Improving Agricultural Resilience to Salinity Through Development and promotion of Pro-poor Technologies (RESADE)

Cost Benefit Analysis
Analytical Framework Report

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Acronyms

BADEA	Arab Bank for Economic Development in Africa
BPH	Best Practices Hub
CBA	Cost-Benefit Analysis
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
FFSoE	Farmer Field School of Excellence
FGD	Focus Group Discussions
ICBA	International Center for Biosaline Agriculture
IFAD	International Fund for Agricultural Development
IIAM	Mozambique's Institute of Agricultural Research
IRR	Internal Rate of Return
KII	Key Informant Interviews
MAE	Ministry of State Administration
MLC	Monty's Liquid Carbon
NARES	National Agricultural Research and Extension Services
NPV	Net Present Value
RESADE	Improving Agricultural Resilience to Salinity through Development and Promotion of Pro-poor Technologies
SSA	Sub-Saharan Africa
TOR	Terms of Reference
WUA	Water Use Association

Executive summary

Agriculture plays an important role in Mozambique's economy, contributing 23 percent to GDP and providing employment for the population living in the rural area. Smallholder farmers cultivate 95 percent of agricultural land, and 70 percent of the population is still dependent on subsistence agriculture (Ministry of Agriculture, 2010), which drives them even deeper into poverty. Therefore, more investment in agriculture is important for poverty reduction. The country has approximately 5,650 thousand hectares of arable land with abundant renewable freshwater resources. However, most farmers cultivate in rainfed agriculture, prone to severe drought.

Salinity is considered one of the limiting factors in agricultural productivity in some agro-ecological zones of Mozambique. The excessive accumulation of salts leads to negative impacts on plant development and induces land degradation. Several reports have indicated extensive salt-affected areas in irrigation facilities in southern and central Mozambique with significant adverse effects on agricultural production and dire consequences for smallholder farmers' economy, livelihood, and sustainable development in general. The problem is severe in the coastal areas of Zambezia, Sofala, and Gaza provinces. The situation has been worsened by poor water management, inadequate fertilizer usage, and climate change impact.

To address soil salinity issues and improve agricultural productivity and farmers' welfare in marginal environments, the International Center for Biosaline Agriculture (ICBA) in partnership with the International Fund for Agricultural Development (IFAD) and the Arab Bank for Economic Development in Africa (BADEA) is implementing the RESADE project aiming at developing low-cost technologies and building capacities among beneficiaries in soil and water management practices that improve fertility and mitigate/avert salinization. These include (a) low-cost, water and energy-efficient small-scale irrigation technologies; (b) best management practices that improve the productivity of existing cropping systems; and (c) adapted climate-smart crops with high tolerance to drought and salinity, and high nutritional and economic value (e.g. quinoa, legumes, etc.).

The project is being implemented in the Moamba district, southern Mozambique, selected due to prevailing salinity problems among other locations where salinity studies were conducted for identifying "hot-spots" for project implementation. A Best Practice Hub (BPH) was established in Moamba district in 2021 and agronomic data on multiple production cycles have been gathered by the project team. That said, the details of the costs and benefits of the evaluated technologies have been neglected. As such, this study aims to explore the economic and social benefits of each promoted technology against the incurred costs – a comprehensive Cost and Benefit Analysis (CBA).

The study methodology consisted of a desk review and a combination of qualitative and quantitative analysis methods. Internal Rate of Return, Net Present Value, Payback Period, and Benefit-to-cost ratios are the parameters employed to assess the viability of the BPH technologies. Initially, the estimates of the CBA parameters considered the actual values per crop experiment treatment accounting for the allocated land size. However, the results were unreasonable as the land size allocated to each crop-experiment-treatment would never justify the level of investment

made in the Hub. As such, a new strategy was employed, consisting of extrapolating the results observed in the allocated small land size to the entire area occupied by the trial, i.e., assuming that the entire area is occupied by the crop-experiment-treatment.

The results show that the IP 19586 variety, Monty (20 L ha^{-1}), biochar (3 ton ha^{-1}) and NPK-15-15-15 for pearl millet, as well as green manure (3 ton ha^{-1}) and NPK 15-15-15 + foliar nutrients for sorghum, are the most viable technologies, mainly considering their Benefit and Cost ratio, payback period and Internal Rate of Return. While those technologies appear to be viable considering the main CBA parameters, the results from the qualitative data have shown that those crops do not have local market emerging yet. As such, we recommend that the sessions with those farmers participating in the hub cover discussion on the benefits of those crops so that they can gradually be introduced into their diet. Furthermore, we recommend that future interventions are context-specific, targeting high-value crops and addressing the most pressing issue of the agriculture value chain for the target location.

1. INTRODUCTION

Soil salinity is one of the most brutal environmental issues threatening global food security and the livelihood of many smallholder farmers and this is expected to exacerbate with the prospects of climate change (Shrivastava & Kumar, 2014; Hassani et al., 2021). The excessive accumulation of salts leads to negative impacts on plant development and induces land degradation. In Mozambique, soil salinity is considered one of the limiting factors in agriculture productivity in some agro-ecological zones. Several reports have indicated extensive salt-affected areas in irrigation facilities in southern and central Mozambique with significant adverse effects on agricultural production and dire consequences for smallholder farmers' economy, livelihood, and sustainable development in general.

The situation has been worsened by poor water management, inadequate fertilizer use, and climate change. Water scarcity during the dry season poses a serious challenge to small-scale farmers in irrigation schemes. In many cases, inappropriate irrigation conditions such as limited water supply to crops due to water shortage during the dry season, causes salt accumulation in the root zone. Sea water intrusion in the delta region, both by surface and groundwater flow has been indicated as another cause of irrigation water quality deterioration with a negative impact on soil quality. To address the salinity problem, the International Center for Biosaline Agriculture (ICBA) implemented Agricultural Resilience to Salinity through the Development and Promotion of Pro-poor Technologies project with financial support from the International Fund for Agricultural Development (IFAD) and the Arab Bank for Economic Development in Africa (BADEA) in collaboration with some SSA countries including Mozambique.

The RESADE project aims to improve food security and reduce the poverty of poor smallholder farmers, particularly women, in salinity-affected areas in Botswana, Gambia, Liberia, Mozambique, Namibia, Sierra Leone, and Togo. This objective is tailed to the following specific objectives: i) To introduce salt-tolerant crops and best agronomic management practices; ii) to develop value chains for introduced cropping systems; and iii) to build the capacity of farmers and extension workers in salinity-resilient and climate-smart agriculture in collaboration with national agricultural research and extension services (NARES). In Mozambique, the ICBA is implementing the RESADE project together with the Mozambique's Institute of Agricultural Research (IIAM).

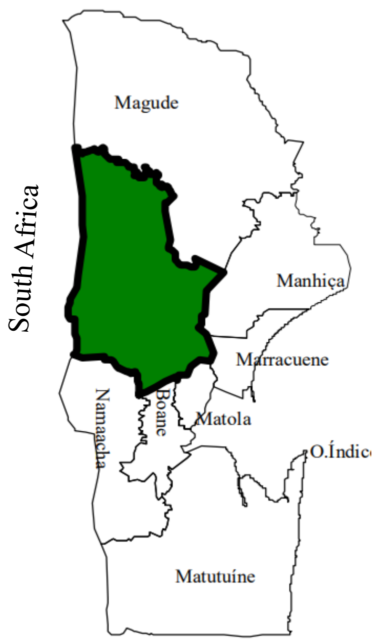
The project is being implemented in Moamba district, southern Mozambique, selected due to prevailing salinity problems among other locations where salinity studies were conducted for identifying "hot-spot" for project implementation. A Best Practice Hub (BPH)[1] was established in the Moamba district in 2021. During this period, the RESADE team has captured reliable and relevant agronomic data including quantity of inputs and yields. That said, the details of the costs and benefits of the evaluated technologies have been neglected. Therefore, this assignment aims at conducting a comprehensive Cost and Benefit Analysis of the technologies evaluated at the BPH. This study will enable us to understand the economic benefits and social gains of the testing and promotion of technologies for the management of salt-affected soils in the Moamba district.

[1] BPH is a platform for technology transfer to farmers demonstrating several solutions to cope with salinity stress. The hub focuses more on a participatory approach involving farmers, researchers and extension services.

