COST-BENEFIT ANALYSIS (CBA) OF TESTED SMALL-SCALE TECHNOLOGIES AND OTHER CROP INTENSIFICATION OPTIONS IN THE GAMBIA

For a project:

Improving Agricultural Resilience to Salinity through Development and promotion of Pro-poor Technologies and Management Strategies in Selected Countries of Sub-Saharan Africa (RESADE)

CLIENT: INTERNATIONAL CENTER FOR BIOSALINE AGRICULTURE (ICBA)

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Acronyms

BPH	Best Practice Hub
BCR	Benefit Cost Ratio
CFSVA	Comprehensive Food Security and Vulnerability Analysis
CIMA	International Centre for Environmental Monitoring
GBoS	Gambia Bureau of Statistics
GDP	Gross Domestic Product
GMD	Gambian Dalasi
GNI	Gross National Income
ICBA	International Center for Biosaline Agriculture
IRR	Internal Rate of Return
MECCNAR	Ministry of Environment, Climate Change and Natural Resources
NARI	National Agricultural Research Institute
NDMA	National Disaster Management Agency
NPK	Nitrogen Phosphorus and Potassium
NPV	Net Present Value
PP	Payback Period
RESADE	Resilience to Salinity through Development and promotion of Pro-poor Technologies and Management Strategies in Selected Countries of Sub-Saharan Africa
SSA	Sub-Saharan Africa
UNDP	United Nations Development Programme

Executive Summary

The Gambia has been one of the implementing countries of the RESADE project. The project activities in The Gambia were implemented as a Best Practice Hub (BPH) at Jahaur community. The project used a farmer-field school approach to disseminate technologies, increase awareness, and empower smallholder farmers at Jahaur and nearby communities. The technologies experimented were:

- Variety testing involving two varieties each of pearl millet (IP 19586 and MC 94 C2), sorghum (ICSV-700 and ICSR-93034) and millet (ILRI 9334 and ILRI 9643)
- Soil amendment strategies involving cattle dung, lime, green manure (Leucaena), biochar, and control. These were successfully conducted on sorghum and millet.
- Fertilization technologies involving NPK 15-15-15, NPK 15-15-15 + foliar nutrients, chicken manure and a control each for sorghum and pearl millet.
- Crop management involves two experiments. Experiment 1 one sowing dates and experiment 2 is on practices to manage water on the plot. Experiment 2 was not implemented. For experiment 1, two factors were considered; sowing date (sowing date 1 and sowing date 2) and crop (sorghum and quinoa). The introduced quinoa failed for both sowing date trials. For sorghum, it was successful for the sowing date experiment..
- Irrigation technology involves drip irrigation and farmers' irrigation practices such as bucket and surface irrigation. However, this trial was not successful.

Quantitative data were collected on the various costs and benefits of each intervention. The profitability of the various technologies was analysed using NPV, BCR, IRR and PP. There were no control experiments for crop variety and crop management experiments, therefore, the control costs and benefits for these technologies are zero. The major findings include:

- The fixed cost of production was GMD 24,599.54 and the variable cost of production varied from GMD 34,444.00 for millet MC 94 C2 variety to GMD 50,614.24 for crop management technologies. The benefit (revenue) for the technologies varied from as low as GMD 50,071.39 for millet MC 94 C2 variety to GMD 354,004.20 for sowing date 1. Across technologies, the highest sorghum yield was obtained under sowing date 1 and the lowest for green manure under crop fertilization trial. For millet, the highest yield was obtained under green manure and the lowest was under NPK 15-15-15 plus foliar nutrients.
- For technologies with control (soil amendment and fertilization), the incremental costs of the treatments varied but were highest under biochar and lowest with the use of chicken manure. While incremental benefit was highest under green manure treatment for millet, biochar, NPK 15-15-15 plus foliar nutrients, and chicken manure had negative incremental benefits under millet. Under sorghum trials, the highest incremental benefit was obtained for chicken manure while lime and green manure had negative incremental benefits.

- For technologies without control (crop varieties and crop management), the incremental costs and benefits are equivalent to the total costs and revenues, respectively.
- The profitability results (NPV, BCR, IRR, and PP) varied by technology and crop. Millet IP 19586 had higher profitability indices than the millet MC 94 C2 variety, although they were both profitable. Sorghum ICSV-700 had higher profitability indices than sorghum ICSR-93034. The NPV and BCR were highesr for the cowpea ILRI 9334 variety than for the cowpea ILRI 9643 variety. Across crops, the profitability of the varietal treatments was higher for cowpeas.
- On soil amendment technologies, the NPV was highest for green manure and the BCR washighest under lime in millet production. Using biochar for millet production will lead to economic losses. For sorghum, NPV and BCR were highest for the cattle dung treatment. Using lime and green manure for sorghum production will lead to economic losses.
- On crop fertilization trials, the use of NPK 15-15-15 for millet production led to the highest NPV and BCR while the use of NPK 15-15-15 + foliar nutrients and chicken manure led to negative NPV and BCR, thus, unprofitable. For sorghum, the NPV and BCR were highest for the use of chicken manure and lowest for the use of NPK 15-15-15 but positive for the three fertilizers.
- From the sorghum analysis, both sowing date are profitable, but it was more profitable under sowing date 1 than sowing date 2.
- The analysis of the project beneficiaries revealed that most of the farmers participated in the BPH activities 3 or 4 times. The major lessons learnt by many farmers were biochar preparation and its use, irrigation technologies, seed production and its usage, and other good agronomic practices such as fertilizer application and harvesting techniques. About 7 in every 10 farmers received input assistance, especially seed from the project. The major needs of the farmers include farm tools, seeds, training and information, fertilizers, and improved infrastructure. The major challenges to crop production by the farmers include lack of input, lack of carting equipment, pests and disease, low income and lack of credits, and poor markets.
- The project implementation was successful due to among others the efficiency of the BPH staff, community (farmers) commitment and participation, and timely input and material supply to the hub. The various treatments of technologies, except for a few, demonstrated high profitability. This provided evidence of the ability of farmers to produce various crops on salty soils by using specific technologies including varietal selection, fertilization, and crop and soil management. It does support national interest by increasing the utilization of margin lands destroyed by salt. Through sensitization/education, the National Agricultural Research Institute (NARI) should encourage farmers to practice these technologies in relation to specific crops while a one-size-fit technology promotion among farmers should be discouraged.

According to the results, more specific recommendations have been provided in the conclusion. Notably, all three crops' promotion will be profitable: For millet production, the IP 19586 should be promoted. Green manure or lime should be used for soil amendment and NPK 15-15-15 for fertilization. For higher profitability of sorghum production, ICSV-700 should be used, and under soils treated with cattle dung and chicken manure, and planting done using sowing date one as experimented in this project. Cowpea production profitability under those conditions should be completed soon. However, according to the NPV, both cowpea varieties' production is profitable.

1 Introduction

1.1 Project Background

A project titled "Improving Agricultural Resilience to Salinity through Development and promotion of Pro-poor Technologies and Management Strategies in Selected Countries of Sub-Saharan Africa" (RESADE), is funded by the International Fund for Agricultural Development (IFAD) and the Arab Bank for Economic Development in Africa (BADEA). The project is implemented in seven sub-Saharan Africa (SSA) countries where salinization of agricultural lands is a growing problem – namely The Gambia, Liberia, Sierra Leone and Togo in Western Africa, and Botswana, Mozambique and Namibia in Southern Africa. In the Gambia, the project was implemented by the International Center for Biosaline Agriculture (ICBA) in partnership with National Agricultural Research Institute (NARI). The project was designed to support national agricultural development policies and strategies of the country by rehabilitating and increasing the productivity of salinity-affected lands, and providing technical assistance in salinity management to other IFAD- and BADEA-funded projects being implemented in the Gambia.

The project activities in The Gambia have been implemented at a Best Practices Hub (BPH) established at Jahaur. The project has used the farmer-field school approach to disseminate technologies, increase awareness, and empower smallholder farmers in Jahaur and its surrounding villages with requisite knowledge on technologies to overcome salinity challenges and increase crop yields. The technologies explored on this project include use of salt-tolerant crop varieties of cowpea, sorghum and pearl millet, use of soil amendments, irrigation methods to reduce salinity through leaching, and soil and moisture conservation and management practices. The project has been running for the past three cropping seasons (from 2021 to date) . The trials were conducted once during the rainy season in each year. Farmers were engaged in project activities at the BPH from the onset. It is therefore necessary to understand the benefit-cost implications of the various interventions under the project to inform further decision-making.

1.2 Project Objectives

The goal of the project is to improve food security and reduce the poverty of poor smallholder farmers, particularly women, in salinity-affected areas in The Gambia and other targeted countries. The development objective of the project is to increase agricultural productivity and incomes in salinity-affected agricultural areas by:

i. Introducing salt-tolerant crops and best agronomic management practices
ii. Developing value chains for introduced cropping systems
iii. Building the capacity of farmers and extension workers in salinity-resilient and climate-smart agriculture in collaboration with the National Agricultural Research Institute (NARI).
iv. Incorporating climate-smart and salinity-resilient agricultural models and approaches into national agricultural development policies and strategies in the seven target countries

1.3 Country Context

The Gambia is a small country on the West Coast of Africa within latitude 13 to 14 degrees north of the equator. It is a narrow strip of land divided into North and South Banks by The River Gambia, which extends inland for more than 400 kilometers on both banks of the river. With a Coastline of about 80 km long, the width varies from 24 to 28 kilometers from its Northern and Southern borders with Senegal, covering an approximate land area of about 11,000 square kilometers.

