agricultural land for GLI and FLI farmers in both provinces. Concerning land ownership and use, as well as irrigation, FLI smallholder farmers owned and cultivated larger land areas than GLI smallholder farmers in Manica province; while the opposite is observed in Gaza province. Possibly, the larger farmed areas in FLI schemes in Manica could be related to farmers receiving irrigation water from springs and the long existing culture of practicing irrigated agriculture, while in Gaza, farmers in FLI schemes have to invest in pumping units.

No pronounced differences were found in terms of water access to irrigate in both cropping seasons (rainy and dry seasons) in Manica province, however in Gaza province, farmers operating in FLI schemes are slightly limited in terms of water access in both seasons than those operating in GLI schemes (81% versus 95%). These findings could be related to larger irrigation investments in GLI schemes in Gaza province. Overall, the use of irrigation equipment (e.g., pumps, pipes, sprinklers) was higher among GLI farmers compared to FLI farmers, with more pronounced difference in Gaza than in Manica province where farmers tap irrigation water from water streams through gravity.

Field evidences show that, technically, the irrigation interval or frequency was empirically set, because it does not follow any crop and/or soil characteristics despite differences in water needs in different crops. These findings support FASIMO interventions, especially the introduction of soil water monitoring sensors and wetting front detectors in support to the management of irrigation, as well as the computation of water productivity and profitability.

Crop rotation was found to be largely practiced in Manica province but not in Gaza. This finding points out the need to make farmers aware of the benefits of adopting crop rotation for their crop management in Gaza province in both scheme types.

Improved seeds and other yield-enhancing agricultural inputs were more likely to be used by farmers operating in the GLI schemes than those in the FLI schemes in both provinces, suggesting higher input market participation in GLI schemes as stated above. This result points towards the need of enhancing farmers' awareness on the benefits of using yieldboosting agricultural inputs in terms of yield gains and profitability, complemented with promotion of increased output market participation.

The proportion of smallholder farmers who were asset poor was greater for smallholder farmers in the GLI schemes than those in the FLI schemes, with considerable differences in Gaza than Manica province. These findings are consistent with our other findings showing that the fraction of food insecure farmers was higher in the GLI schemes than FLI schemes, with greater differences in Gaza than Manica province as well. Such difference may be explained by the fact that farmers in GLI are often identified and supported based on their level of vulnerability, while FLI farmers do not receive external support. This means that farmers in FLI already have resources to initiate and operate their agriculture business with no or with minimal support from third parties. Overall, government investment in irrigation (GLI) targets asset poor smallholder farmers; while farmers developing FLI schemes are overall better off in terms of assets possession, fact that enables them to invest in irrigation.

"In a nutshell, there is widespread acknowledgment of workload imbalance between female and male farmers. Additionally, female farmers face limitations to participate in irrigated agriculture in farmer-led schemes compared their counterparts in government-led schemes."

Preliminary results of gender dynamics study indicated that in terms of women participation, land and water access, men own the land and women become landowners when they become widowed. Nevertheless, in both farmer- and government-led irrigated schemes, women have access to irrigated plot through membership. Overall, irrigated plots owned by women are smaller (0.2 ha) in government-led compared to those explored by women in farmer-led (0.5 ha) irrigation schemes. However, it is worth highlighting that this is a particular situation found in the studied schemes, since there are women owning irrigated area of over 0.5 ha in other government-led schemes outside project's intervention. Men, in both farmer- and government-led schemes farm about the same size (0.8-1.0 ha) of irrigated plots. Therefore, in general, men own more irrigated area compared to women regardless of scheme type (gov or farmer-led).

Women participation in both irrigation schemes in Gaza is over 50% while in Manica the trend is below 30% especially for farmer-led schemes. This can be explained by the social dynamics in the southern Mozambique, where there are more women engaged in agriculture, since most men migrate to South Africa, major population centres or elsewhere looking for paid work.

In terms of participation in the market, women in government-led schemes tend to diversify more the crops they sell (beans, lettuce, onions, kale, tomato and cabbage) with preferences for beans, lettuce, tomato and cabbage compared to crops grown in farmer-led (lettuce, onion, kale and cabbage with preferences for lettuce and kale).

Key remarks from female and male farmers' perceptions regarding selected Pro-WEAI empowerment domains indicated that: (i) male farmers exert greater control and autonomy over resources such as land, assets and income compared to their female counterparts, however widows are entitled the same level of control and autonomy over these resources; (ii) there is a widespread acknowledgment of the existing imbalance in the workload between female and male farmers; (iii) women empowerment in terms of accessing an income generating source can lead to intimate partner violence, which are mostly triggered and driven by the traditional social norms; and (iv) it is embedded in traditional social norms that movement of female farmers should be limited, while their male counterparts are freer to travel.