2. METHODOLOGY FRAMEWORK

2.1. Study site characteristics

The project intervention area is located in Maputo province, Moamba district, in southern Mozambique. Moamba district is situated 75 Km from the capital, between 25° 27' and 25° 50' South, 31° 59' and 32° 37' East. The district borders with Massitonto River in the north, which separates with both Boane and Namaacha districts, in the East borders with Manhiça and Marracuene districts, in the west the district borders with South Africa. Agriculture is the major driving factor of the local economy due to existing irrigation facilities in the region. The district has very limited land suitable for agricultural use. Most soils are of poor fertility and low suitability under rainfeed agriculture. Only limited areas along the rivers and irrigation system show moderate suitability. Livestock production is one of the major sources of income for some populations in Moamba.



The total surface area of the district is about 4,628 Square Kilometers, with 115,127 inhabitants, according to national statistics. The estimated population density is about 76 inhabitants per square Kilometer.

Maputo province falls within a tropical climate, according to the Köppen classification. The average monthly temperature is around 24°C. The cumulative rainfall ranges from 580 and 590 mm, rarely exceeding 800 mm in a normal year, with pick in December and January. The evapotranspiration potential is generally higher in summer with an average of 1,433 and 1,500 mm.

The region suffers from severe water deficit in the growing period. The 1/2*ET is in general low than precipitation in most of the growing season. The establishment of irrigation infrastructure in the region was designed to reduce water deficit for crop production.

Climate change poses a serious challenge to farmers who depend on natural resources for their livelihood. Agriculture activities are highly dependent on good rainfall patterns and favorable temperature regimes. In recent years, southern Mozambique, and Moamba in particular suffered from severe drought and most recently in 2022 suffered from excessive rain, leaving rural families vulnerable to food insecurity. Several government and agriculture development organizations relief programs with packages of agriculture input and tools were directed to Moamba and other regions affected by heavy rains and floods.

While the impact of the disaster was swift the recovery has been slow. Farmers have been adapting measures to create resilience to climate change such as crop diversification, adoption of early mature varieties, planting at different times not at once to avoid crop failure, intensification of production in irrigation facilities during the dry season, and expansion to the rainfed areas during the rainy season, use of drought tolerant cultivars and raising livestock. The RESADE Baseline Report has indicated that selling their labour to other successful farmers or working in South

Africa, especially young people, are among the alternative sources of income which is used in times of scarcity.

2.2. BPH and farms firm characteristics

For addressing the problem of management of salt-affected soils, the RESADE project set 5 major components, namely:

- ✓ Component 1: Assessment and mapping of salinity-affected agricultural areas and selection of areas for project implementation.
- ✓ Component 2: Participatory development of improved salinity management technologies and practices at BPHs and related capacity building.
- ✓ Component 3: Scaling up of climate-smart and salt-resilient agricultural production systems from BPHs to the farming communities in the targeted areas.
- ✓ Component 4: Learning, knowledge management, and policy dialogue.
- ✓ Component 5: Project coordination including Monitoring and Evaluation.

Each of these components has several activities tailed with a result framework with clear tasks, expected results, or output. The Best Practice Hub falls under Component 2 of the project, and it appears to be the core activity of the project. Project reports indicate that BPH is a knowledge hub and learning center where several soil, crop, and water management innovations are being tested and promoted (see the description of the experiments in the BPH in the following sections). Scientists from different disciplines, farmers, extension officers, and students interact to evaluate the performance of innovations used for enhancing farmer's decision-making capacity on the management of salt-affected soils.

2.2.1. Crop fertilization

The experiments established in the BPH aim to address fundamental questions related to soil, water, and crop management innovations. The crop fertilization experiment with the following treatment structure was designed primarily to evaluate the effect of crop response to inorganic fertilizer and other crop nutrient applications.

- ✓ Treatment 1 (Control) – no fertilizer applied.
- ✓ Treatment 2 - recommended fertilizer rate (200 kg/ ha NPK and 150 kg/ha Urea).
- ✓ Treatment 3- recommended fertilization (NPK + Urea) - foliar application.
- ✓ Treatment 4- Cattle manure (6 tons/ha).

According to the Coordinator of RESADE Mozambique (Ricardo Maria), although the split application of micronutrients represents additional cost on labour because nutrients should be applied more than once, it may have a comparative advantage due to cyclomerize between crop requirement and foliar fertilization.

2.2.2. Soil amendment

Soil amelioration can be achieved by the addition of amendments to the soil prior to planting. To ascertain the effect of soil amendment on soil and crop productivity in order to determine the optimal amendment and dose that improves crop productivity and income under salinity conditions, several soil amendments were tested including limestone, Monty's Liquid Carbon (MLC), biochar, and green manure. Two levels for each soil amendment (low and high rates) were tested.

- ✓ The limestone was tested at 7 ton ha^{-1} for high and half (3.5 ton ha^{-1}) for low rate.
- ✓ The MLC was tested at 10 L ha^{-1} and 20 L ha^{-1} for low and high rates respectively. This was applied twice, in the soil at the planting stage and 15 days after emergence.
- ✓ The biochar was tested at 6 tons ha^{-1} for a high rate and 3 tons ha^{-1} for a low application rate.
- ✓ As for green manure, fresh cowpea crops before flowering were incorporated into the soil at 3 ton ha^{-1} for a high rate and 1.5 ton ha^{-1} for a low rate.

Several agronomic data and soil conditions through soil testing prior to and after planting were collected by the RESADE local team to determine the effect of treatment on crop yield and soil amelioration. For enhancing crop productivity, minimizing the risk of crop failure due to biotic and abiotic stress, good crop management by changing planting dates, or integrating strategies that maximize water use productivity are essential. To evaluate different crop management strategies, two planting dates were tested: The first planting date (SD1) was on April 29, 2022, and the second planting date (SD2) was on May 30, 2022, approximately a month later.

Another experiment tested two factors with three treatments each:

i) Weeding management (control- no weeding, chemical and manual weeding).
ii) Soil practices (no practices, mulching, interactive practices - soil ridging).

2.2.3. Water management

Salt-affected soils need good management of available water for sustainable crop production. Small-scale irrigation systems can help farmers to have a year-round production rather than relying on rains. Irrigation systems such as Californian or drip irrigation can alleviate the negative impact of salinity on soil and crops. A comparative study was conducted to evaluate the performance of drip irrigation systems as opposed to farmers' practices (surface irrigation) and assess crop productivity under tested systems.

Adding extra irrigation water above the required is an integral part of the management of salt-affected soil. The extra amount of water will maintain an acceptable root zone salinity, depending on the salinity of the water it is being irrigated with. The experiment aims to evaluate the effect of several leaching fractions on crop productivity in order to determine the optimal one.

2.2.4. Crop management

Good crop management is important for better yield and high return on farmers' investment in input, the water usage fees for irrigating the crop, and other costs. The first step of crop management is sowing. For a plant to germinate and grow, good seed placement in the farrow and planting depth needs to be observed. Many farmers lack knowledge about where seeds should be placed under drip irrigation systems or farrows to achieve maximum water and nutrient use efficiency by crop and prevent adverse effects due to soil salination in areas with high salinity hazards. The sowing of all crops is done manually in the open furrow in the prepared soil seed bed, places the seed in the exposed moist soil, covers the planted seed, and then often packs the soil down to assure firm seed-soil contact.

According to RESADE country's reports, crop management has been an important topic of the Farmer Field School of Excellence (FFSoE) aimed at building farmer's decision-making capacity for improved soil and water management of salt-affected soil (RESADE Technical Report, 2022). In many cases, low plant density per ha has been limited by the machinery which is set for 1-meter row spacing instead of 0.8 m for cereal crops as recommended by the Agricultural Research Institute. Planting of major horticulture crops is conducted during the cool season when water demand is low due to low evaporation and pest pressure is minimal due to low temperature.

After planting, continuous crop maintenance follows. Field observation in surrounding farmers of the Best Practice Hub (BPH) shows poor plant stand, and the incidence of pests and diseases which affect crop productivity. This problem is worsened by poor soils and high land use intensity. For improving soil fertility, balanced fertilization is important. Farmers have been using blanket NPK inorganic fertilizer for basal band application and urea for band top-dress to assure nutritional sufficiency for plant growth. The addition of manure also has been used to improve soil fertility status. However, there is limited knowledge among farmers about the right amount of fertility for specific crops. To address this, the RESADE project has been promoting sustainable fertilizer use by tailoring fertility type and quantity to crop requirements, including teaching farmers the safe use of pesticides (RESADE technical report, 2021).