The country is divided into seven administrative regions: Central River, Lower River, North Bank, Upper River, and West Coast Regions; one Municipality and a City Council. It is one of the most densely populated countries in SSA with a density of 214 persons per square kilometer[1]. In addition, the country has one of the fastest population growth rates of 3.1 percent per annum; with an estimated population of 2.3 million in 2019 and a projected population of 3.5 and 4.5 million by 2035 and 2050 respectively.[2]

1.3.1 Socioeconomic Conditions

The Gambia is faced with a limited economy arising from the poor performance of agriculture and relatively very small industrial activities. Its struggling productive sectors, limited industrial potential, and service provision, and increasing cost of living make it one of the poorest countries in the world. Thus, The Gambia is classified as a low-income country, with a Gross National Income (GNI) per capita of USD 772.2 in 2021; and is ranked 174 out of 191 countries and territories[3].

The country has a youthful population with over 60 percent of its population under the age of 30. These young people face many challenges including limited access to quality and market-relevant education to be productive in today's competitive and dynamic labor market. With only 0.4 percent and 2.6 percent of youths respectively completing university and post-secondary education (Certificate/Diploma), young people in the country are less competitive in international and local job markets. As a result, many young people are deprived of economic opportunities, making them vulnerable to poverty, crime, and irregular migration.

1.3.2 Education and Gender

Generally, education levels in the Gambia are low with only 42 percent of adult men and women being literate.[4] However, there has been a recent significant development in Primary and secondary

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[1] GBoS 2013 Population and Housing Census

[2] Population Reference Bureau, "International data: Gambia", PRB database. Available at www.prb.org/international/geography/gambia.

[3] Human Development Index, 2021

[4] UNDP, 2018.

education. Government policies provide for universal access to basic education, but the quality of education remains of concern.[5]

The patriarchal society of The Gambia, male hegemony, and other sociocultural factors interplay to influence gender relationships, resulting in a Gender Inequality Index value of 0.620, ranking it 150 of 162 countries in the 2018 index[6]. These inequalities do cause social exclusion involving women and girls from actively participating in decision-making in society. Women's lack of access to land and productive capital reduces their ability to secure financial services. Women and girls are disadvantaged due to socio-cultural norms and practices, as well as by discriminatory provisions in customary law. Compared to men, rural women are mainly employed in agriculture and food production, but they have limited or no access to productive resources such as land, credit, technology, and information, and have lower literacy levels. Female participation in the labour market is 72 percent compared to 82 for males[7].

1.3.3 Poverty and Food Insecurity

Poverty levels remain quite high in The Gambia. Over half (53.4 percent) of the estimated population is living on less than USD 1.25 per day, making the country one of the poorest in the world. Poverty rates are higher in rural areas, where the households typically work in the agricultural sector, while in urban areas the largest share of the poor participate in the informal service sector. The poverty rate (based on the national poverty line) in rural areas was estimated at 76 percent in 2020 compared to 34 percent in urban areas. Low productivity, particularly in a rain-fed agricultural economy, is a major cause of rural poverty and food insecurity. Food insecurity disproportionately distresses households, affecting mainly those residing in rural areas. The last Comprehensive Food Security and Vulnerability Analysis (CFSVA)[8] revealed that food insecurity has increased by about 5.6% since 2011. Smallholders in rural regions remain particularly vulnerable to recurring shocks and the lean season, and they lack suitable access and integration to (local) markets. With declining productivity over the years[9], the country's rural population faces a higher threat of food poverty. To overcome these threats, the huge potential of the agricultural sector has to be tapped.

1.3.4 Climate Change and Vulnerability

The Gambia's environmental opportunities are key drivers of its food systems. Four diverse agro-ecological zones are suitable for a wide range of agricultural products, and abundant water

[5] "The Gambia Annual Education Yearbook".

[6] UNDP, "Human Development Report 2018", available at http://hdr.undp.org/en/data. Last accessed 17.02.2020.

[7] The Gambia national gender policy 2010- 2020

[8] Comprehensive Food Security and Vulnerability Analysis (CFSVA), 2016

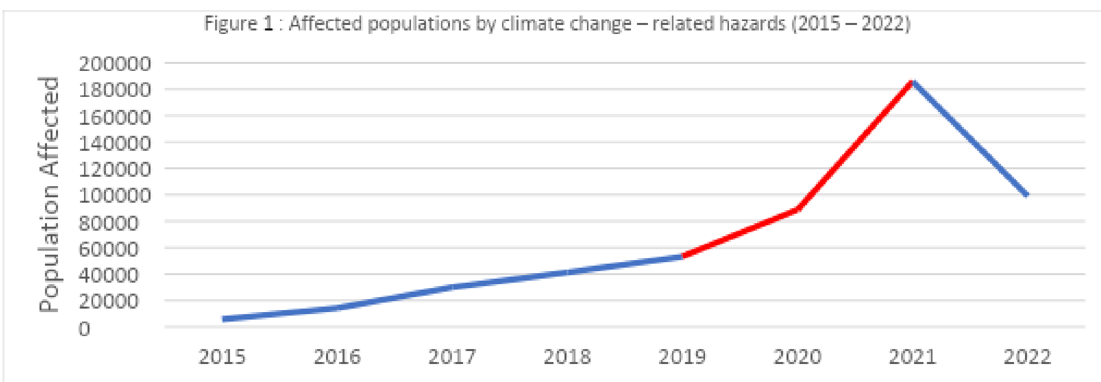
[9] GNAIP, 2010-2015 (pp 21)

resources (118 thousand ha of surface water regimes and two major aquifers with good recharging capacities) with the potential to irrigate over 80 thousand ha of lowland ecologies[10].

However, the country is highly vulnerable to natural disasters and impacts of climate changes, such as windstorms, flash floods, wildfires, and soil salinisation due to the rising sea level (Figure 1). It's Sudano-Sahelian weather is characterized by long dry season of seven months (November to May) with the changing agricultural climate resources unleashing rising temperatures, declining trend in annual rainfall (of 30 percent since 1970s) to an average rainfall of 800 mm in 2020; and sea level rise with frequent occurrence of extreme weather events. It has been projected that annual temperatures will progressively change by +3.1°C by 2100, and annual rainfalls will decline to less than 500 mm per year by the same year[11].

Food systems in The Gambia are being affected by extreme weather events. CIMA (2018), reported that the current climate conditions in The Gambia (including annual droughts) are potentially affecting 216,000 people (14 percent of total population), and on average 15 percent of annual GDP (US$108 million).

The Gambia is also vulnerable to seasonal shocks caused by variability of weather, especially during the rainy season. An instance was on July 30th and 31st, 2022, when the country experienced the highest rainfall in the last few decades, recording 276mm. Over 4,000 households (approximately 42,000 people) were severely affected across the country, with 11 deaths recorded, while many households were internally displaced as their houses were inundated[12].



Source: NDMA 2023

[10] MECCNAR (2018): Baseline Survey Report: Project: Large-scale Ecosystem-based Adaptation in the Gambia River Basin: Developing a climate resilient, natural resource-based economy.
[11] Third National Communication of the Gambia under the UNFCCC, 2020
[12] NDMA, 2022

Figure 1. Affected population by climate change-related hazards (2015-2022)

1.3.5 Agriculture Sector Overview

Agriculture is the principal source of livelihood for the rural population. It employs approximately 70 percent of the population and contributes only 24 percent of the GDP. Farming is mainly rain-fed, with three percent of arable land under irrigation, although irrigation is expanding in the floodplains along The Gambia River, mainly for the cultivation of rice and vegetables. Small-scale and mixed cropping systems (rice, millet, maize, sorghum, and cassava), traditional livestock rearing, semi-commercial production (groundnut, cotton, and sesame), horticulture, and a vibrant fisheries sub-sector characterize the sector.

The agriculture sector is dominated by crop farmers (71.9 percent[13]) cultivating field crops (mainly cereals), while producing vegetables (mostly by women) and livestock. The sector is, however, constrained by several factors such as adverse climatic conditions, degrading environment, and overdependence on foreign aid. It suffered a dramatic decline in productivity due to the changing agricultural climate resources, driven by a huge decline in the value of crops that was not fully offset by an increase in fishing and aquaculture. The country produces less than 50 percent of its domestic food requirements[14], making it dependent on imports and exposing its vulnerability to international market price fluctuations. Due to low agricultural production, the cost of food increased by 22 percent in June 2023 compared to price levels in the same month of the previous year[15], triggering an Alert for Price Spike[16].

Looking forward, the development of the agriculture value chain in The Gambia is a national priority that underscores promotion of salt tolerant varieties, agri-business and agro-processing; rebuilding and revitalizing the agricultural market infrastructure through cooperatives and commodity exchanges. This is attainable through quality assurance mechanism to strengthen access to export markets; increased production and productivity using sustainable land and water management practices to address hunger and food security needs; and promotion of climate smart agriculture to build rural resilience[17].

[13] FAO, European Union and CIRAD. 2022. Food Systems Profile - The Gambia. Catalysing the sustainable and inclusive transformation of food systems.

[14] FAO, "Gambia at a glance", available at http://www.fao.org/gambia/gambia-at-a-glance/en/

[15] Trading Economics, Gambia Food Inflation, available at https://tradingeconomics.com/gambia/food-inflation last accessed 28 January 2020

[16] The Alert for Price Spikes is an indicator that monitors the extent to which a local food commodity market experiences unusually high food price lev.