Concerning workload, a daily routine exercise undertaken with women and men during the situational analysis revealed more workload for female farmers. Women, apart from spending time working with their husbands in the field, they do other domestic chores such as fetching water and firewood, cooking, cleaning and taking care of children. Soil water and nutrient monitoring tools contributed to reduce the burden and workload of both female and male farmers. For instance, Ms. Sofia Johane went from 2 days irrigation interval, to a flexible and on demand irrigation schedule of 4-7 days on her cabbage plot (Annex 9). This gave her more time for other on-farm activities like farming maize, and for off-farm activities such as taking care of her 5 children and household chores (e.g., cleaning, cooking, etc).

B. *Objective 2. To improve water use efficiency and productivity through improved and cost-effective soil and water management technologies*

"In a nutshell, using water monitoring tools (WMT) saves irrigation water - the use of WMT for decision making on 'when and how much to irrigate' has reduced the irrigation frequency, saved money and has given farmers more time to carry out other tasks and generate more revenues"

Water monitoring tools (water sensors and wetting front detectors) were installed in 8 irrigation schemes of Gaza and Manica provinces and monitored during two seasons from September 2020 to March 2022, with greater emphasis on the second cold season, since the first coincided with outbreak of COVID-19. The irrigation systems used in those schemes vary from sprinkler, drip, and furrow, and the main crops produced were cabbage, maize, beans, baby corn and tomato. Research results demonstrate findings from selected schemes as result of installation and use of water monitoring tools. To access the impact of WMT comparison in their land size between baseline and endline survey.

Between the baseline and endline surveys, owned agricultural land increased from 2.6 ha to 3.3 ha among beneficiaries, while it basically did not change averaging about 2.0 ha among nonbeneficiaries. This finding suggests that FASIMO might have prompted beneficiaries to look for additional agricultural land after having seen the benefits of installing soil water and nutrients monitoring tools (WFD and Chameleon) in their plots. However, Figure 1 also shows that irrigated agricultural land registered no change between the baseline and endline surveys, with an average of about 0.6 ha, for both beneficiaries and nonbeneficiaries (annex13)