With respect to pest control, farmers have been using different chemical products depending on the type of crop and the level of infestation. However, many farmers have been applying pesticides without proper protection such as masks, proper gloves, eye grass protection, and attention to wind blow direction when spraying chemicals, among other measures. Soil amendments and some crop fertilization tested in the BPH represent innovative strategies not tested by farmers before. These measures are required for soil reclamation. It is estimated 40% to 60% yield loss if the crop is not cleared from weed.

Generally, weed control has been conducted manually. The number of weeding varies from two to three, depending on water availability. In the dry season, weed pressure is reduced when compared with the rainy season, when the demand for labour is generally at the pick level. Weed control has been accomplished through hoe. Introduced water conservation measures provide an opportunity for farmers to learn how mulching techniques can suppress weeds and reduce evapotranspiration of the crop. The application of herbicides is not widely used by farmers for weed control.

Two irrigation systems, drip irrigation system in the left and farrow irrigation system in the right

2.2.5. Farmer Demonstration Practice

According to the RESADE project portfolio, the Best Practice Hub encompasses testing of soil, water, crop management, and introduction of new crops and varieties. The Farmer Demonstration Plot as part of the Hub represents an important complement where innovation being promoted in the Hub is tested by farmers so they have a chance to evaluate technical challenges and viability before adoption.

2.2.6. Building Decision-making capacity among farmers through Farmer Field School

The farmer field school (FFS) is an integral part of the RESADE project and enhances farmer's decision capacity on the management of salt-affected soils. It has been used widely for many years as an education tool and extension method for improving farmer decision-making capacity, problem-solving, and learning techniques for improved crop productivity and farmer's livelihood. In Mozambique, the method has been used extensively by the Food and Agriculture Organization of the United Nations (FAO) and international agricultural development organizations with support from government extension officers.

Amid straightening farmers' knowledge and skills, according to RESADE-Mozambique technical reports, the FFS is an integral part of the project activity with two stages: i) Building capacity of trainees; and ii) Training of farmers on relevant aspects mapped from the training of facilitators and fine-tunned to fit to local conditions. In general, rural farmers have low literacy levels, hands-on training assists in better decision-making for improved crop production.

Photo: Farmer Field School. Source: RESADE communication team

Soil salinity is one major problem of agricultural production in the RESADE project intervention site. According to the project's baseline report, results have indicated limited knowledge among farmers on best management practices for mitigating the effect of salinity. However, the impact of soil salinization in this facility is well understood by growers. Personal communication with the project staff (Carmona), it is estimated that 16 -20% of 480 ha of block II irrigation facility in Moamba districts is affected by salinization.

To fill the knowledge gap on the production and utilization of soil amendment for salt-affected soils and demonstrated low-cost biochar production unit, the available report indicates that several FFS were conducted as part of the RESADE project, including hands-on training on biochar production and utilization, assembly of seed processing and testing, FFS on sustainable fertilizer use, soil amendment application, establishment of irrigation system and maintenance among other training activities.

Course evaluation reports suggested that the trainings conducted were important steps for building capacity among farmers for improved capacity on decision-making on the management of salt-affected soils.

Photo: Training workshop organized by RESADE Mozambique. Source: RESADE team

2.3. Identification of practices, and the crops produced

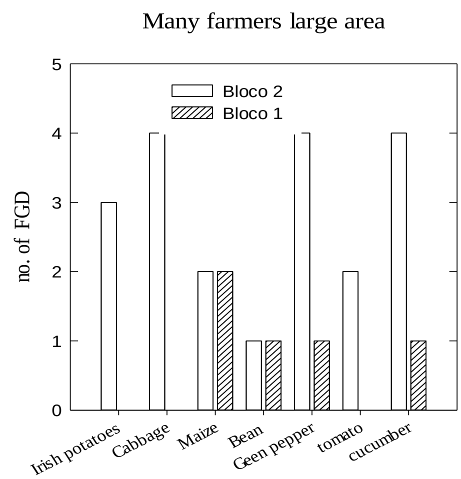
According to existing RESADE project reports, Moamba district played an important role in horticulture production from which Maputo city relied on produce supply. Currently, production has stagnated due to a number of reasons, including low investment in the agriculture sector, degradation of irrigation infrastructure, limited technical support, and lack of information for judicial decision-making for improved crop management. The decline of crop production in the district is exacerbated by limited rainfall which has been attributed to climate change and variability. The existing irrigation facilities are managed by farmers through the Water Use Association (WUA) and provide water for supplementary irrigation. However, due to the high cost of electricity, the WUA faces challenges in covering electricity bills and maintenance of motor pumps. Improving production in the district is, however, the local government's top priority.[2]

[2] Source https://resade.biosaline.org/media/resade-mozambique.

The crop spectrum in the region is quite diverse. Some crops are cultivated in large areas because of their high value or demand in the local market. Others such as sorghum and millet are considered lost crops, particularly due to high bird attacks and lack of market.

A report from RESADE's Best Practice Hub indicates tomatoes, beans, maize, cowpea, and cabbage as major crops. The project's focus groups discussion (FGD) organized by the RESADE project with two farmers' cooperatives (Bloco 2 and Bloco1) indicates that the majority of farmers cultivate in large areas Irish potatoes, cabbage, maize, bean, green pepper, tomatoes, and cucumber. However, there is a seasonal variation of dominant crops cultivated in the region because of a high incidence of pests and diseases in the summer. Some crops such as tomatoes, cabbage, and Irish potatoes are cultivated mostly in the winter.

There is a government effort to promote the production of vegetable crops in a controlled environment. However, poor crop performance has been observed due to inadequate crop management, which makes a good environment for the breeding of a wide range of pests.



In Moamba district, about seven crops have been cultivated in the BPH as follows: sorghum, pearl millet, cowpea, barley, quinoa, blue panic, and Buffel grass. While sorghum, pearl millet, cowpea, and barley have been growing, the other three crops (quinoa, blue panic, and Buffel grass) did not grow and may be discontinued. It is worth mentioning that while barley has grown, only biomass was harvested in the first season. In the meanwhile, only cowpea is being grown outside the BPH. The other crops are not grown in the surrounding villages especially because of limited knowledge and difficulty in controlling pests, especially birds. Please refer to Table 1 for detailed information on the crops and technologies being implemented inside and outside the hub.

As for the demonstration cluster, about 32 smallholder farmers from surrounding villages have been participating in the BPH to learn about the technologies being evaluated, and are expected to select those technologies they may want to apply in their own farms. About 44% of the farmers who participate in the BPH in the Moamba district are women (Table 2). While the farmers have participated in the farmer school since the establishment of the experiments, the RESADE team has no information on the adoption of the evaluated technologies in the surrounding villages. Note that the project aims at having at least 50% of women adopt the technologies being evaluated at BPH.

Table 1. List of crops and technologies implemented inside and outside the hub

Crops	In the Hub			Outside the Hub		
	Technologies	Number of seasons	Periods	Technologies	Number of seasons	Periods
Sorghum	• Fertilizer • Soil amendment • New Crops and Varieties • Crop management 1 & 2 • Irrigation systems	2	• Secondary season of the 2021/22 agri. campaign • Main season of 2022/23 • Secondary season of 2022/23 (still under cultivation).			
Pearl Millet	• Fertilizer • Soil amendment • New Crops and Varieties • Crop management 1 & 2 • Irrigation systems	2	• Secondary season of 2021/22 • Main season of 2022/23 • Secondary season of 2022/23 (still under cultivation).			
Cowpea	• New Crops and Varieties • Crop management 1 & 2 • Irrigation systems	2	• Secondary season 2021/22 • Main season of 2022/23	• Traditional seeds • Manure • Chemical fertilizers	2	• Main season of 2021/22. • Main season of 2022/23.
Barley	• New Crops and Varieties	1	• Secondary season of the 2021/22. • Secondary season of 2022/23 (still under cultivation).			
Quinoa	• New Crops and Varieties	*	• Secondary season of the 2021/22.			
Blue panic	• New Crops and Varieties	*	• Secondary season of the 2021/22.			
Buffel grass	• New Crops and Varieties	*	• Secondary season of the 2021/22.			