[17] National Development Plan: 2018 - 2021

2 Methodology Framework

2.1 Study Site Characteristics

This study is carried out in the Central River Region North of The Gambia. It is mainly an agrarian climatic region with an annual rainfall amount of less than 600mm. The ecology is a Sahelian agroecological zone with a saline ecosystem at the lowland. The economic activity of the people in the community is mainly farming, vegetable gardening, and livestock rearing. Most of the farm produce is taken to the weekly market called "loumo" at the regional urban center in Farafenni. The assessment is conducted in Jahaur where the Farmer Best Practice Hub (BPH) is established and in Genji Wolof, one of the beneficiary communities (Figure 2).

Figure 2. Land productivity of soil amendment and crop fertilization experiments

BPH and farmer field school characteristics

The Best Practice Hub (BPH) was established in Jahaur, at Central River Region North of The Gambia. The total land size of the hub is one hectare with perimeter fence. It is located about 400m from the community. A farmer field school approach is used in the hub where the farmers themselves carry out all the activities. Farmers also undergo different training programs on the various technologies to enable them to adopt and practice it at their farm plots within the hub or their field (Figure 3).

Figure 3. Best Practice Hub at Jahaur

2.2 Identification of practices, and the crops produced.

An experimental data mainly on the yield and yield components was obtained from the Hub. About six trials were put into practice in the first year and second years and these include: 1) Soil amendments, 2) crop management, 3) Crop variety assessment 4) Fertilization 5) irrigation, and 6) leaching fraction trials. However, irrigation and leaching fraction trials were not successful in both seasons. Three crops were successfully studied: (1) pearl millet, (2) sorghum, and (3) cowpea. Two improved varieties for each crop were successfully tested in crop varietal assessment.

Detailed information on each intervention is given as follows:

(1) Soil amendments

This experiment aims to evaluate the impact of several soil amendments 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 are tested with low and high doses including manure (cow dung), Green manure (Leucaena), biochar and Limestone. These amendments were widely reported to have a positive effect on soil properties, plant growth and crop productivity. In this trial, the following treatments were studied for sorghum and pearl millet: Cattle dung, Limestone, Green manure (Leucaena), Biochar, and Control. The control treatment under this experiment involves the production of millet and sorghum without using any of manure (cow dung), green manure (Leucaena), biochar and limestone. The seed varieties used under the soil amendment trials were ICSV-700 for sorghum and IP 19586 for millet.

(2) Fertilization

Fertilization is one of the solutions to increase crop salinity tolerance as it helps plants to avoid the negative effects of sodium and chloride. This trial aims to evaluate the effect of different fertilizers applied in soil or via foliar spray on crop productivity in order to determine the best combination with satisfactory yield outcomes. In this trial, the following treatments were studied for both sorghum and pearl millet: NPK 15-15-15, NPK 15-15-15 + foliar nutrients, Chicken manure and Control. A control treatment under this experiment involves producing sorghum and millet without any of the fertilization, thus, no use of NPK 15-15-15, NPK 15-15-15 + foliar nutrients and chicken manure on the control plots. The seed varieties used under the fertilization trials were ICSV-700 for sorghum and IP 19586 for millet.

(3) Crop management

Crop management is a factor that could improve plant performance, seed and biomass yield. This trial was purposely related to the types of crop management such as sowing dates and weed management and practices to conserve water in small-scale farmers' fields. However, only sowing dates were successfully implemented. In this trial, the following treatments were studied: sowing date 1 and sowing date 2 for ICSV-700 sorghum and Quinoe Q3. However, Quino was not successful in this trial.

(4) Introduction of New Crops and Varieties

Seed diversity has always been an important part of farmers' sustenance in Africa. There is an indication that crop diversity has altered over a period of time mostly because of official initiations and the introduction of high-yielding varieties of various crops. The launch of new cultivated species and improved varieties of crops is for enhancement of plant production, quality, and nutritious value and improving crop tolerance against biotic and abiotic stresses including disease, salinity, drought, and heat. The introduction of new crops and varieties will expand crop diversification in the salinity-affected areas of targeted countries of West and Southern Africa considering the high returns from value-added crops with equal marketing opportunities. For the improvement of the livelihood of salt-affected areas, 12 improved varieties of 6 salt-tolerant crops have been selected. However, only six varieties of 3 crops were successfully implemented in the BPH. In this trial, the following treatments were studied: Two Varieties of Pearl millet (that is IP-19586 and MC 94 C2), two varieties of Sorghum (i.e ICSV-700 and ICSR - 93034) and two varieties of Cowpea (i.e ILRI 9334 and ILRI 9643).

(5) Irrigation system

Small-scale irrigation systems can help farmers to have year-round production rather than relying on rain. Irrigation systems such as Californian or drip irrigation can alleviate the negative impact of salinity on soil and crops. The objective of this trial is to evaluate the performance of Californian and drip irrigation systems as compared to farmers practices (bucket system, surface irrigation…etc) and assess crop productivity under the tested system. However, this trial has not been successful in the hub.

(6) Leaching fraction

The leaching fraction is the amount of extra irrigation water that must be applied above the amount required by the crop in order to maintain an acceptable root zone salinity depending on the salinity of the water it is being irrigated with. This trial aims to evaluate the effect of several leaching fractions on crop productivity in order to determine the optimal one. However, this trial has not been successful in the hub.

2.3 Data collection and description

Data collection and description of the BPH

Both quantitative and qualitative data were collected on the various costs and benefits of each intervention. Fixed costs of machines and equipment were obtained directly from the project. Some of the items were bought in US Dollars and United Arab Dirham. However, all costs were converted to Gambian currency (GMD) using the forex exchange rate[18] . Where the cost and price of items are unavailable, a prevailing market price is used to determine the cost and price.

The conventional market prices approach was used for the valuation of costs and benefits. Differences in the value of output were assumed to reflect differences in crop yield for each intervention. Here the changes in productivity and the changes in input levels either indicated losses or gains. All costs were converted into monetary values using their respective quantities and market prices. Labour costs were considered to be the product of the number of man-days required for a particular task and the market price of labor per day within the community. Quantities and market prices were obtained during interviews and were crosschecked by the coordinator of BPH. The average wage for a man-day was equivalent to 200GMD in the region. The benefits were also converted into monetary values by multiplying respective quantities of yield for each crop by their market value.

Data collection and description of farmers (beneficiaries)

A total of 30 beneficiary farmers were selected from two communities, Jahaur and Genji Wolof. The beneficiaries are farmers who have worked at the BPH or have received training through a farmer school day. The farmers were selected from a beneficiary list from the project. At the community level, beneficiary farmers who were readily available and willing to participate in the data collection were interviewed. The data was collected using computerized mobile data collection by the researcher, assisted by trained research assistants. The beneficiary data was analyzed, generally using a percentage distribution of the responses.

[18] 1AED = 17.95 GMD and 1USD = 60GMD

2.4 Analysis method (Cost-Benefit Analysis model)

The data is analyzed using the CBA approach. The CBA is estimated for each treatment under each intervention. There are various indicators for CBA. These include the net present value (NPV), benefit-cost ratio (BCR), internal rates of return (IRR) and payback time. These are given as follows.

The NPV is estimated as[19]:

$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \qquad (1)$$

Where T represents the duration at which the intervention is practiced, B represents the benefits, C represents the costs, and r is the relevant discount rate. The prevailing lending rate (Interest rates on bank credit to the private sector) of The Gambia which is 19.5 percent[20] is used as the discount rate. Given equation 1, the NPV for each treatment (w) under each intervention is estimated against a chosen control group (m) as:

$$NPV_i^{w-m} = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[\sum_{i}^{i} P_{bit} * \Delta Y^{w-m} - \sum_{i}^{i} P_{cit} * \Delta Q_{it}{}^{w-m} \right] \qquad (2)$$

where P_{bit} is the unit price of the commodity, P_{cit} is the unit cost of the cost item, ΔY^{w-m} and $\Delta Q_{it}{}^{w-m}$ are respectively the incremental yield and incremental cost due to the treatment.

The BCR is estimated as:

$$BCR = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} / \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{T} \frac{P_{bit} * \Delta Y^{w-m}}{(1+r)^t} / \sum_{t=0}^{T} \frac{P_{cit} * \Delta Q_{it}{}^{w-m}}{(1+r)^t} \qquad (3)$$

Decision rule: Generally, an NPV>0 or BCR>0 indicates a profitable intervention/treatment. Therefore, the higher the NPV/BCR value, the higher the profitability, hence the preferred treatment.

[19] Akinyi et al. (2022). Cost-benefit analysis of prioritized climate-smart agricultural practices among smallholder farmers: evidence from selected value chains across sub-Saharan Africa. Heliyon, 8, e09228.
AND Zizlavsky (2014). Net present value approach: method for economic assessment of innovation projects. 19th International Scientific Conference; Economics and Management 2014, ICEM 2014, 23-25 April 2014, Riga, Latvia

[20] The Gambia Lending Interest rate in 2021. Retrieved at https://www.theglobaleconomy.com/Gambia/Lending_interest_rate/

The IRR is the interest rate at which the NPV of future cash flow is equal to the initial investment. It calculates the discount rate that gives the trial a zero NPV. It thus represents the return on investment achieved when a project reaches its breakeven point, meaning that the project is only marginally justified as valuable. In this study, a trial is worthy of acceptance if the IRR>r where r is given as 19.5%.

The payback analyzes the risk associated with the investment in a specific experiment or trial. It is calculated as:

$$Payback = \frac{Initial\ investment}{Net\ cash\ flow} = \frac{Total\ cost}{Total\ benefit}$$

The details of the C and B are provided in the excel sheet. The qualitative data is analyzed using content analysis where the data are presented on themes, mostly, as a support to the quantitative information.