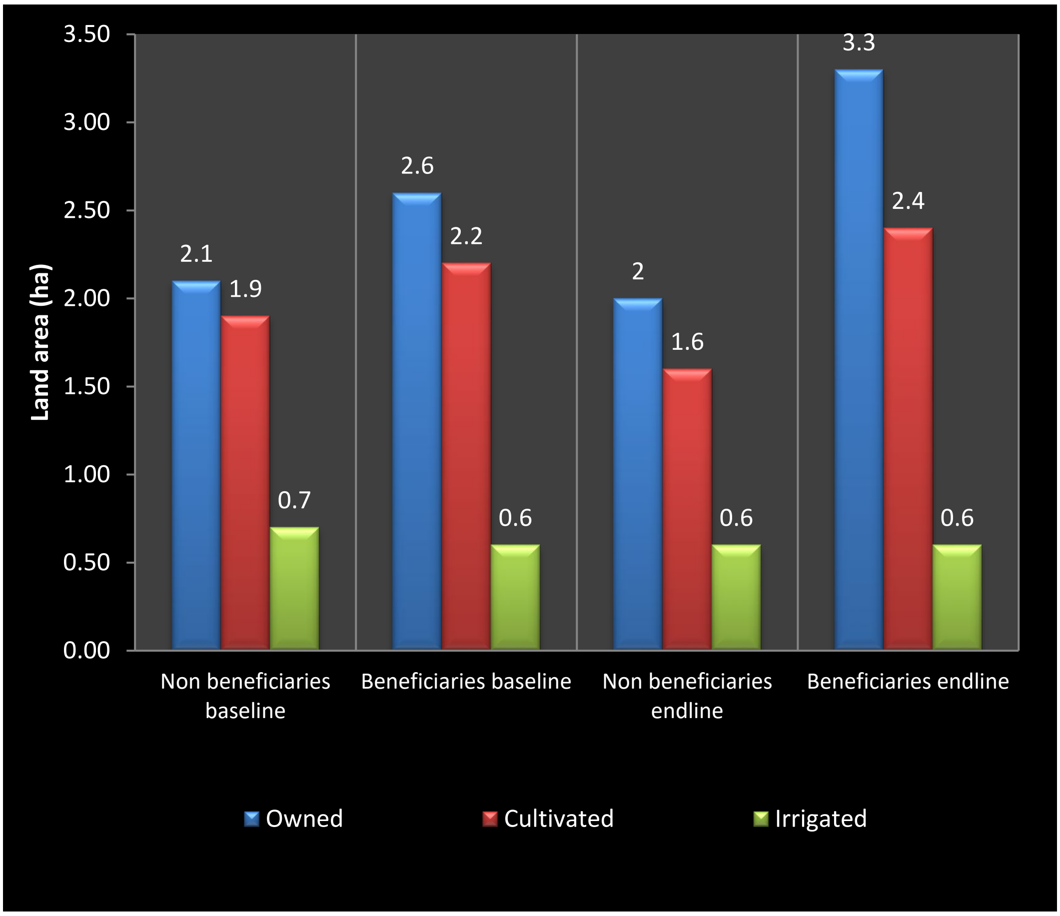

Figure 1: Owned, cultivated, and irrigated agricultural land

To start with, as report in the second interim technical report, farmers in Makateco scheme managed to reduce the number of irrigation events and water applied, while increasing their yields, cutting back fuel costs and having spare time to pursue other tasks, including income generating activities. The spare time was used on rainfed agriculture, more time to participate in community affairs, and perform household chores such as care for the children, cooking, washing clothes, hand craft and more. Additionally, farmers from Makateco have been expanding their cropped from 1ha in the first season to 2 ha in the second, and now have added 1 hectare to be parcelled and cultivated as individual plots, whose fate of the harvest is determined by the owner.

In Rivoningo Association where farmers used to irrigate daily before having the tools installed, during the season from April to August, 2021, farmers reduced irrigation events by increasing irrigation interval to 2 to 3 days. As mentioned in previous sections, this led to reduction almost by half the amount of fuel (and the associated costs) spent during the season compared to the period before the installation of tools. Table 2 shows the number of irrigation events in Rivoningo for tomato and beans in two cropping seasons after the use of tools, respectively, before the use of tools the number of irrigation events were 100.

Table 2: Soil water monitoring tools reduce irrigation events and costs (after the tools)

	Tomato (Set 2020 - Jan 2021)	Common Beans (Apr – Aug 2021)
No of irrigation events	50	48
Cost of the irrigation (MZN/ha)	19,000	15,520

Applied water (m3/ha)	4000	1920
Yield (kg/ha)	1373	2013
Water Productivity (Kg/m3)	0,34	1,05

Similar to Makateco, the reduction of irrigation frequency enabled farmers from Rivoningo to carry out other activities like farming in dryland. The main crops are maize and cowpea, where they obtained on average 600Kg and 160 kg, and 12,000 MZN and 8,000 MZN in revenues, respectively (Figure 1). These achievements encouraged farmers to continue farming vegetables under irrigation and using the tools for their decision-making on whether and how to irrigate. Additionally, in Gaza Province where most irrigation schemes use motor pumps to deliver water, farmers are more inclined to adopt such technologies. Less use of fossil fuels not only saves money, but also leads to environmental protection through cutting out emissions from running pumps.

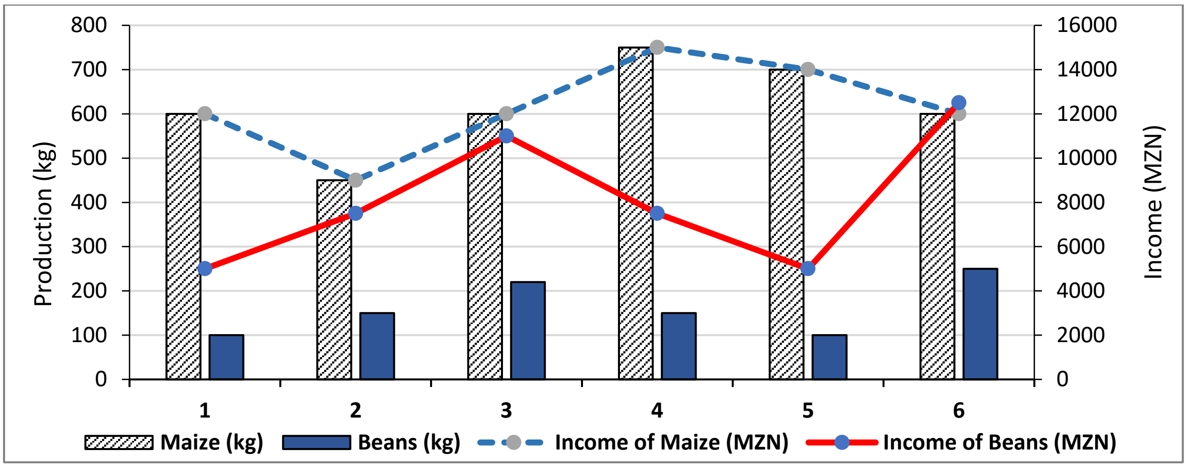

Figure 2: Harvest (kg) and income (MZN) obtained in the cropping at dryland during the extra-time in Rivoningo