** Quinoa, Blue panic, and buffel grass did not grow. The Mozambique team did not receive Sugar Beat seeds.*

Table 2. Farmers' information (participation in the Hub)

Gender	Number (n and %)	Literate (n and %)	Illiterate (n and %)	Age<30 (n and %)	Age 30-60 (n and %)	Age >60 (n and %)
Male	18 (56%)	5 (30%)	13 (70%)	3 (17%)	12 (67%)	3 (17%)
Female	14 (44%)	4 (30%)	10 (70%)	0 (0%)	7 (50%)	7 (50%)
Total	32 (100%)	9 (28%)	23(72%)	3 (10%)	19 (59%)	10 (31%)

2.4. Data collection and description

The study methodology consisted of a desk review and a combination of qualitative and quantitative methods. The quantitative component consisted of both primary and secondary data collected from the project intervention area and neighboring villages. The consultant created a spreadsheet indicating the necessary information, but most of the data was provided by the RESADE team in Mozambique. In case primary sources were not available, secondary data sources were used. Note that the information about quantities was provided per each treatment of the technology being evaluated.

The qualitative component consisted of four focus group discussions (FGD) conducted to i) explore the reasons behind the take-up level of the technologies in the surrounding villages; and ii) discuss the prospect of employing the technologies evaluated at the BPH. To allow everyone to participate in the discussion, two different FGDs with 5-6 women each and the other two with 5-6 men each were created. Additionally, the consultant conducted some key informant interviews (KII) with some technicians who have been working at the BPH, including the RESADE local coordinator.

2.5. Analysis method

The cost-benefit analysis was carried out for each experiment, a comparison was made between treatment arms, to evaluate and recommend the best technology options to be disseminated to smallholders. The report includes detailed information on the calculations and assumptions for the estimation of various parameters including IRR, NPV, Payback Period, and Benefit-to-cost ratios. A description of each of the components is presented below.

(i) **Net Present Value (NPV):** is the value of the discounted future net benefits, i.e., it estimates all the money that will be spent and received with the production and commercialization of each of the evaluated crops (Akinyi et al, 2022). This study compares the changes in cost and benefits of the technologies evaluated at the BPH as opposed to their corresponding control groups. Based on the approach employed by Akinyi et al (2022), the incremental benefits will be evaluated in terms of the positive change in crop yields multiplied by the crop unit price. The incremental costs will be evaluated as the changes in quantities used for inputs (e.g. seeds, fertilizers, biochar, etc.), services, labour, machinery, and equipment multiplied by their respective unit prices. Based on this, the NPV is expected to be estimated as shown in Equation (1).

$$NPV_j = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[\sum_j^j P_{jt} * \sum_{j=1}^{j} C_n * Q_{jt}\right] \quad (1)$$

Where T corresponds to the lifecycle of the evaluated technology, r is the relevant discount rate, P_{jt} represents the unit price of the crop j (sorghum, pearl millet, and cowpea) in time t, $\boldsymbol{Y}^{□}$ is the in yield of crop j per experiment, C_n is the unit cost for the inputs, $\boldsymbol{Q}_{jt}^{□}$ is the change between the units of inputs for the BPH.

(ii) **Internal Rate of Return (IRR):** is the discount rate at which (NPV=0) investment is zero. At this rate, it is equal to the present value of the investment cost of exploration and benefits. The IRR measures the annual interest rate effectively provided by the set of capital invested in an investment during its useful life as shown in Equation (2). *CF* is the sum of the cash flows incurred in each year (t) that characterize that investment, then updated at a conveniently chosen discount rate (i).

$$0 = \sum_{i=0}^{n} \frac{CF_t}{(1+i)^t} \tag{2}$$

(iii) **Benefit-Cost Ratio (B/C):** consists of determining the relationship between the NPV of benefits and the value of costs for a given discount rate, thus, the project will be economically viable if it presents a value of B/C>1. Equation (3) shows how the B/C ratio is estimated.

$$\frac{B}{C} = \frac{Total\ of\ benefits(B)}{Total\ of\ Costs\ (C)} = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}} \tag{3}$$

Where B_t represents benefits associated with the BPH in time t and C_t represents the costs associated with the BPH in time t.

(iv) **Payback period:** evaluates the risk associated with investing in the BPH, which is translated into time within which the generated cash flow would be required to recover the total amount invested. It is estimated as indicated in Equation (4).

$$Payback\ period = \frac{Initial\ investment}{Net\ cashflow\ period} \tag{4}$$

2.6. Variables for CBA (cost, output, and life cycle and land variables and classifications)

The list includes of necessary variables includes: i) the quantity, unit price, and cost of inputs (machinery and equipment, labour, chemicals, services); ii) crop yield, crop unit selling price, and revenue. For crops that are not commonly grown in the area like pearl millet and sorghum, the crop unit selling price was based on the price of seeds.

The lifecycle T of the evaluated technology, which is critical in the computation of the key parameters employed in the study, was determined by the number of years during which the project is expected to be active multiplied by the number of production cycles expected per year. According to the RESADE documents made available, the project is expected to be implemented for 4 years. Considering the availability of water for the whole year, we assumed 2 production seasons or cycles per year. As such, our computations are based on a total of 8 (T) production cycles.

Initially, the estimates of main CBA parameters considered the actual values per crop-experiment-treatment, and land size allocated to each treatment. However, the results were unreasonable as the land size allocated to each crop- experiment – treatment would never justify the level of investment made in the Hub. As such, a new strategy was employed, consisting of extrapolating the results observed in the allocated land size to the entire area occupied by the trial, i.e., assuming that the entire area is occupied by the crop - experiment – treatment.

3. RESULTS AND DISCUSSION

3.1. An elaborate list of costs

Overall, the BPH technicians were able to provide us with a lot of information pertaining to inputs and equipment used in the implementation of each experiment for all evaluated crops (cowpea, sorghum, and pearl millet). However, most of the provided information was aggregate as most of the activities are being undertaken by a service provider hired by the RESADE Project. For instance, the RESADE team in Mozambique was able to provide us with the total cost paid after 4 months of implementation of the experiments for the evaluated season, which combines the cost of sowing, fertilizer application, spraying, weeding, and harvest, but the team was not able to provide disaggregate values.

The structure of the implementation of the project in Mozambique made it very hard to get precise estimates on the cost incurred to implement the experiment for a specific crop as the service provider is not paid per activity. Since our strategy was based on having cost information at the crop-experiment-treatment level, there was a need to establish an acceptable manner to estimate quantities of inputs and corresponding costs as precisely as possible. Therefore, the share of land occupied by each crop-experiment-treatment, in relation to the total size of the land being used for the experiments (6050m^2 =0.605ha), was vital to enable us to get the estimates presented below. While the cost tables below will show numbers based on the actual land size allocated to each crop-experiment-treatment, the final analysis is based on the extrapolated numbers as mentioned in the previous section.

3.1.1 Cowpea

Three experiments are being implemented for the cowpea, namely: i) new crop and varieties; ii) crop management; and iii) irrigation systems (drip irrigation and gravity irrigation). The installation cost for the experiments including the training cost of farmers was about 2.36 million Meticais, mainly due to the cost of the irrigation system, which alone was reported to cost over 2,220,000 Meticais. However, there was some difference when it comes to inputs used as these varied from one experiment to another and cost is also dependent on the share of the experiment in relation to the whole experiment. The treatments of the crop management experiment had the lowest cost of inputs whereas the experiment on the gravity irrigation system had the highest cost of inputs. The same applied to the operational cost. It is worth mentioning that the RESADE team in Mozambique did not indicate any maintenance cost as this should be accounted for by the service provider hired to help the team implement the project. Please refer to Table 3 for detailed information on the list of costs for cowpeas per experiment.

Table 3. List of costs for cowpea per experiment

Cowpeas.xlsx

3.1.2 Sorghum

Five experiments are being implemented for sorghum, namely: i) soil amendments; ii) new crops and varieties; iii) fertilization; iv) crop management; and v) irrigation systems (Drip irrigation and gravity irrigation). Like in the case of cowpeas, the installation cost for the experiments including the training cost of farmers was about 2.36 million Meticais, mainly due to the cost of the irrigation system, which alone was reported to cost to over 2,220,000 Meticais. There was some difference when it comes to inputs used as these varied from one experiment to another and cost is also dependent on the share of the experiment in relation to the whole experiment. Overall, the experiment registered the lowest costs of inputs whereas the experiment on the irrigation systems had the highest cost of inputs, which is a similar pattern as that observed in the case of cowpea. Please refer to Table 4 for detailed information on the list of costs for sorghum per experiment.