2.5 Variables for CBA

The variables used in the analysis include both fixed cost and return variables and the list is shown in Table 1.

Table 1. List of variables for CBA

Fixed cost items	**Variable cost items**
Farm machines	**Inputs**
Packing machine	Seeds
Power tiller	Herbicides
Manual Seeder	Pesticides
Seed Cleaner machine	NPK 15:15:15
Pedal thresher	Chicken manure
Seed Sorting Machine	Urea
Quinoa shelling Machine	Biochar
Equipment	Limestone
Seed Cleaner	Cattle dung
Hoes	Green manure (Leucaena)
Garmin GPS	Plastics
Tapeline	Bags
Weighing scale	Others
Portable bag closer	**Farm operational cost**
Temperature and humidity sensor	Manual ploughing
Chaff cutter	Sowing
Multi crop Thresher	Fertilizer application without foliar
Soil Auger	Fertilizer application + foliar
Mechanical Shaker	Biochar application

Caliper	Cow dung application
Salinity meter	Chicken manure application
Canon Camera	Pesticide application
Camera Accessories	Weeding
Laptop	Scaring birds/rodents
Dell briefcase	Harvesting
Projector	Transportation
BPH Establishment	Training and feeding
Borehole	Threshing and winnowing
Storage tanks	**Revenue Items**
Solar pumping system	Yield of crops
Drip irrigation system	Market Price
Fencing	

3 Results and Discussion

3.1 An elaborate list of costs.

Table 2 shows the list of items considered in the cost estimation for the various experimental trials. Overall, a total of 29 fixed cost items and 27 variable cost items were considered. However, the specific number of cost items varied based on the treatment.

Table 2. List of cost items

Item	Quantity	Price/unit	Useful life (years)	Salvage value	Annualized value	Annualized value per plot
Farm machines						
Packing machine	1	114,000.00	10	1,140.00	11,286.00	594.00
Power tiller	1	510,000.00	10	5,100.00	50,490.00	2,657.37
Manual Seeder	1	17,160.00	10	171.60	1,698.84	89.41
Seed Cleaner machine	1	9,276.75	10	92.77	918.40	48.34
Pedal thresher	1	31,800.00	10	318.00	3,148.20	165.69
Seed Sorting Machine	1	111,000.00	10	1,110.00	10,989.00	578.37
Quinoa shelling Machine	1	78,000.00	10	780.00	7,722.00	406.42
Equipment						
Seed Cleaner	1	205,680.00	10	1,028.40	20,465.16	1,077.11
Hoes	35	150.00	3	0.75	1,749.75	92.09
Garmin GPS	1	22,437.50	5	112.19	4,465.06	235.00
Tapeline	1	250.00	3	1.25	82.92	4.36
Weighing scale	1	850.00	5	4.25	169.15	8.90
Portable bag closer	1	9,420.00	3	47.10	3,124.30	164.44
Temperature and humidity sensor	1	14,100.00	5	70.50	2,805.90	147.68
Chaff cutter	1	51,420.00	5	257.10	10,232.58	538.56
Multi crop Thresher	1	41,033.70	5	205.17	8,165.71	429.77
Soil Auger	1	21,540.00	5	107.70	4,286.46	225.60
Mechanical Shaker	1	59,863.25	5	299.32	11,912.79	626.99
Caliper	1	2,400.00	5	12.00	477.60	25.14
salinity meter	1	41,590.15	5	207.95	8,276.44	435.60
Canon Camera	1	38,718.15	5	193.59	7,704.91	405.52
Camera Accessories	1	10,949.50	3	54.75	3,631.58	191.14
Laptop	1	71,782.05	5	358.91	14,284.63	751.82
Dell briefcase	1	1,974.50	5	9.87	392.93	20.68
Projector	1	27,643.00	5	138.22	5,500.96	289.52
BPH Establishment						
Borehole	1	159,028.80	15	795.14	10,548.91	555.21
Storage tanks	2	262,109.40	15	1,310.55	34,860.55	1,834.77
Solar pumping system	1	304,753.80	5	1,523.77	60,646.01	3,191.90
Drip irrigation system	1	712,366.80	5	3,561.83	141,760.99	7,461.10
Fencing	1	385,831.20	15	1,929.16	25,593.47	1,347.02
TOTAL FC					**467,391.19**	24,599.54

3.2 A list of economic benefits and social benefits

- The quantifiable economic benefit considered in this analysis is the revenue under each treatment.
- One important social benefit would have been the contribution of the treatments to reduce greenhouse gas emissions from the treatments if measured. However, in Table 3, we listed some economic and social benefits.

Table 3. List of economic benefits and social

Economic Benefits
Adoption of new agricultural technologies
Access to more productive and salinity-tolerant seed varieties
Restoration of soil fertility
Increase of Arab land
Recovery of degraded land and its cultivation
Increase in agricultural productivity and income
Increase in crop diversity and food security
Group purchase and sale of inputs and agricultural products
Access to credit loans and agricultural financing
Improvement and development of new agribusiness
Capacity built and knowledge increased
Social Benefits
Social Strengthening of Social Cohesion
Creation of social groups
Connection with different stakeholders of the value chain
Women empowerment
Ease of access to basic social services
Better perception of agricultural activity
Vitalization of community work

3.3 Monetary value of costs

The total fixed and variable cost of production for the various treatments is shown in Table 4. The total fixed cost of production is GMD 24,599.54 while the variable cost varies based on the treatment and the crop. For the crop variety experiment, there is no significant difference in the total cost of production between the two varieties of the three experimented crops. For the soil amendment experiment, the total cost of production is lowest for the control and highest for the Biochar treatment for both millet and sorghum. Also, for both millet and sorghum, the fertilization experiment shows that the cost of production is highest when NPK 15-15-15 is used together with foliar nutrient application and lowest when no form of fertilizer is used. The total cost of production is independent of the sowing date. Generally, the crop management experiments are more costly than the other experiments and lowest for the crop varieties experiments.

Table 4. Fixed, variable, and total costs of production

Intervention		Treatment	Fixed cost	Variable cost			TOTAL COST		
				Millet	**Sorghum**	**Cowpea**	**Millet**	**Sorghum**	**Cowpea**
Crop varieties	Millet	IP 19586	24,599.54	9,844.47			34,444.00		
		MC 94 C2	24,599.54	9,844.47			34,444.00		
	Sorghum	ICSV-700	24,599.54		9,849.75			34,449.28	
		ICSR-93034	24,599.54		9,849.75			34,449.28	
	Cowpea	ILRI 9334	24,599.54			9,863.07			34,462.60
		ILRI 9643	24,599.54			9,863.07			34,462.60
Soil amendment		Cattle dung	24,599.54	17,076.90	17,083.50		41,676.44	41,683.04	
		Lime	24,599.54	16,521.90	16,528.50		41,121.44	41,128.04	
		Green manure (Leucaena)	24,599.54	18,051.90	18,058.50		42,651.44	42,658.04	
		Biochar	24,599.54	22,251.90	22,258.50		46,851.44	46,858.04	
		Control	24,599.54	15,981.90	15,988.50		40,581.44	40,588.04	
Fertilization		NPK 15-15-15	24,599.54	13,503.80	13,509.08		38,103.34	38,108.62	
		NPK 15-15-15 + foliar nutrients	24,599.54	14,103.80	14,109.08		38,703.34	38,708.62	
		Chicken manure	24,599.54	13,481.30	13,486.58		38,080.84	38,086.12	
		Control	24,599.54	13,131.30	13,136.58		37,730.84	37,736.12	
Crop management		Sowing dates 1	24,599.54		26,014.70			50,614.24	
		Sowing dates 2	24,599.54		26,014.70			50,614.24	

3.4 Quantify and determine benefits.

Table 5 shows the yield and associated revenue from the various experiments. The price per kilogram of the three crops is shown as a table footnote, showing that the unit price for each crop is the same irrespective of the experiment. The yield and revenue from the sorghum crop variety experiment are significantly higher for the ICSV-700 variety than the ICSR-93034 variety; the revenue difference is as high as GMD 26,855.74, which is more than the fixed cost of production. For the millet variety experiment, the yield and associated revenue are not significantly different considering a revenue difference of only GMD 4,289.5 for the IP 19586 variety over the MC 94 C2 variety. The yield and revenue for cowpea is significantly different between the two experimented varieties. Specifically, this is highest for the ILRI 9334 variety (GMD 270,283.50) compared with the GMD 187,932.60 of the ILRI 9643 variety; a difference of GMD 82, 350.90.

The yield and revenue for sorghum experiments are lowest under green manure treatment (GMD 29,097.36) and highest for the cattle dung treatment (GMD 68,566.44). For millet, the yield and revenue are highest for the green manure (GMD 90,053.60) and lowest for the biochar treatment (GMD 48,429.50). This means that although green manure is suitable for millet production, it is not for sorghum production, instead, cattle dung should be used for sorghum production.

The benefits of fertilization experiments differed based on the treatment. For sorghum, the benefits are highest for chicken manure applications and lowest for the control. For millet, the benefits are highest for the NPK 15-15-15 treatment and lowest for the NPK 15-15-15 plus foliar nutrient treatment. Thus, while chicken manure is more suitable for sorghum production than the other treatments under fertilization, the application of only NPK 15-15-15 is suitable for higher millet yield and revenue.

There is a significant difference in the benefits of using sowing date 1 for sorghum production than sowing date 2. When compared across experiments, using sowing date 1 treatment is more suitable for sorghum production than all other treatments but for millet production, the use of green manure can guarantee higher farm benefits.