Another positive experience in using the tools is found in Manica in 7 de Abril Principal[7] (government-led) and 7 de Abril Anexa[8] (farmer-led), both with farmers cultivating their fields individually. At 7 de Abril Anexa irrigation scheme for instance, farmers increased their irrigation interval as a result of using the tools. The number of irrigation events declined as the irrigation interval changed from 5 days to 7 days for maize, and from every 3 days to 4 days for cabbage and common bean for farmers using the tools, while farmers without tools continued their usual irrigation interval. Interestingly, Figure 3 indicates that 50% of farmers with tools reported to have expanded their cultivated area, whereas only a quarter of farmers without tools increased their cultivated area .This area expansion can be partly attributed to the fact that these farmers began to spent less time on irrigation, and thus with more time to further cultivate their land. Furthermore, farmers also used the time saved farming on rainfed, as well as, on commercialization of banana, sugarcane, and other income generating activities. The revenues from these extra-activities resulted in earnings of 9,500 MZN/month from selling products, 2,100 MZN/month for manufacturing artisanal products, and 3,600 MZN/month for extraction of gravel and stones.

[7] *The 7 de Abril Principal irrigation scheme has 20 ha, using sprinklers receiving water from springs through gravity. No pumping is required, and the main crops are cabbage, maize and common beans.*

[8] *The 7 de Abril Anexa is a*

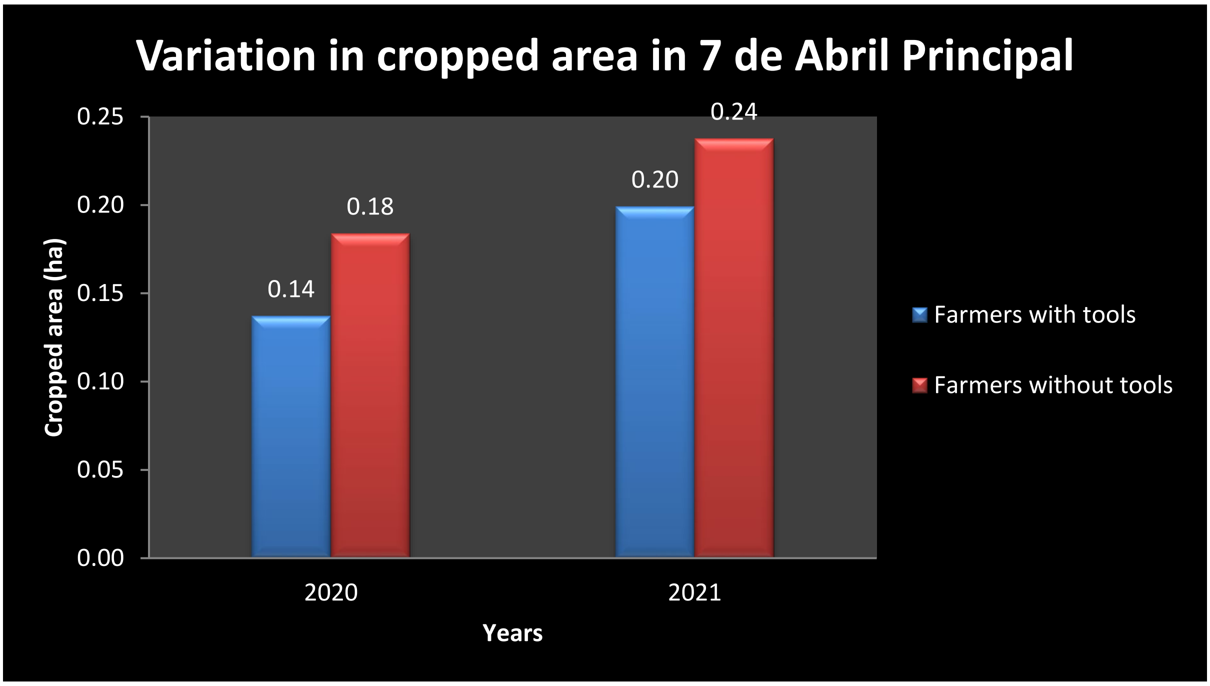

Figure 3: Variation of cropped area between 2020 and 2021 seasons for farmers with tools and without tools in 7 de Abril irrigation scheme.