Table 4. List of costs for sorghum per experiment

Sorghum.xlsx

3.1.3 Pearl millet

Three experiments are being implemented for pearl millet, namely: i) soil amendments; ii) new crops and varieties; and iii) fertilization. The installation costs, including the cost of training farmers, for all experiments were about 2.36 million Meticais. A similar pattern as that observed in the case of other crops can be observed in the case of pearl millet with respect to other costs. Please refer to Table 5 for detailed information on the list of costs for pearl millet per experiment.

Table 5. List of costs for pearl millet per experiment

Pearl millet.xlsx

3.2. A list of economic benefits

Sorghum and millet are important crops in arid and semi-arid regions of Mozambique. The RESADE project intervention location is characterized by a semi-arid climate and the annual cumulative rainfall rarely exceeds 696 mm, sufficient to achieve reasonable sorghum and millet grain yield which cannot be achieved by other cereal crops under a rainfed production system. Several authors have indicated that sorghum flour is rich in phytochemical components, including tannins, phenolic acids, anthocyanins, phytosterols, and policosanols, with the potential to benefit human health. Therefore, sorghum crops for human health have gained increased interest due to their antioxidant activities, cholesterol-lowering properties, and anticarcinogenic and antidiabetic effects.

Additionally, the introduced cowpea varieties have great potential for adoption due to their high yield potential as opposed to other varieties common in the area. This is very important as cowpea is not only a source of income for smallholder farmers but also an important source of protein for resource-constrained farmers. Cowpea leaves and green pods are used to prevent or treat several human ailments such as measles, smallpox, adenitis, burns, and ulcers. Similarly, the cowpea grain is used to cure several ailments, including astringent, antipyretic, and diuretic (Khare, 2008).

Overall, the introduction of new technologies, which are being promoted by RESADE via FFS, is building the capacity of local farmers in salinity-resilient and climate-smart agriculture. The prospect of using degraded land is the most important benefit indicated by farmers during the focus group discussions. More importantly, these are reported to be improving the yields of the beneficiaries for both the promoted crops and other common crops in the Moamba district. However, given the inability to precisely quantify the social benefits of the technologies implemented under RESADE, this study focuses on the economic and observed benefits of each of the technologies. Further investigation of the potential social benefits of the introduced technologies is recommended.

The main challenge encountered in the estimate of the economic benefits is mainly the fact that yields are based on potential estimates, not actual values as only cowpea was harvested during the evaluated period. This relied on a computer model, which has been used widely as a tool for supporting decision-making in agriculture and natural resources management. Plant phenology and biomass yield have been used for estimating grain yield. In the RESADE trial, in the absence of actual grain yield due to uncontrolled factors (bird attack) in tested cereals, the following mathematical equations were used:

- Sorghum Yield (Var. CR1VM2D_drip): $Y = 1/2.4*x_i$
- Sorghum Yield (Var. CR1VM2f_farraw): $Y = 1/2.4*xi$
- Millet crop (IP19586): $Y = *x_i$
- Millet crop (MC94C2): $Y = *x_i$

Where Y is predicted grain yield in ton ha^{-1} and X is actual biomass yield in ton ha^{-1} measured in i^{th} treatment.

3.2.1 Cowpea

All the main cowpea components (leaves, green pods, and grains) are consumed in the region where the RESADE project is being implemented. However, it was not possible to gather information on the quantity of leaves and green pods for each experiment in the evaluated period. The RESADE team provided only information on the estimated grain yield and quantity of biomass per hectare. Based on these estimates, it was possible to estimate the quantity of harvested in land size allocated to the experiment. Please note that the estimate assumes the same yield and biomass levels for each of the experiments as it was not possible to gather precise information for each experiment. Please refer to Table 6 for detailed information on the yield and total production per each experiment.

Table 6. Yield and production estimates for cowpeas per each experiment

Cowpeas yield and production estimates.

The information on output was then used to compute the value of production, assuming a price of 35 Mt/kg for cowpea grain. While there is no local market for biomass, the monetary value was imputed based on the average value most farmers in the neighboring communities would be willing to pay for the biomass, which is estimated at 2 Mt/kg. Detailed results of the monetary values of economic benefits for cowpea per each experiment can be seen below (Table 7).

Table 7. Monetary value of economic benefits for cowpea per each experiment

Cowpeas Economic Benefit.xlsx

3.2.2 Sorghum

As mentioned at the beginning of this sub-section, it was not possible to harvest the sorghum due to bird attack. However, it was possible to gather information on the quantity of biomass per hectare, which was then used to compute the yield of sorghum and total production for each experiment. The results show the experiment on soil amendments have the highest yields whereas the experiments on irrigation systems recorded the lowest yield. Please refer to Table 8 for detailed information on the yield and total production per each experiment.

Table 8. Yield and production estimates for sorghum per experiment.

Sorghum yield and production estimates.

The information on output was then used to compute the value of production, assuming a price of 50 Mt/kg for sorghum grain. The monetary value of biomass was imputed based on the average value most farmers in the neighboring communities would be willing to pay for the biomass, which is estimated at 2 Mt/kg. Detailed results of the monetary values of economic benefits for sorghum per each experiment can be seen below (Table 9).

Table 9. Monetary value of economic benefits for sorghum per each experiment

Sorghum economic benefits.xlsx

3.2.3 Pearl millet

Like in the case of sorghum, the yield of pearl millet was computed based on the quantity of biomass per hectare, as it was not possible to harvest the crop due to bird attack. The results show the experiment on fertilization had the highest average yield whereas the experiment on new crops and varieties recorded the lowest average yield. Please refer to Table 10 for detailed information on the yield and total production per each experiment.

Table 10. Yield and production estimates for pearl millet per each experiment.

Pearl Millet yield and production estimates.

The information on output was then used to compute the value of production, assuming a price of 45 Mt/kg for pearl millet. The monetary value of biomass was imputed based on the average value most farmers in the neighboring communities would be willing to pay for the biomass, which is estimated at 2 Mt/kg. Detailed results of the monetary values of economic benefits for sorghum per experiment can be seen below (

Table 11).

Table 11. The monetary value of economic benefits for pearl millet per each experiment

Pearl millet economic benefits.xlsx

3.3.List of social benefits

Several social benefits can be attributed to the RESADE project in villages surrounding the Hub including social strengthening of social cohesion, creation of social groups (cooperatives), Ease of access to new agricultural equipment, and better perception of soil salinity and new agricultural practices. A description of each benefit is provided below.

Social Strengthening of Social Cohesion: farmers producing in marginal environments are affected by multiple and complex problems that need collective action from agriculture practitioners, development organizations, and the engagement of the beneficiaries. The RESADE project, through of creation or strengthening of existing community-based organizations contributed to knowledge exchange between farmers and the community as well as between research, extension, and farmers. The introduction of agricultural machinery contributed to timesaving and allocation in other social activities. Mechanization also has a positive impact especially on young girls as they have more time which could be used for school activities. During the implementation of the project, the farmer field schools were a great opportunity for interaction and networking among stakeholders and promoted knowledge sharing among agricultural practitioners, agriculture training colleges, and farmers strengthening the linkage between these stakeholders.

Creation of social groups (cooperatives): the RESADE project is working with two farmer cooperatives well-balanced in terms of gender. The challenges and opportunities of the function of cooperatives were identified through focus group discussion (FGD) as part of the development of Farmer Field School and from a baseline study of the RESADE project. To improve bargaining power, reduce costs, and improve access to the market the farmer cooperatives were straightened. It is believed that this intervention improved access to agriculture services, expanded market access, and hence improved income. The training also contributed to social cohesion and networking among farmers.

Ease of access to new agricultural equipment: agriculture operations, when conducted manually are labor-intensive. Much of the agriculture activities in the rural area are conducted manually by family members, especially girls and women representing substantial investment in time and effort. Some farmers hire extra labor when the demand for some agriculture operations is high. Mechanizing agriculture operations with small and easy-to-handle and maintain equipment is important for reducing labor demand and increasing productivity. The RESADE project investment in seed processing, screening, and packing and two-well tractors will greatly contribute to labor savings on seed production and land preparation. These innovative ideas ultimately enhance crop productivity.