Table 5. Yield and revenue under various experiments

Intervention		Treatment	Sorghum		Millet		Cowpea	
			Yield (kg/ha)	Revenue	Yield (kg/ha)	Revenue	Yield (kg/ha)	Revenue
Crop varieties	Millet	IP 19586			1,553.17	54,360.85		
		MC 94 C2			1,430.61	50,071.39		
	Sorghum	ICSV-700	2,361.50	89,737.00				
		ICSR-93034	1,654.77	62,881.26				
	Cowpea	ILRI 9334					3003.15	270,283.50
		ILRI 9643					2088.14	187,932.60
Soil amendment		Cattle dung	1,804.38	68,566.44	2,046.53	71,628.55		
		Lime	1,247.44	47,402.72	1,923.93	67,337.55		
		Green manure (Leucaena)	765.72	29,097.36	2,572.96	90,053.60		
		Biochar	1,604.14	60,957.32	1,383.70	48,429.50		
		Control	1,396.93	53,083.34	1,610.52	56,368.20		
Fertilization		NPK 15-15-15	1,690.81	64,250.78	1,332.32	46,631.20		
		NPK 15-15-15 + foliar nutrients	2,254.19	85,659.22	655.24	22,933.40		
		Chicken manure	2,523.89	95,907.82	1,069.49	37,432.15		
		Control	1,587.78	60,335.64	1,135.00	39,725.00		
Crop management		Sowing dates 1	9,315.90	354,004.20				
		Sowing dates 2	3,582.05	136,117.90				

NB: Price per kg for sorghum, pearl millet and cowpea were 38 GMD/kg, 35 GMD /kg and 90 GMD /kg, respectively

3.5 Incremental costs and benefits

Incremental costs

Table 6 shows the cost of each treatment over their respective control cost of production. The incremental cost for the crop varieties and crop management experiments zero due to the absence of control treatments. For soil amendment experiments, more extra costs are invested in biochar treatments for both millet and sorghum than the other treatments. The use of lime only increases the cost of production by GMD 540.00. For the fertilization experiments, the NPK 15-15-15 plus foliar nutrients application treatment led to more extra cost of financial investment in the production of millet and sorghum.

Table 6. Incremental cost of treatment experiments over control cost

Intervention		Treatment	Incremental Cost (GMD) Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586	0.00		
		MC 94 C2	0.00		
	Sorghum	ICSV-700		0.00	
		ICSR-93034		0.00	
	Cowpea	ILRI 9334			0.00
		ILRI 9643			0.00
Soil amendment		Cattle dung	1,095.00	1,095.00	
		Lime	540.00	540.00	
		Green manure (Leucaena)	2,070.00	2,070.00	
		Biochar	6,270.00	6,270.00	
		Control	0.00	0.00	
Fertilization		NPK 15-15-15	372.50	372.50	
		NPK 15-15-15 + foliar nutrients	972.50	972.50	
		Chicken manure	350.00	350.00	
		Control	0.00	0.00	
Crop management		Sowing dates 1		0.00	
		Sowing dates 2		0.00	

Incremental benefits

Figure 4 shows the land productivity of the treatments under soil amendment and fertilization. It represents the percentage increase in yield over the control yields. Generally, lime and green manure for sorghum soil amendment trials recorded lower yields than the control yield while biochar for millet recorded lower yields than the control millet yield. For the fertilization experiment, NPK +foliar nutrients and green manure under millet production recorded lower yields than the control millet yield. Overall, the highest land productivity was recorded under green manure for millet production and chicken manure under sorghum production.

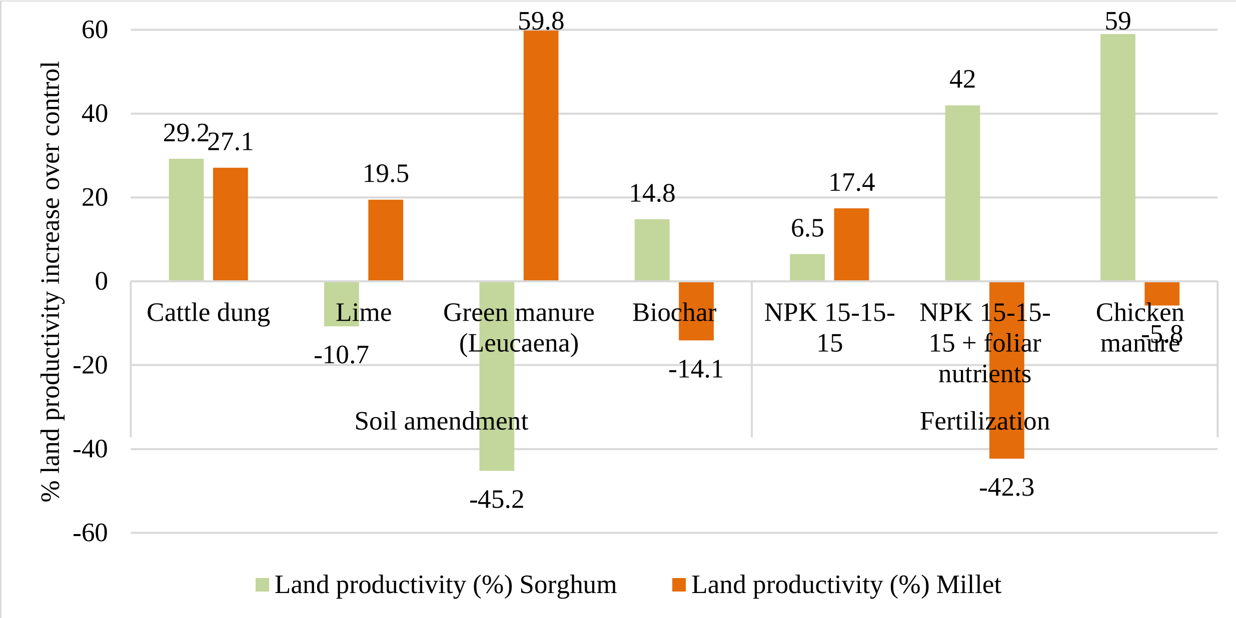


Figure 4. Land productivity of soil amendment and crop fertilization experiments

Table 7 shows the incremental benefits of each experiment. This is estimated as the difference between the total revenue of the trial under the experiment and its respective control treatment. Like the incremental cost, the incremental benefits are zero for the trials under the crop variety and crop management experiments. For soil amendment experiments, the green manure trial under millet and cattle dung under sorghum production had the highest incremental benefits while biochar under millet and lime and green manure under sorghum resulted in less benefits than in the control trials.. For the fertilization experiments, only NPK 15-15-15 trial under millet production had a positive incremental benefit while there was a positive incremental benefit for all fertilization trials under sorghum production.

Table 7. Incremental benefits of treatment experiments over control benefit

Intervention			**Incremental Revenue (GMD)**		
		Treatment	**Millet**	**Sorghum**	**Cowpea**
Crop varieties	Millet	IP 19586	0.00		
		MC 94 C2	0.00		
	Sorghum	ICSV-700		0.00	
		ICSR-93034		0.00	
	Cowpea	ILRI 9334			0.00
		ILRI 9643			0.00
Soil amendment		Cattle dung	15,260.35	15,483.10	
		Lime	10,969.35	-5,680.62	
		Green manure (Leucaena)	33,685.40	-23,985.98	
		Biochar	-7,938.70	7,873.98	
		Control	0.00	0.00	
Fertilization		NPK 15-15-15	6,906.20	3,915.14	
		NPK 15-15-15 + foliar nutrients	-16,791.60	25,323.58	
		Chicken manure	-2,292.85	35,572.18	
		Control	0.00	0.00	
Crop management		Sowing dates 1		0.00	
		Sowing dates 2		0.00	

3.6 Cost Benefit Analysis (NPV and BCR)

Assumptions

- Since there are no controls for the crop varieties and sowing date experiments, their incremental cost and benefit are assumed to be zero each.
- The interest rate used is the prevailing national interest rate as of December 2022
- Where BPH was not able to provide the unit cost of a cost item, the prevailing market price of the item is assumed.
- The yield was estimated on the assumption that the grain weights per plant are equal, and the plant emergence rate remains constant as the plant population at harvest.
- The profitability analysis is based on economic profitability. The social benefits and costs were unmeasurable and hence cannot be included in analysing the profitability indices.
- The labor cost for most farm operations is done by the community in the hub. However, the economic cost was attached to all activities carried out in the hub using current wage for a man-day.

Net present value

The NPV that compares the cash inflows to the cash outflows and takes into account the interest rate is shown in Table 8. The NPV suggests the profitability of the various treatments, hence, higher NPV is preferred. For millet crop variety experiments, the profitability for IP 19586 variety is higher than the profitability of MC 94 C2. For sorghum, the ICSV-700 variety had significantly higher profitability than the ICSR-93034 variety while cowpea ILRI 9334 variety resulted in higher profitability than cowpea ILRI 9643 variety. Therefore, in terms of varietal selection, millet IP 19586, cowpea ICSV-700 and sorghum ILRI 9334 are appropriate for promotion.

For millet soil amendment experiments, the use of green manure resulted in the highest profitability while using biochar leads to a significant loss of GMD11,890. For sorghum soil amendment experiments, the use of cattle dung led to the highest profitability followed by biochar while the use of green manure and lime resulted in losses. Consequently, we recommend the use of green manure and cattle dung amendment for millet, while cattle dung and biochar may be profitable for sorghum cultivation.