The study demonstrated that simple soil moisture and nutrient monitoring tools can trigger changes in smallholder farmer's practices, such as reduction in irrigation frequency and increased crop and water productivity. The adoption process is encouraging, from farmers perspective, although it is a gradual process with some farmers quickly learning and using the tools properly, while others require more engagement. Another important aspect on adoption is that the IRRIGA Project, a World Bank Group funded project has confirmed its interest in implementing the use of the tools in their irrigation schemes in Manica province. The staff from FASIMO are currently supporting IRRIGA on developing the terms of reference and planning where the tools will be installed, and how farmers will be trained. FASIMO's experience indicates that there is a need for continued support and regular monitoring of the WMT throughout the adoption process before farmers begin seeing the tools as instrumental fort their decision-making on when to irrigate.

C. *Objective 3. Testing innovative and user driven business and farmer organizational models that improve profitability for farmers engaged in the government funded and farmer led smallholder irrigation schemes*

The introduction (and testing) of innovative and user driven business and farmer organizational models to improve profitability has been initiated from the moment when the Project had a fair understanding of the context where irrigation schemes are managed and how farmers are organized. This included the understanding of factors contributing to the success and failures of irrigation schemes in Mozambique. Of importance to highlight is the COVID-19 pandemic that greatly affected the delivery of the project, particularly in establishing agricultural innovation platforms to serve as forums for dialogue and networking between farmers and various value chain actors which would accelerate the introduction of innovations. The restrictions imposed by COVID-19 limited gatherings of groups of people, and the project staff conducted fewer field visits, especially in 2020 - the first year of the pandemic. However, ever since the pandemic situation improved, the project has carried out a number of activities towards improving organizational and profitability of smallholder farmers, namely, (i) introduction of improved agricultural inputs to build farmers' resilience to external shocks, (ii) promote exchange visits for reciprocal learning between farmers.

"The introduction of improved agricultural inputs contributes to build farmers' resilience and readiness to external shocks"

Both, the COVID-19 pandemic and extreme climate events (tropical cyclones and floods) in Mozambique have adversely affected the livelihoods of farmers. The introduction of agricultural inputs was designed with the purpose of supporting smallholder irrigation farmers to build their resilience to respond to these external shocks. Farmers readiness to respond to shocks is measured by their capacity to continue with their means of livelihoods after they have suffered from an external shock. Therefore, FASIMO introduced agricultural inputs to test whether this would contribute to increase farmers' readiness and resilience.

The agricultural inputs were introduced in the winter season April to August 2021, and benefitted around 80 farmers in all eight irrigation schemes in Manica and Gaza provinces (Annex 10). Overall, the results from the follow-up survey on the impacts and results from the agricultural inputs indicates that 60% of beneficiary farmers have been able to generate revenues and profits that allow them to reinvest in the following season. For instance, in Makateco irrigation scheme – a government-led scheme, the revenues earned were not only used to purchase improved agricultural inputs for the following season, but were also used to buy new irrigation hose pipes to irrigate the newly expanded area of 1 hectare. In the present cold season, farmers in Makateco will gain farm the same common beans variety provided by FASIMO, as they affirmed that the variety introduced to them is highly productive and attracts higher selling prices. Another success was found in Chitsogoanine – a farmer-led scheme, where about almost 9 in 10 farmers were able to generate revenues enough to reinvest in the next cropping season.

In short, the provision of agricultural inputs contributed beyond what had initially been anticipated by triggering farmers' passion and ambition to expand their cultivated area, and to adopt and continue using improved inputs. This validates the premise that the agriculture business will be attractive as long as farmers earn from it and improve their livelihoods.

"Exchange visits lead to mutual peer-learning and positive change among smallholder farmers"

The section 3 "Progress towards milestones" on "*Indicator 46: Report on the value addition of linkages/networks between farmers and other stakeholders, showing the benefits gained by men, women and youth farmers on production, productivity and strengthening the agricultural value chain*" brings interesting findings as a result from the exchange visit between farmers from Makateco, Rivoningo and Tiva Kurima associations in Gaza. For example, the change in leadership and election of new members to the management committee at Tiva Kurima scheme triggered by exchange visit is an indication that farmers can learn much quicker from their peers. Similarly, quick changes due to participation in the exchange visit were reported in Makateco, such as setting up a bank account for the association, early planning of agricultural season and allocation of individual plots.

In summary, exchange visits enabled mutual learning and networking among smallholder farmers, and this was translated into farmers reorganizing themselves, having more transparent and democratic leadership, and being able to improve the planning and goals.

D. Objective 4. Development of cost-effective mapping techniques of irrigated areas in Mozambique

To illustrate the extent of irrigation that is not recorded, consider the map in Figure 5.