Better perception of soil salinity and new agricultural practices: The salinity problem in the irrigation facility is a well-known problem among farmers in the irrigation facility. More and more land becomes progressively unproductive and subsequently is abandoned. However, a baseline study of the RESADE project clearly showed that strategies for mitigating the salinity problem are limited among resource-constrained farmers while understanding the extent, trend, and soil reclamation for the district of Moamba to retake the leading role in food supply for Maputo city is government's priority (RESADE Mozambique). The use of Farmer Field School (FFS) and consistent exposure to the performance of different soil, water, and crop management technologies to farmers create awareness about the impact of salinity on different crops and strategies of soil amendments for sustainable production under a marginal environment.

3.4.Cost and Benefit Analysis

This section will focus on the main parameters of the CBA, including Profitability, IRR, NPV, payback period, and Benefit-Cost ratio. In this sub-chapter, the analysis of each parameter will be made simultaneously for each crop-experiment-treatments. The results presented below are based on a few basic assumptions, including a discount rate of 6.32[3]% and that the investment could last for around 8 cycles – while this is beyond the expected duration of the RESADE.

3.4.1. Profit

Unlike the other parameters which are computed accounting for the lifecycle of the project, the profitability was computed based on the costs incurred in the specific year that the crops were produced as well as the monetary values of the recorded benefits. The value of investment is extremely high and would never be surpassed by the benefits. In fact, the results show that the costs are more than 15 times the monetary value of economic benefits (negative profit). For the experiment on crop varieties, although negative, the IP 19586 variety of pearl millet, traditional variety of cowpea, and ICSV-700 variety of sorghum showed higher or highest profitability as opposed to their respective counterparts. As for soil amendment, the biochar (3 ton ha^{-1}) for pearl millet, and green manure (3 ton ha^{-1}) for sorghum show the highest profitability as opposed to their respective controls. Please refer to Table 12 for detailed information on the profitability per crop – experiment – treatment.

Table 12. Profitability per crop – experiment - treatment

Intervention (crop)		Treatment	Level/ varieties	Profitability (Meticais)		
				Pearl Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586		-1935420		
		MC 94 C2		-2431876		
	Sorghum	ICSV-700			-2317042	
		ICSR-93034			-2431879	
	Cowpea	Traditional				-2935819

[3] This is based on interest rate on passive operations for 2023 published by Bank of Mozambique.

Intervention (crop)		Treatment	Level/ varieties	Profitability (Meticais)		
				Pearl Millet	Sorghum	Cowpea
		TVU-9443				-2967795
		IT-16				-2960944
Soil amendment		Monty	10 L/ha	-2207269	-1885566	
			20 L /ha	-2240169	-1922338	
		Lime	3.5 ton/ha	-2180711	-1927342	
			7-ton/ ha	-2231538	-1963876	
		Green manure (Leucaena)	1.5 ton/ ha	-2281760	-1933448	
			3 ton/ ha	-2144482	-1762517	
		Biochar	3 ton/ ha	-2030094	-1886909	
			6 ton/ ha	-2308430	-1911019	
		Control	Level 1	-2227751	-1866299	
			Level 2	-2169920	-1883805	
Fertilization		NPK 15-15-15		-2029951	-2209359	
		NPK 15-15-15 + foliar nutrients		-2047745	-2094521	
		Chicken manure		-2056955	-2192806	
		Control		-2046081	-2227523	
Crop management	sorghum	SP1-control			-2183930	
		SP2-mulching			-2170708	
	cowpea	SP1-control				-2903348
		SP2-mulching				-2902031
Irrigation Experiment	Cowpea	Drip	TVU-9443			-2612484
			IT-16			-2590225
	Sorghum		ICSV-700		-2445732	
			ICSR-93034		-2377670	
	Cowpea	Farrow	TVU-9443			-2608606
			IT-16			-2594747
	Sorghum		ICSV-700		-2385417	
			ICSR-93034		-2397916	

3.4.2 Net Present Value (NPV)

NPV is another key parameter in the CBA, which considers the time value of money. The purpose of the analysis is to determine whether the projected earnings generated by the BPH technologies will exceed the anticipated costs. Should the NPV be positive, then this would mean the BPH technology generates projected earnings that exceed the anticipated cost and otherwise if the NPV is negative. Only the IP 19586 variety yielded positive NPV for pearl millet – the other experiment-treatments resulted in negative NPV. As for sorghum, the results show that all soil amendment treatments yielded positive NPVs. Finally, all NPVs are negative for the cowpeas. Please refer to Table 13 for detailed information on the profitability per crop – experiment – treatment.

Table 13. Net Present Value per crop – experiment- treatment

Intervention (crop)		Treatment	Level/ varieties	Net Present Value (Meticais)		
				Pearl Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586		262274		
		MC 94 C2		-2781947		
	Sorghum	ICSV-700			-2077793	
		ICSR-93034			-2781969	
	Cowpea	Traditional				-5916438
		TVU-9443				-6068154
		IT-16				-6026143
Soil amendment		Monty	10 L/ha	-1404679	567975	
			20 L /ha	-1606421	342492	
		Lime	3.5 ton/ha	-1241826	311809	
			7-ton/ ha	-1553493	87785	
		Green manure (Leucaena)	1.5 ton/ ha	-1861449	274368	
			3 ton/ ha	-1019672	1322498	
		Biochar	3 ton/ ha	-318259	559741	
			6 ton/ ha	-2024987	411898	
		Control	Level 1	-1530274	686114	
			Level 2	-1175660	578771	
Fertilization		NPK 15-15-15		-317382	-1417492	
		NPK 15-15-15 + foliar nutrients		-426494	-713316	
		Chicken manure		-482968	-1315992	
		Control		-416291	-1528876	
Crop management	sorghum	SP1-control			-1261564	
		SP2-mulching			-1180487	
	cowpea	SP1-control				-5672970
		SP2-mulching				-5664891
Irrigation Experiment	Cowpea	Drip	TVU-9443			-3889417
			IT-16			-3752930
	Sorghum		ICSV-700		-2866913	
			ICSR-93034		-2449560	
	Cowpea	Farrow	TVU-9443			-3865637
			IT-16			-3780655
	Sorghum		ICSV-700		-2805433	
			ICSR-93034		-2882077	

3.4.3 Internal Rate of Return

The IRR is another essential parameter employed to evaluate each BPH technology. The higher the IRR on a BPH technology and the greater the amount it exceeds the cost of capital the more net cash the BPH generates. Negative IRR means that the aggregate amount of cash flows caused by an investment is less than the amount of the initial investment - in this case, there will be a negative return on investment in the BPH technology. Table 14 shows the IRR for each crop-experiment-treatment. The IP 19586 variety, Monty (10L ha^{-1}), Lime (3.5 ton ha^{-1}), green manure (3 ton ha^{-1}), biochar (3 ton ha^{-1}), and all fertilization treatments yielded positive IRR for pearl millet and for sorghum except in the control experiment of sorghum. All soil amendment and crop management treatments yielded positive IRR for sorghum. The results do not show the IRR for cowpeas because the iteration formula could not find a valid result within the given constraints, and this was kept empty as constraints could not be changed.

Table 14. Internal Rate of Return per Crop – experiment

Intervention (crop)		Treatment	Level/ varieties	IRR (%)		
				Pearl Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586		21%		
		MC 94 C2		-27%		
	Sorghum	ICSV-700			-9%	
		ICSR-93034			-27%	
	Cowpea	Traditional				-
		TVU-9443				-
		IT-16				-
Soil amendment		Monty	10 L/ha	1%	23%	
			20 L /ha	-2%	21%	
		Lime	3.5 ton/ha	4%	21%	
			7-ton/ ha	0%	19%	
		Green manure (Leucaena)	1.5 ton/ ha	-6%	20%	
			3 ton/ ha	6%	30%	
		Biochar	3 ton/ ha	14%	23%	
			6 ton/ ha	-7%	22%	
		Control	Level 1	-1%	24%	
			Level 2	4%	23%	
Fertilization		NPK 15-15-15		14%	1%	
		NPK 15-15-15 + foliar nutrients		13%	10%	
		Chicken manure		12%	2%	
		Control		13%	-1%	
Crop management	sorghum	SP1-control			3%	
		SP2-mulching			4%	
	cowpea	SP1-control				-

Intervention (crop)		Treatment	Level/ varieties	IRR (%)		
				Pearl Millet	Sorghum	Cowpea
		SP2-mulching				-
Irrigation Experiment	Cowpea	Drip	TVU-9443			-
			IT-16			-
	Sorghum		ICSV-700		-35%	
			ICSR-93034		-19%	
	Cowpea	Farrow	TVU-9443			-
			IT-16			-
	Sorghum		ICSV-700		-36%	
			ICSR-93034		-	

3.4.4 Payback

Even though the previous parameters show that most treatments would not be profitable, Table 15 shows a significant number of treatments that would return the investment within the 8 cycles considered for the study, especially for pearl millet and sorghum. An analysis comparing the treatments for each experiment tested for pearl millet and sorghum is presented below. It is worth mentioning that all treatments tested for the cowpea yielded very high payback periods, mostly because of the combination of the high cost of inputs and the relatively low value of benefits.