The fertilization experiments for millet show that the use of only NPK 15-15-15 is profitable while the use of chicken manure and NPK 15-15-15 plus foliar nutrients results in significant losses. For sorghum fertilization experiments, profitability is positive for all treatments. Thus, the use of any form of fertilization can increase the profitability of sorghum production. However, the profitability for NPK 15-15-15 plus foliar nutrients is highest followed by using chicken manure and lowest for NPK 15-15-15. Therefore, we concluded that, in fertilization, NPK 15-15-15 should be use for millet production, while the three fertilizers including NPK 15-15-15, NPK 15-15-15+foliar nutrients and Chicken manure would be profitable for sorghum production.

Sowing date 1 in sorghum production has resulted in more than triple the benefits from sowing date 2. Hence, it is important to produce sorghum on sowing date 1.

Table 8. Net present value of the various experiments

Intervention		Treatment	NPV (GMD)		
			Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586	16,666.81		
		MC 94 C2	13,077.31		
	Sorghum	ICSV-700		46,265.87	
		ICSR-93034		23,792.45	
	Cowpea	ILRI 9334			197,339.66
		ILRI 9643			128,426.78
Soil amendment		Cattle dung	11,853.85	12,040.25	
		Lime	8,727.49	-5,205.54	
		Green manure (Leucaena)	26,456.40	-21,804.17	
		Biochar	-11,890.13	1,342.24	
		Control	0.00	0.00	
Fertilization		NPK 15-15-15	5,467.53	2,964.55	
		NPK 15-15-15 + foliar nutrients	-14,865.36	20,377.47	
		Chicken manure	-2,211.59	29,474.63	
		Control	0.00	0.00	
Crop management		Sowing dates 1		253,882.81	
		Sowing dates 2		71,551.18	

Benefit cost ratios of project interventions

The benefit cost ratio of the experimental trials is shown in Table 9. As explained earlier, a BCR value above 1 indicates a profitable treatment and the higher the BCR, the higher the profitability of the treatment. For crop varieties intervention, the profitability of the project is guaranteed as the BCR are all above 1. For the millet variety experiments, the IP 19586 variety has resulted in higher BCR than the MC 94 C2 variety. Also, for sorghum, the ICSV-700 variety has resulted in a higher BCR than the ICSR-93034 variety while for Cowpea, the BCR for ILRI 9334 variety is higher than that of the ILRI 9643 variety. Therefore, the 6 crop varieties are promising in increasing productivity, farmers revenue and market supply chain.

The Millet soil amendment experiments showed that all the treatments were profitable except Biochar and the profitability was higher for the lime treatment than green manure and cattle dung. For sorghum soil amendment experiments, Biochar was slightly profitable, cattle dung was more profitable while lime and green manure treatments resulted in losses. Overall, the use of lime has resulted in the highest BCR for millet followed by NPK 15-15-15 application while for Sorghum; the use of chicken manure had the highest BCR followed by the application of NPK 15-15-15 plus foliar nutrients.

The application of NPK 15-15-15 in millet production resulted in a profitable outcome while NPK 15-15-15 plus foliar nutrients and chicken manure led to economic losses. All sorghum fertilization trials were profitable (BCR>1), especially the use of chicken manure.

Consistent with the NPV in the previous section, the BCR for sowing date 1 is higher than sowing date 2. However, the BCR for both treatments are more than 1 showing the success of crop management intervention on sorghum growing,

Table 9. BCR analysis of experimental treatments

Intervention		Treatment	BCR		
			Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586	1.58		
		MC 94 C2	1.45		
	Sorghum	ICSV-700		2.60	
		ICSR-93034		1.83	
	Cowpea	ILRI 9334			7.84
		ILRI 9643			5.45
Soil amendment		Cattle dung	13.94	14.14	
		Lime	20.31	-10.52	
		Green manure (Leucaena)	16.27	-11.59	
		Biochar	-1.27	1.26	
		Control	0.00	0.00	
Fertilization		NPK 15-15-15	18.54	10.51	
		NPK 15-15-15 + foliar nutrients	-17.27	26.04	
		Chicken manure	-6.55	101.64	
		Control	0.00	0.00	
Crop management		Sowing dates 1		6.99	
		Sowing dates 2		2.69	

Internal rate of return

The results on the internal rate of returns (IRR) of the various experiments is shown in Table 10. The decision is that if the IRR is greater than the discount rate of 19.5%, then the trial is worth promoting. From the result, all the variety trials for the three crops had more IRRR rates than the discount rate. For soil amendment experiments, the use of biochar for millet production as well as the use of green manure and lime for sorghum production are not desirable. For fertilization, all trials for sorghum are desirable while only NPK 15-15-15 for millet production is desirable. Crop management experiments showed although the two sowing dates for sorghum had higher IRR than the discount rate, the sowing date 1 is most desirable for higher profitability.

Table 10. Internal rate of returns of trials

Intervention		Treatment	IRR (%)		
			Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586	57.8		
		MC 94 C2	45.4		
	Sorghum	ICSV-700		160.5	
		ICSR-93034		82.5	
	Cowpea	ILRI 9334			684.3
		ILRI 9643			445.3
Soil amendment		Cattle dung	71.9	64.5	
		Lime	63.8	15.3	
		Green manure (Leucaena)	111.1	-31.8	
		Biochar	3.4	30.1	
		Control	38.9	30.8	
Fertilization		NPK 15-15-15	22.4	68.6	
		NPK 15-15-15 + foliar nutrients	-40.7	121.3	
		Chicken manure	-1.7	151.8	
		Control	5.3	59.9	
Crop management		Sowing dates 1		599.4	
		Sowing dates 2		168.9	

Payback Period

The results on the payback analysis of the experiments are shown in Table 11. This shows that it will take less than a year to generate adequate cash flows to offset the initial investment into the trial. The exceptions were on green manure under sorghum soil amendment experiment, and NPK 15-15-15 plus foliar nutrient and chicken manure under fertilization experiments on millet.

Table 11. Payback analysis of experiments

Intervention		Treatment	Payback		
			Millet	Sorghum	Cowpea
Crop varieties	Millet	IP 19586	0.63		
		MC 94 C2	0.69		
	Sorghum	ICSV-700		0.38	
		ICSR-93034		0.55	
	Cowpea	ILRI 9334			0.13
		ILRI 9643			0.18
Soil amendment		Cattle dung	0.58	0.61	
		Lime	0.61	0.87	
		Green manure (Leucaena)	0.47	1.47	
		Biochar	0.97	0.77	
		Control	0.72	0.76	
Fertilization		NPK 15-15-15	0.82	0.59	
		NPK 15-15-15 + foliar nutrients	1.69	0.45	
		Chicken manure	1.02	0.40	
		Control	0.95	0.63	
Crop management		Sowing dates 1		0.14	
		Sowing dates 2		0.37	

4 Analysis of RESADE project beneficiary information

4.1 Demographic characteristics

The demographic characteristics of the project beneficiaries are presented in Table 12. A significant proportion (93.3%) of the sampled beneficiaries were females. Most (40%) of the beneficiaries have ages between 24 and 35 years while an additional 20% have ages less than 24 years. These suggest that the beneficiaries are at their active age and the lessons learnt by the farmers can be sustainably implemented over the medium to long-term. While 30% of the beneficiaries interviewed were heads of their households, the remaining 70% were other members of the household. The level of education is high among the farmers considering that over 50% of them had either bachelor's or master's degrees. Most of the farmers have high experience in crop production given that only 30% of them were into crop production for less than 10 years and about 7% were into farming for over 39 years. Such farm experiences can be used to improve crop production.

Table 12. Demographic characteristics of project beneficiaries

Characteristic	Definition	Frequency	Percentage
Sex	Male	2	6.7
	Female	28	93.3
Age	Under 24 years	6	20.0
	24-35 years	12	40.0
	36-44 years	5	16.7
	45-60 years	7	23.3
Household status	Head	9	30.0
	Non-head	21	70.0
Education	Higher school	8	26.7
	Diploma	4	13.3
	Bachelor's degree	10	33.3
	Master's degree	6	20.0
	Others	2	6.7
Experience	Less than 10 years	9	30.0
	10-19 years	9	30.0
	20-29 years	7	23.3
	30-39 years	3	10.0
	39+ years	2	6.7

4.2 Membership in organizations

Table 13 shows that 90% of the project beneficiaries were members of at least one farmers association. Specifically, most beneficiaries (81.5%) belonged to grower associations while the association with the least membership is the supplier association. All beneficiaries into supplier association had their membership for over 5 years. The grower association members generally had less years of membership than other associations. All farmers who belonged to an agricultural cooperative received seeds, fertilizers, and training services while 80% and 60% of them respectively received market information and tractor services. The major services received by grower association members include training services and improved access to seeds. Expectedly, all beneficiaries in the trader association had received market information. All farmers who are members of the association indicated that the services provided are beneficial except one farmer who is a member of the grower association.

Table 13. Membership in association by project beneficiaries

Response	Membership		Years of membership		
	Freq.	%	1-2 years	3-5 years	5+ years
Membership in organization					
Yes	27	90.0			
No	3	10.0			
Types of organization					
Agricultural cooperatives	5	18.5	0.0	40.0	60.0
Grower association	22	81.5	13.6	31.8	54.6
Trader association	4	14.8	0.0	25.0	75.0
Supplier association	3	11.1	0.0	0.0	100.0

4.3 Access to extension services

Access to extension services is high among the farmers (Table 14). In terms of frequency, the majority (51.9%) of those who accessed extension services received them once or twice every month during the production season while about 26% received extension services only once in the production season. The extension services received by most farmers include education on how to adopt new technologies, crop diversification and rotation practices, pests and diseases management, irrigation management, and linkages with input supplies and markets.