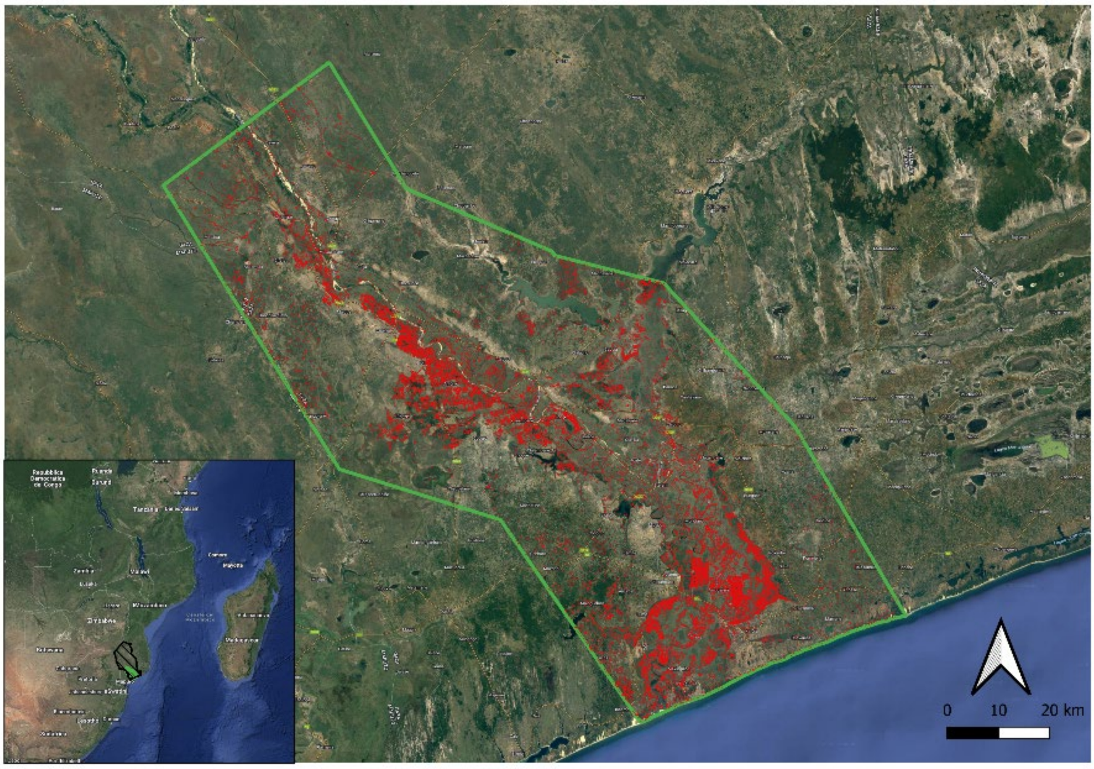

Figure 4: A remote sensing case study map of the Lower Limpopo area (around Chokwe and Xai-Xai) marked in green and in red the irrigation hotspots.

One of the FASIMO case studies covers the lower Limpopo River and its banks, from Chokwe to Xai-Xai, and contains the sizeable Chokwe irrigation scheme and two large privately owned rice schemes near Xai-Xai. This case study covers an area of 780,000 hectares, of which 80,000 hectares were classified as irrigated agriculture. This classification was done using remote sensing imagery and machine learning algorithms, which is a method to map large areas that are otherwise difficult to cover by car or would take a long time.

Approximately 10% of the case-study area is covered by irrigated agriculture, of which the majority is not included in formal records. In contrast, the Mozambican National Irrigation Plan mentions that there is 90,000ha of irrigated land in the whole of Mozambique, which is about the same area as mapped in Chokwe and Xai Xai, while many other irrigation areas are known.

Of the 80,000 irrigated hectares in the study area, between 4,000-7,000 hectares are in the government-led irrigation scheme in Chokwe (HICEP), and about 10,000 hectares are in the Xai Xai rice schemes, leaving around 60,000 hectares of smallholder irrigation, initiated, and maintained by smallholder farmers themselves. Even if the classification overestimates the extent by 50%, the area that covers irrigated agriculture through farmers' own investments is twice the size of the production area irrigated through government or large private sector investments. This shows that FLID has a significant contribution to local food production.

To ensure long-term use of the knowledge generated throughout the process of identification and classification of irrigation, 20 participants attended, from UEM, INIR, ISPM and ISPG and were trained with skills of mapping irrigation embedded in their organizations.