The pearl millet IP 19586 variety requires only 3 seasons to recover the investment made, which is shorter than one-third of the payback period observed for the MC 94 C2 variety. While the results show payback periods shorter than 8 seasons for all soil amendment and fertilization treatments, comparing the tested treatments for each of those two experiments, we find that only biochar (3 tons ha^{-1}) yielded a payback period that is shorter than that observed in the corresponding control whereas none of the fertilization treatments yielded a payback period shorter than that observed for the control.

The sorghum ICSV-700 variety requires about 7 seasons to recover the investment made, which is smaller than that observed for the ICSR-93034 variety. The results show payback periods shorter than 8 seasons for all soil amendment, fertilization, and crop management treatments. However, comparing the tested treatments for each of the three experiments, we find that only NPK 15-15-15 + foliar nutrients and mulching yielded a payback period that is shorter than that observed in the corresponding controls whereas none of the soil amendment treatments yielded a payback period shorter than that observed for the control.

Table 15. Payback period (seasons) per crop – experiment-treatment

Intervention (crop)		Treatment	Level/ varieties	Payback period (seasons)		
				Pearl Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586		3		

Intervention (crop)		Treatment	Level/ varieties	Payback period (seasons)		
				Pearl Millet	Sorghum	Cowpea
		MC 94 C2		10		
	Sorghum	ICSV-700			7	
		ICSR-93034			10	
	Cowpea	Nada				134
		TVU-9443				92
		IT-16				76
Soil amendment		Monty	10 L/ha	6	3	
			20 L /ha	6	4	
		Lime	3.5 ton/ha	5	4	
			7-ton/ ha	5	4	
		Green manure (Leucaena)	1.5 ton/ ha	7	4	
			3 ton/ ha	5	3	
		Biochar	3 ton/ ha	4	3	
			6 ton/ ha	6	3	
		Control	Level 1	6	3	
			Level 2	5	3	
Fertilization		NPK 15-15-15		4	6	
		NPK 15-15-15 + foliar nutrients		4	5	
		Chicken manure		4	6	
		Control		4	6	
Crop management	sorghum	SP1-control			6	
		SP2-mulching			5	
	cowpea	SP1-control				103
		SP2-mulching				98
Irrigation Experiment	Cowpea	Drip	TVU-9443			72
			IT-16			45
	Sorghum		ICSV-700		12	
			ICSR-93034		9	
	Cowpea	Furrow	TVU-9443			73
			IT-16			53
	Sorghum		ICSV-700		12	
			ICSR-93034		13	

3.4.5 Benefit and Cost Ratio

Table 16 confirms that none of the cowpea treatments is viable. However, the IP 19586 variety, Monty (20 L ha^{-1}), biochar (3 ton ha^{-1}), and NPK-15-15-15 for pear millet have BC ratios exceeding one and surpassing the ratios observed in the control. Green manure (3 ton ha^{-1}) yielded a higher BC ratio for sorghum as opposed to the corresponding control level. It is worth highlighting that all other soil amendment treatments for sorghum have a BC ratio above 1, but those do not surpass the BC ratio observed in control. The NPK 15-15-15 + foliar nutrients for sorghum showed a BC ratio above 1 and greater than that observed in the control.

Table 16. Benefit and Cost Ratio per Crop – experiment-treatment

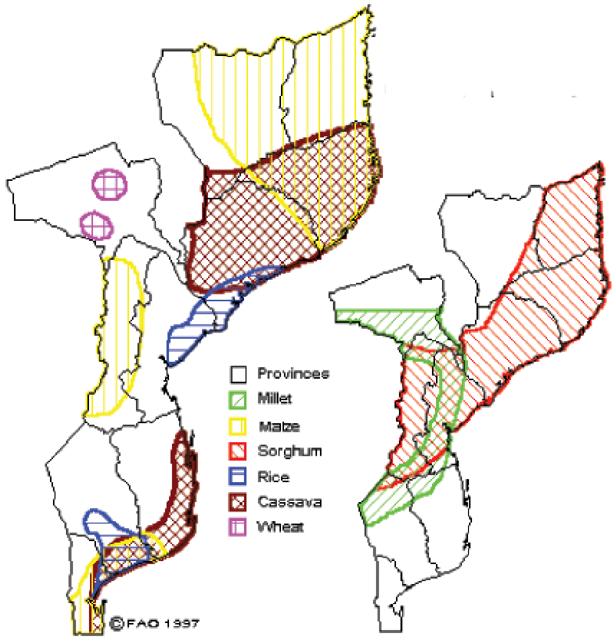
Intervention (crop)		Treatment	Level/ varieties	BCR		
				Pearl Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586		1.22		
		MC 94 C2		0.49		
	Sorghum	ICSV-700			0.69	
		ICSR-93034			0.49	
	Cowpea	Nada				0.03
		TVU-9443				0.04
		IT-16				0.05
Soil amendment		Monty	10 L/ha	0.87	1.49	
			20 L /ha	1.21	1.42	
		Lime	3.5 ton/ha	0.93	1.39	
			7-ton/ ha	0.85	1.30	
		Green manure (Leucaena)	1.5 ton/ ha	0.73	1.40	
			3 ton/ ha	0.99	1.73	
		Biochar	3 ton/ ha	1.20	1.46	
			6 ton/ ha	0.72	1.39	
		Control	Level 1	0.83	1.53	
			Level 2	0.95	1.50	
Fertilization		NPK 15-15-15		1.21	0.87	
		NPK 15-15-15 + foliar nutrients		1.18	1.09	
		Chicken manure		1.16	0.90	
		Control		1.18	0.83	
Crop management	Sorghum	SP1-control			0.92	
		SP2-mulching			0.94	
	Cowpea	SP1-control				0.04
		SP2-mulching				0.04
Irrigation Experiment	Cowpea	Drip	TVU-9443			0.07
			IT-16			0.12

Intervention (crop)		Treatment	Level/ varieties	BCR		
				Pearl Millet	Sorghum	Cowpea
	Sorghum		ICSV-700		0.42	
			ICSR-93034		0.55	
	Cowpea	Furrow	TVU-9443			0.07
			IT-16			0.10
	Sorghum		ICSV-700		0.42	
			ICSR-93034		0.40	

3.5.Take-up level of the BPH technologies by local smallholder farmers

This sub-chapter is based on the information gathered during the 4 focus group discussions held separately with a total of 23 female and male smallholder farmers: 2 focus group discussions held with 12 farmers (6 female and 6 male) who participated in the FFSoE and other 2 focus group discussions held with 11 farmers (5 female and 6 male) who did not participate in the FFSoE. On average, the farmers participating in the Hub were 44.8 years old and 25% of them could not read or write whereas those not participating in the Hub were, on average, 51.4 years old and mostly able to read and write (64%). The farmers had an average of two plots with a total size of 1.5 hectares. The group of farmers participating in the Hub reported to have participated about 5 times in the Hub demonstrations.

The most common crops reported by the respondents are maize, cucumbers, beans (green and butter), tomatoes, cabbage, peppers, cassava, and onions. Maize and beans are the most grown crops in both groups (participants of the hub and non-participants). Cabbage was the third most-produced crop for the group that participated in the Hub demonstration, and, on the other hand, okra was the third for the non-participants. The other crops reported to be grown in the villages surrounding the Hub include okra, potatoes, chili, cabbage, and lettuce.



In fact, these findings are overall consistent with those observed in the baseline study of the RESADE project which indicated Irish potatoes, cabbage, maize, bean, green pepper, tomato, and cucumber. Green bean, lettuce, cabbage, cassava, sweet potato, cowpea, okra, and pumpkin as dominant crops for both domestic consumption and sale. Sorghum and millet crops are cultivated in arid regions while other cereals such as maize, and rice are cultivated in central and northern Mozambique where rainfall pattern in normal years meets crop water demand. The figures above illustrate the general crop distribution in Mozambique.