Table 14. Access to extension services by project beneficiaries

Response	Frequency	Percentage
Access		
Yes	27	90.0
No	3	10.0
Frequency of access		
Rarely (once in 3 months)	7	25.9
Sometimes (once or twice in a month)	14	51.9
At least once a week	6	22.2
Types of services received		
Technical (production)	1	3.7
Adopting new technologies	17	63.0
Pest and disease management	12	44.4
Climate change adaptation	5	18.5
Crop diversification/rotation	10	37.0
Input supply/markets	9	33.3
Market/Price information	8	29.6
Irrigation management	11	40.7
Advice on farm credit/loan	4	14.8

4.4 Participation in BPH

Figure 5 shows the number of times of participation in activities undertaken on the BPH. This shows that most of the project beneficiaries participated in the activities of the BPH three or four times in a year. While 20% participated only once or twice, about 13% participated over 20 times. The high level of participation by the farmers is necessary to improve their understanding of the various activities under the project and to enable them practice similar activities on their own farms.

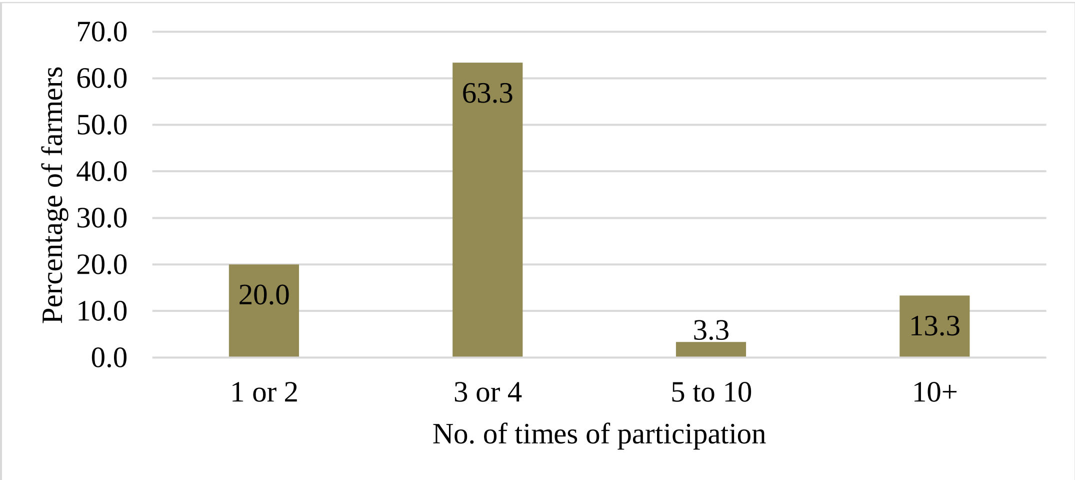


Figure 5. Frequency of participation in BPH activities

4.5 Lessons learned under RESADE project

The specific lessons learnt by the RESADE project beneficiaries are provided in Figure 6. The major lesson learned is on biochar technology, specifically, on its production and application. Also, 70% and 60% of farmers also learned irrigation technologies and seed production practices under the project, respectively. Nonetheless, only a few (13.3%) farmers learned how to make compost. The high level of reported lessons learned under the project is an indication of the high potential impact of the project in transforming the crop production practices of the farmers.

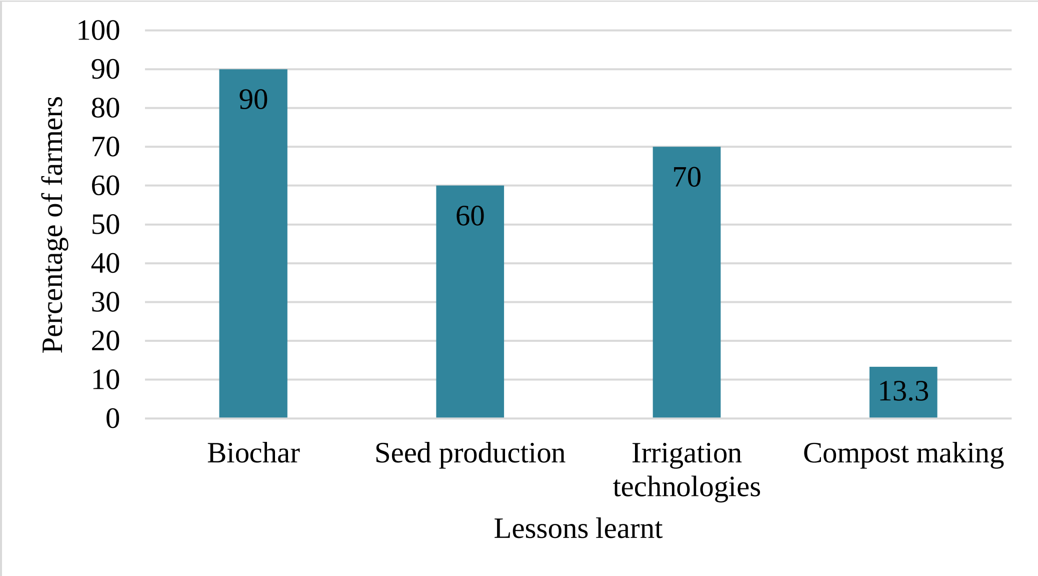


Figure 6. Lessons learned under the RESADE project

4.6 Receipt of materials under the project

Figure 7 details whether the project beneficiaries had received any specific material or not. Overall, 70% of the farmers indicated received at least one project material. Specifically, the main materials received include seeds and biochar. The high access to improved seeds under the project will ensure high yield on the farmers' fields and to improve the self-food sufficiency of the farming households and the country at large.

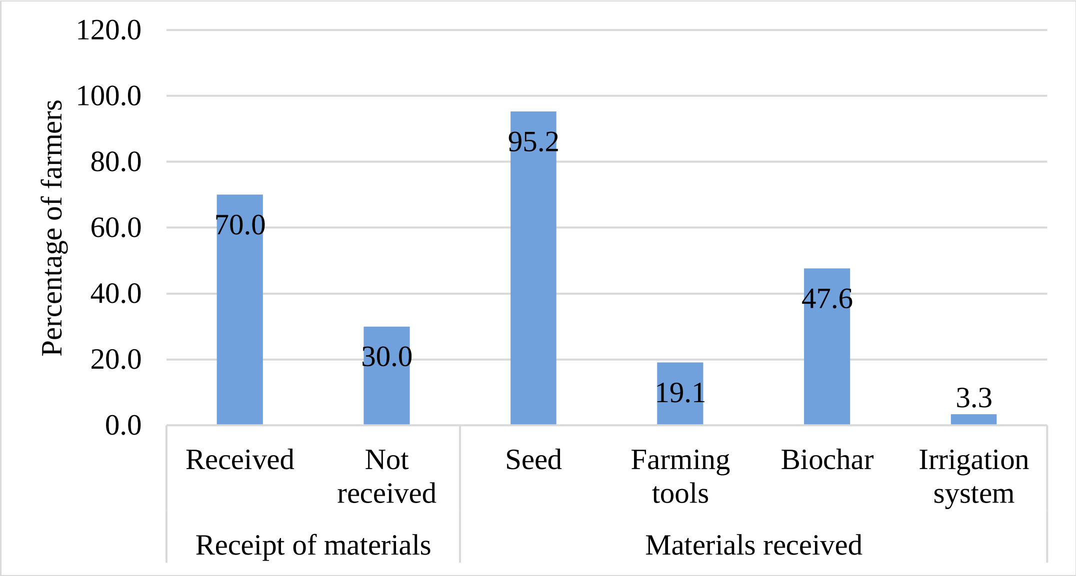


Figure 7. Receipt of materials under the project

4.7 Access to market

Access to market is an important aspect of crop production and for improving the livelihood of farmers. The majority of the beneficiaries (87%) revealed they have access to markets for both their production input and output (Figure 8). However, the majority of these farmers accessed local community markets. These markets have low infrastructure with generally unfavorable input and output prices. This can serve as a disincentive for the farmers, hence, the need to connect the farmers to district and other large commercial markets.