5. Synthesis towards Agriculture and Food Security (AFS) themes

The development of smallholder irrigation is seen by the Government of Mozambique as a useful approach to increase agricultural productivity, increase food security, reduce poverty, and increase resilience to climate variability. Aligned with this goal, this project intended to recommend evidence-based irrigation development models to be considered for the smallholder farmers.

Increasing agricultural productivity, market access and income

The project introduced and continues to **promote the use of simple and user-friendly water and nutrients monitoring tools, that have shown great evidence on improving productivity and profitability of smallholder farmers**. Through the soil water and nutrient monitoring tools, smallholder farmers have been able to reduce by half their irrigation costs and water applied, while having spare time to carry out other activities such household chores and income generating activities. Smallholder farmers have realized the usefulness of the tools and their willingness to adopt such technologies indicates the potential that this technology can bring if promoted and used in several irrigation schemes, particularly those applying irrigation water using pumps, as reduction in applied water is directly related to cutting back the costs to run water pumps.

In addition to using tools, **the project has introduced improved agricultural inputs (seeds and fertilizers) as a strategy to build farmers' resilience to external shocks**, such as the recent COVID-19 pandemic and the cyclic extreme weather events affecting Mozambique with more increasing intensity and frequency in last 15 years. The adoption and use of improved and well-adapted seed varieties, coupled with appropriate crop management practices, including tillage, crop density, furrow lengths and water management resulted in more yield. Furthermore, farmers were sensitized in selecting marketable crops, this is, select crops based on the market prospects and price. For instance, farmers from Makateco and Rivoningo irrigation schemes in Gaza province are now opting to grow common beans in winter season instead of widely produced winter vegetables that often lead to oversupply and lower prices. The recommendation of improved agricultural inputs (e.g., certified seeds and fertilizers) will contribute in short run to increase production and productivity, while enabling farmers to supply good quality harvest. An analysis of factors of success showed that good quality agricultural products are vital to attract better prices, easier to market and with higher revenues.

Informing Policy

Strategically, the project is directly engaging with policy makers at the National Irrigation Institute (INIR), since INIR is the Government entity in Mozambique overseeing irrigation planning and development under the Ministry of Agriculture and Rural Development. The main policy points that have been communicated at this time are: a) the development of smallholder irrigation should consider new approaches, other than the current government-led, where infrastructure are developed by the Government and partners and transferred to farmers without a proper engagement with the beneficiaries throughout the process of irrigation development; (b) the possibility of improving farmers productivity and profitability by investing and promoting simple soil and water monitoring tools, given their benefits to save water, nutrients, time allocated to irrigation and financial resources due to reduced pumping, and, (c) the possibility of including new areas where irrigation is happening (e.g. farmer-led irrigation) that are currently not included in government planning and support.

The key messages, lessons, and recommendations on how irrigation can be supported and developed in Mozambique will be utilized by various irrigation stakeholders and government.

This is an important opportunity given development partner's investments in irrigation in the country. One recent outcome of policy advocacy and changes in practice resulting from FASIMO is the fact that INIR is currently in the process of purchasing soil and water monitoring tools to be used in sites from the IRRIGA Project - a World Bank Group funded project aiming at developing about 3,000 hectares[9].

Another policy change the project is seeking to influence is on identification and classification of irrigation in Mozambique, as the current official government statistics only account for the conventional irrigation schemes developed by the government and multilateral partners. FASIMO is undertaking surveys and mapping of all types of irrigation, not just government funded irrigation schemes. The project has come up with sound cost-effective approaches and procedures combining remote sensing data, ground data and machine learning algorithms able to identify and classify irrigated cropland and other land classes and uses. The project found much more irrigated area than what is reported in official government reports, highlighting the importance and existence of irrigation initiatives happening throughout Mozambique, and contributing to food security and income generation. This has important policy implications for the planning and support to irrigation in Mozambique. The project is already taking a proactive policy engagement by involving staff from the National Irrigation Institute (INIR), UEM, ISPM and ISPG on the mapping exercise from early stages. Moreover, the training provided to staff from the aforementioned institutions will ensure a quick uptake of the lessons and expand its use countrywide. This information on the true scale of irrigation, especially farmer-led irrigation, will assist in water use planning and understanding where food is produced.

[9] *Currently the ToR are being developed which will indicate the pilot irrigation schemes where the tools will be installed and used.*

5 Project outputs

FASIMO Project planned different outputs along the life of the Project. The planned outputs range from papers, posters, leaflets, policy briefs and technical reports. All outputs are in draft form except posters. Table 3 summarizes the planned outputs and the completion possible completion time.