With regards to the take-up of the BPH technologies, the results indicate that farmers are adopting fertilization, new varieties of cowpeas, drip irrigation, biochar, and late and timely sowing. The main reasons for adopting those technologies include early maturing, improved soil health, diminished salinity, and high yield (Table 17). Note that because of recognition of the scarcity of water in this region, the promotion of drip irrigation systems among small-holder rural farmers is a government strategy. A number of small drip irrigation kits with approximately 1 ha irrigation capacity were distributed to farmers. Some resources endowed farmers in Moamba invested in their own irrigation facility which improved water use efficiency, labour saving, and crop productivity.

Table 17. Reasons for adopting some of the BPH technologies.

Technologies	Reasons for adopting
Fertilization	High yield
Drip irrigation	Efficient use of water and reduced labour need with reduced irrigation time
Cowpea new varieties	Early maturing (constrained by the availability of seeds locally)
Late sowing	Improved soil health
Early sowing	Efficiency in the use of rainfall

The other technologies that are being promoted in the BPH are not being adopted for various reasons including high cost, lack of local service providers, labor shortage, lack of local market, and bird attacks (Table 18).

Table 18. Reasons for not adopting some of the BPH technologies.

Technologies	**Reasons for adopting**
Gravity irrigation	High cost
Mulching	Inappropriate size of farmers' plots – labour shortage
Limestone	Lack of local service providers
Biochar	Inappropriate for large plots
Pearl millet	Lack of local market
Sorghum	Lack of local market and bird attack
Quinoa	Lack of local market

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

The RESADE project has been introducing salt-tolerant crops and best agronomic management practices in the areas where it is being implemented. In Mozambique, the project is being implemented in Moamba district, southern Mozambique, which is heavily affected by salinity problems. The project has been implemented since 2021 and agronomic data on multiple production cycles have been gathered by the project team. However, no effort had been made to assess the viability of the crops and best agronomic practices being introduced through the project. Therefore, this study aims to explore each promoted technology's economic and social benefits against the incurred costs. The study methodology consisted of a desk review and a combination of qualitative and quantitative methods. IRR, NPV, Payback Period, and Benefit-to-cost ratios are the parameters employed to assess the viability of the BPH.

The results show that different experiments are being implemented for each crop as follows:

- ✓ Pear millet: soil amendments; new crops and varieties, and fertilization.
- ✓ Sorghum: soil amendments, new crops, and varieties, fertilization; crop management, and irrigation systems.
- ✓ Cowpea: new crop and varieties, crop management, and irrigation systems.

We find that the IP 19586, Monty (20 L ha^{-1}), biochar (3 ton ha^{-1}), and NPK-15-15-15 for pearl millet as well as green manure (3 ton ha^{-1}) and NPK 15-15-15 + foliar nutrients for sorghum are most viable technologies mainly considering their Benefit and Cost ratio, payback period and Internal Rate of Return. While those treatments appear to be viable considering the main CBA parameters, the results have shown that those crops do not have local market emerging. Other crops are mostly common in the district such as vegetables, maize, cassava, and sweet potato.

We also find that most treatments are not viable, especially cowpea treatments which did not yield any viable treatment – investment cannot be recovered even within 8 production cycles of continuous implementation of the activities. This is explained by both the input and output sides. On the input side, this is justified by the high value of investment in irrigation systems and equipment as well as the high costs of inputs and labor for operational activities such as sowing, fertilization, weed control, and harvesting. As for the output side, a low yield level was reported for cowpeas. Additionally, bird control was reported to have constrained the implementation of the experiment during the evaluated period, which prevented the RESADE team from harvesting two of the evaluated crops, mainly sorghum and pearl millet.

4.2. Recommendations

- ✓ The RESADE local team has had a hard time providing us with the required meaningful cost and production information. This is mostly due to the fact that there is no system that they can use to record all inputs and outputs for each experiment. As such, we recommend that ICBA develops a monitoring system that would require the staff involved in the implementation of the project in each country to fill in data on a regular basis (e.g. weekly basis).

- ✓ Crop profitability is affected by several factors that include financial, technical, socio-economic, and cultural. Market availability has been indicated as a driving factor for decision-making on crop selection for the allocation of limited farmer's resources (labour, capital, and time). While the IP 19586 variety, Monty (20 L ha-1), biochar (3 ton ha-1), and NPK-15-15-15 for pearl millet as well as green manure and NPK 15-15-15 + foliar nutrients for sorghum are viable, the unavailability of an emerging local market jeopardize its take-up rates. As such, we recommend the organization of sessions with those farmers participating in the hub to cover discussion on the benefits of those crops so that they can gradually be introduced into their diet.
- ✓ RESADE baseline study indicated maize, common bean, cabbage onion, tomatoes, green bean, groundnut, Irish potatoes, garlic, okra, pepper, and chili as major crops cultivated by farmers in the project intervention area. On the other hand, crop spectrum analyses in the project site and in the rainfed production system of the district show green bean, lettuce, cabbage, cassava, sweet potato, cowpea, okra, and pumpkin leaves as major crops cultivated by many farmers in a small area, while sorghum and Millete were considered lost crops. Quinoa, barley, and buffer grass are assumed as new crops, not cultivated in the region.
- ✓ Based on the above observations, the study recommends that future intervention should be context-specific, that is, should target high-value crops and address the most pressing issue of the agriculture value chain for the target location.
- ✓ Building a value chain for introduced crops is knowledge-intensive because new information needs to be generated or the transferability of proven technologies for those crops needs to be assessed in the local conditions.

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Annex 1. Guide for the Focus Group Discussion

Name and signature of the interviewer:____________________ Date:________________

I. Information on the participants

Name of the respondent	Gender 01=Male, 02=Female	Age	Literacy 01=literate (can read & write), 02=illiterate (cannot read & write)	When the participant started participating the BPH FFS	How many times the respondent participated	Land size outside the BPH	Which crops each participants grow?

II. Information on crops and technologies

1. What are most common crops in the surrounding villages?

2. What did the participants learn from the RESADE project?

Instruction: ask how many farmers in the group discussion participated in each of the trainings below and insert the number.

Training	**Number of people who participated**
1. Biochar	
2. Seed production	
3. Irrigation technologies	
4. Soil management	
5. Post harvest techniques	
6. Other (Specify)	

3. Are there any participants who learned the technologies from other farmers who participated in the trainings?

Instruction: ask how many farmers in the group discussion learned the technologies from others who participated in each of the trainings below and insert the number.

Training	**Number of people who learned from others**
1. Biochar	
2. Seed production	
3. Irrigation technologies	
4. Other (Specify)	

4. What did farmers try to implement in their own farms? (list of technologies)

Instruction: ask how many farmers in the group discussion tried to implement the technologies and insert the number.

Training	**Number of people who tried to implement technologies**
1. Biochar	
2. Seed production	
3. Irrigation technologies	
4. Other (Specify)	

5. If someone did not try to implement, ask the reasons for not trying to implement?

6. What did farmers adopt in their own farms?

Instruction: ask how many farmers in the group discussion adopted the technologies and insert the number.

Training	**Number of people who adopted the technologies**	**Number of farmers they taught the tecnology**
1. Biochar		
2. Seed production		
3. Irrigation technologies		
4. Other (Specify)		

7. If someone did not adopt, ask the reasons for not adopting?

8. Did you receive any materials (seeds or tools) from the project?

Materials	**Number of people who received the materials**
1. Seed (specify the varieties)	
2. Farming tools	
3. Biochar	
4. Other(specify)	

9. If someone implementing the technologies did not receive the materials, ask where do they acquire necessary inputs to implement the technologies they learned in the hub?

III. Livelihoods and sustainability

10. How did the new technologies change the livelihoods of the farmers?

11. From the technologies they learned, what are those that farmers think have potential to positively impact their lives?

12. Do farmers think there is a local demand for the technologies/materials they have learned?

13. **If there is demand for technologies, what is the willingness from the farmers to fulfil the demand?**

14. **If there is demand for the technologies, what have the been the main challenges to take advantage of the increased demand?**

15. **How to link these with real market**
16. **How to transform some products in local food?**
17. **What are the market possibilities of the new crops?**
18. **Which crops they think the demand may increase and reasons behind?**

19. **Which new varieties will be profitable for them?**

20. **What are their opinion on the benefit of the technologies?**

21. **What are their opinion on the cost of applying new technologies?**

What is farmer's opinion about the market for each of the introduced crops?

22. **Are they willing to continue applying those technologies?**