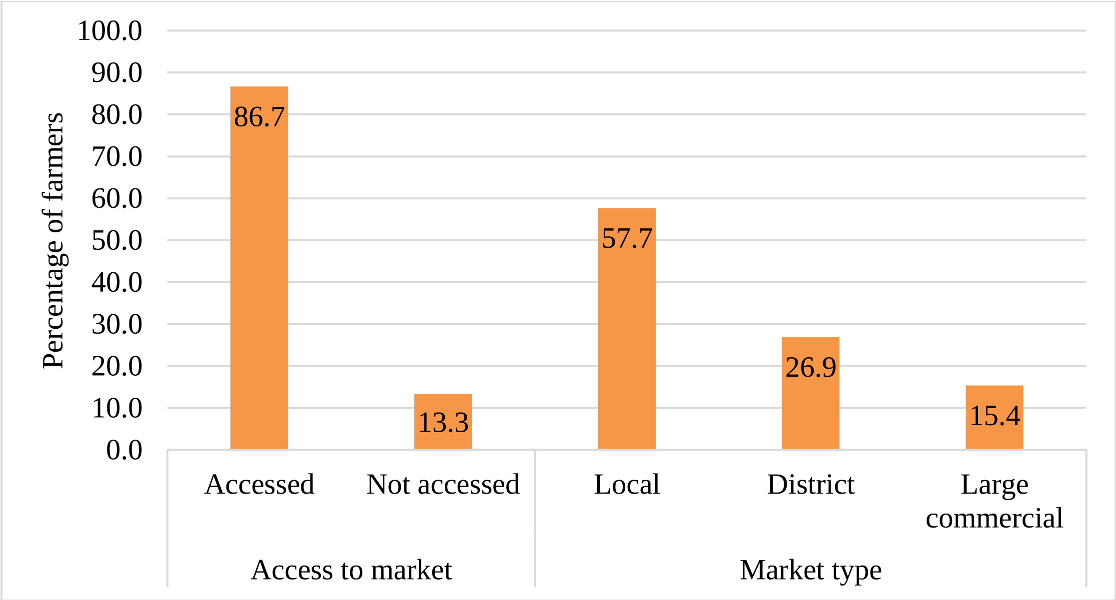


Figure 8. Access to market by project beneficiaries

4.8 Needs of farmers

The farmers outlined the specific items they needed to enhance their crop production (Figure 9). The need for the majority (93.3%) of the farmers is farm tools. These are basic production tools such as hoes, spraying machines, and safety tools that can facilitate their adoption of new production technologies. Another major need of over 73% of the farmers is access to improved seeds, training, and access to information. The farmers expressed a high desire towards the use of improved seed varieties, but not only do they lack access but also, they do not have adequate information on the sources and types of the improved seed varieties that can optimize their yields. The desire to be trained is an opportunity for the RESADE project to harness in order to make significant impact on their farmers. Related to seeds is the need for fertilizers by 63.3% of the farmers. The farmers need information and access to crop specific fertilizers that can enhance their yields, especially as demonstrated under the RESADE project. Although access to agricultural credit has often been reported low, only 40% of the farmers expressed the need for credit facilities, particularly because they have expressed the need for specific inputs such as seeds and fertilizers.

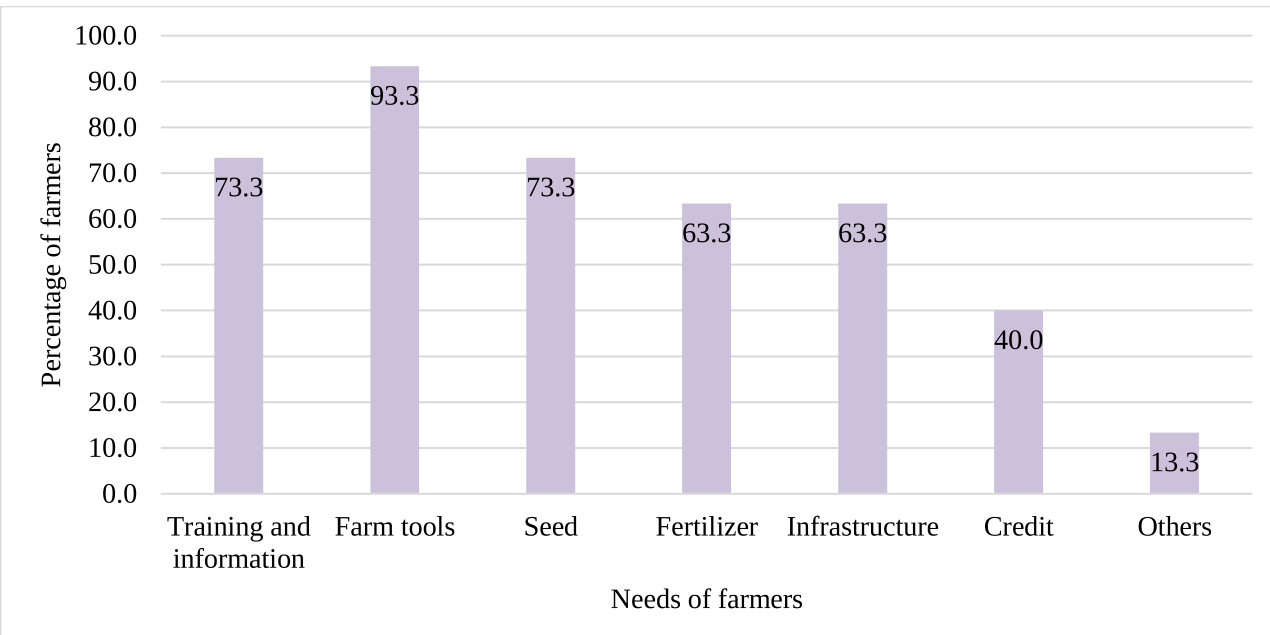


Figure 9. Needs of farmers

4.9 Constraints of farmers

Crop production is faced with several challenges. These challenges affect the production outcomes such as yield and income of the farmers. Specifically, the beneficiary farmers outlined the following specific challenges to their crop production.

- Lack of inputs (e.g., fertilizers and seeds). The lack of production input has been expressed by the farmers as their needs in the previous section.
- Lack of drawn animals and farm implements. The farmers lack the necessary tools for performing farm activities such as land preparation and harvesting equipment.
- Salinity of farmlands. A major justification of the RESADE project is to design production practices and innovations to respond to the salinity of the soils. Therefore, the generally positive economic returns as observed in profitability of the treatments means that the farmers can select appropriate technologies to mitigate the salinity impacts on their crop production.
- Pests and diseases. The emergence of pests and diseases is affecting crop production levels. It is important to provide training and education to the farmers to effectively manage pests and diseases on their farms.
- Low income and lack of credit. The low income from crop production is a major challenge to the adoption of improved technologies and expansion of production areas to take advantage of the benefits of economies of scale. Although credit is not a need for most farmers, its provision can help address the low income of the farmers.
- Low access to market and market information. Access to production and marketing information is reportedly low and a major concern for the farmers.
- Lack of storage and transport facilities. There are no storage and transport facilities for the various crops produced by the farmers. Therefore, the farmers are compelled to sell their excess production mostly after harvest where prices are low and are struggling to bring their products to the market.

5 Conclusion and Recommendation

Conclusion

This study has revealed that the technologies introduced by the project are able to enhance the ability of crops to perform very well in salt conditions and has proven that marginal lands can be used for the production of the three crops given the right technology. This helps to demystify the belief of many people that the area is salty and cannot be used. Thus, through the intervention of this project, it is now proven that the tested crops and vegetables can be grown using appropriate technologies. This supports national interest by increasing the utilization of margin lands destroyed by salt.

Some of the key factors that have influenced the success of the project include:

- ✓ Frequent Training of farmers;
- ✓ Efficiency of the BPH implementing staff;
- ✓ Input and materials supply to the hub;
- ✓ Reclamation of marginal lands;
- ✓ Community commitment and participation.

However, the following major challenges were encountered during project implementation:

- ✓ Late delivery of inputs (Seeds and Fertilizers);
- ✓ Mobilization of community labor especially for weeding;
- ✓ Manual ploughing services /

With respect to the different technologies tested at BHP, the NPV and BCR varied by technology and crop. Millet IP 19586 had higher NPV (the benefit net of the investment) and BCR than the millet MC 94 C2 variety, although they were both profitable. Sorghum ICSV-700 had higher NPV and BCR than sorghum ICSR-93034. The NPV and BCR was highest for the cowpea ILRI 9334 variety than the cowpea ILRI 9643 variety. Across crops, the profitability of the varietal treatments was higher for cowpea. For the soil amendment technologies, the NPV was highest for green manure and the BCR is highest under lime in millet production. Using biochar for millet production will lead to economic losses (negative NPV and BCR). For sorghum, NPV and BCR were highest for the cattle dung treatment. Using lime and green manure for sorghum production will lead to economic losses.

For the crop fertilization trials, the use of NPK 15-15-15 for millet production led to the highest NPV and BCR while the use of NPK 15-15-15 + foliar nutrients and chicken manure led to negative NPV and BCR, thus, unprofitable. For sorghum, the NPV and BCR were highest for the use of chicken manure and lowest for the use of NPK 15-15-15.

In addition, from the result, all the variety trials for the three crops had more IRRR rates than the discount rate. The results on the payback analysis of the experiments show that it will take less than a year to generate adequate cash flows to offset the initial investment into the trial for most of the treatments.

However, the observed low profitability of biochar especially under millet production is not due to irrelevance of the biochar as a soil amendment technology. These were due to low seed germinations observed on these treatments.

Since the project participants have reported high lessons learnt and the farmers also indicated a high need for training and information, it can be concluded that there is high market potential for the project interventions (treatments).

Recommendation

- For millet production, the IP 19586 should be promoted. Green manure or lime should be used for soil amendment and NPK 15-15-15 used for fertilization.
- For higher profitability of sorghum production, ICSV-700 should be used, and under soils treated with cattle dung and chicken manure, and planting done using sowing date one as experimented in this project.
- Through sensitization/education, National Agricultural Research Institute (NARI) should encourage farmers to practice these technologies in relation to specific crops. A one-size-fit technology promotion among farmers should be discouraged.
- It is important to explore the best methods to promote these successful technologies for farmers to be able to appropriately implement them in their own fields.
- Considering the soil fertility status and water stress condition of the study site, promoting physically effective and financially efficient measures would help to improve adoption of these technologies.
- The project could lessen the effects (on farmers) of the initial negative returns from investment in these technologies by encouraging and supporting farmers to practice these technologies on their farmlands.
- For the continuity of the RESADE project, the study recommends that community should be encouraged to perceive the project as their own. The project should acknowledge and incorporate farmers' own strategies on crop management in their fields, and should endeavour to make available information on the cost and benefits of stakeholder participation.
- For further research, attempt should be made to investigate the interrelationship between production factor demands of the various technologies and farmers production factor endowment. This is important because it has been established that labour and capital availability, for instance, are key influencing factors in farmer's technology adoption decisions. These factors are needed for both the establishment of these technologies and crop production.

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Annexes

Picture of community farmers working in the HUB