Table 3: Planned Project outputs

Order	Output Name	Type of Output	Completion time
1	Tools	Policy Brief	September 2023
2	Gender	Policy brief	September 2023
3	Water Productivity	Paper	September 2023
4	Socio-Economic	Paper	September 2023
5	3-4 Journal articles on remote sensing and machine learning of irrigated agriculture	Journal papers	Q2/Q3 2023

6 Problems and challenges

FASIMO planned different activities and tasks involving different partners and authors. Accomplishment of these activities were dependent on the well and aligned plan with stakeholder in the research ground. Therefore, some challenges arose, such as COVD-19 and Floods

A. COVID-19 situation

Due to the impact of the Covid-19 pandemic, we replaced the planned situation analysis with a socio-economic survey that was complimented by individual semi-structured interviews in five irrigation schemes.

Impacts/implications to the project: project staff based in the capital Maputo were advised to work from home from January to February 2021 due to enforced curfew. This led to changes for instance in the Project Annual Meeting which originally had been planned to be held in Gaza Province close to the implementation sites. Due to the higher risk of infection, the annual meeting was held virtually via Zoom, which unfortunately did not allow discussions based on the field visit that was part of the original plan.

Coping strategy: Farmers affected by COVID-19 benefited from agricultural inputs, which were provided as credit, and were returned to the farmers' association management board to serve as a revolving fund, reaching more farmers. In addition to inputs, farmers continued to be assisted using an SMS knowledge exchange platform (IRIPO), which enabled the sending and receiving of essential information, thus increasing and reinforcing the uptake of new agricultural practices.

B. Floods in Gaza and tropical depression in Manica

The heavy rains, storms and cyclone affected farmer activities in the project targeted sites. For instance, 4 of the 5 sites in Gaza were severely flooded, resulting in loss of crops and thus hampering project field activities. Meanwhile, in Manica, although the sites were not flooded (given the higher topography), the access roads were severely affected by the excessive rainfall events, thus limiting the project staff to physically engage with farmers.

Impacts/implications to the project: with most of the fields flooded in Gaza and degraded road conditions in Manica, fieldwork was affected. The floods in Gaza resulted in loss of crops in the field, and this significantly affected crop and water productivity as chameleon (moisture) sensors and wetting front detectors were submerged or washed away and needed to be replaced.

Coping strategy: provision of agricultural inputs allowed farmers affected by hazards to reinvest in their farming activities. Also, the project team, closely assisted by the IDRC Project Responsible Officers, redesigned the interventions to focus on key activities that would lead to the ultimate goal of the project, which was to influence policy by providing evidence-based recommendations on irrigation development models for Mozambique.

7 Overall assessment and recommendations

FASIMO project was well designed and structured. All the administrative tools were in place to give the smooth steps along the life of the project. Despite the interruption by COVID-19, floods in Gaza and tropical depression in Manica, which led to loss of an entire cropping season, the adjustments made to the project, help to salvage the project from major drawbacks. This was a good achievement in terms of management of the project.

Regarding dissemination of project outputs to the wider audience, it would be better if IDRC would allow project teams to host stakeholder workshops after project closure. This would offer an opportunity to aggregate more evidence, including from endline surveys, spill over impacts, and where applicable, publications. Such rich data would be synthesized and disseminated widely to benefit more stakeholders.

8 Annexes:

Annex 1: Paper Brief 1 – Successful Irrigation Development Models in Mozambique

Annex 2: Paper Brief 2 - Successes and Failures of Irrigation Development in Mozambique

Annex 3: Improving Water Productivity in Farmer-led and Government-led Irrigation Schemes

Annex 4: Summary of Gender and Empowerment on FASIMO Project

Annex 5: Report on end of season workshop in Gaza Province

Annex 6: Report on end of season workshop in Manica province

Annex 7: Report on farmers exchange visit in Gaza

Annex 8: Report on training on mapping irrigated areas using remote sensing

Annex 9: Case study on use of saved time and money in Manica

Annex 10: Report on improved agricultural inputs to build farmers resilience.docx.

Annex 11: First Workshop FASIMO's Result and lessons Dissemination.

Annex 12: Relatório do Seminário de Divulgação de Resultados do Projecto FASIMO December 2022 (Portuguese)

Annex 13: FASIMO Endline Survey Report (Draft)

Annex 14: Dissemination Report

Annex 15: Final impact report

Annex 16: Understanding the extent of Farmer-Led Irrigation Development (FLID) and its implications for policy.

Annex 17: Modern agricultural tools usage for improved agriculture in farmer-led smallholder irrigation in Mozambique. Manuscript under internal review (accepted for presentation at 24th WaterNet/WARFSA/GWP-SA Symposium, October 2023).