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Profitability and Farmer Acceptability of Selected Climate Smart Technologies and Practices for Maize-Beans Production in Drought-Prone Areas, Uganda

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Abstract

Climate change is increasingly affecting farm-level decisions on when to plant and which climate smart agriculture (CSA) options to use. This study was conducted to determine the profitability and farmer acceptability of different CSA options for maize-bean production in drought-prone areas of Uganda. It was conducted on-farm in Rakai and Nakasongola districts during 2020 and 2021. Variables included: planting date (early vs late); varieties (common beans: NABE 4 and NAROBEAN 2, and maize: Longe 5 and Bazooka); intercropping versus pure stand; and fertiliser use (manure, Diammonium phosphate (DAP) or combination). The experimental design was split-split plot, replicated six times. Over two years, early planting caused 16% and up to 46% higher yields of maize and beans, respectively, than late planting, resulting in 14% - 28% and 18% - 43% higher Benefit/Cost (B/C) ratio for maize and beans, respectively. Intercropping reduced maize and beans yield by 16% - 25% and 52% - 57%, respectively. The B/C was highest for sole maize; intercropping was more profitable than sole beans. Fertilizer (DAP) was most profitable when Bazooka was early-planted as sole crop followed by intercrop. For late planted-crop, manure was better. These practices were more beneficial when applied simultaneously for both crops excluding bean variety. Farmers' lessons stressed the importance of early planting and fertilizer use; however, majority indicated they were to adopt more than two of the practices tested.

Keywords

Climate Change Adaptation, Cost-Effectiveness, Decision Making, Integrated

Soil Fertility Management, Technology Adoption

1. Introduction

Climate change is increasingly affecting farmer's decisions regarding when, how and which varieties to plant, which soil and other management practices to invest in [1] [2]. These uncertainties may lead to crop failure and consequently, economic losses. Many Sub-Sahara African (SSA) countries are vulnerable to climate change [3]. According to [4], climate change may result in a drop in Uganda's crop net revenues of up to 90% by 2100. Smallholder farmers are likely to be most affected because of inadequate resources to invest in adaptation and diversification measures [5] [6].

Recent reports indicate that climate change is affecting the value chains of crops, livestock and fisheries, causing food insecurity, malnutrition, poverty and high cost of living [7] [8] [9]. Climate change is also escalating soil productivity decline, adversely reducing maize and bean productivity, yet these crops provide affordable diets and income for low-income households in developing countries. In many regions of Uganda, especially the cattle corridor, agricultural production is already being adversely affected by rising temperatures, increased temperature variability, changes in levels and frequency of precipitation, a greater frequency of dry spells and droughts, and increasing intensity of extreme weather events [10].

To minimize the impacts of climate change, there is increasing need to guide smallholder farmers on the various possible coping strategies. Although farmers have coping mechanisms for weather-related challenges, they have inadequate knowledge on the most feasible options for adapting their production systems to increasing frequency and severity of extreme weather events [11]. Even with increasing access to weather information, farm-level adjustments and decisions to adapt to climatic changes are very slow and many doubtable by farmers, partly due to limited information on the profitability and benefits associated with different practices. Climate-smart agriculture (CSA) approach aims at increasing agricultural productivity, achieving food security, enhancing resilience of farmers to climate change, and mitigating greenhouse gas emissions from agriculture [12]. This can be achieved through area-specific assessment of social, economic and environmental conditions to identify appropriate agricultural production technologies and practices [3].

Considering the vulnerability of many agricultural systems in SSA, it is essential to upscale CSA practices to improve the resilience and livelihood of farmers. Many CSA practices exist for example, Integrated Soil Fertility Management (ISFM) approaches through the use of organic and inorganic fertilizers, water management, minimum tillage, cover crops, intercropping, and crop rotation, among others [5] [13], supported by drought-tolerant, high yielding and early maturing varieties. However, adoption of these practices by smallholders in SSA has been limited, partly because of inadequate knowledge on their agronomic benefits and profitability [5] [14].

Intercropping of maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) is one of the widely used practices of producing food crops on smallholder farms in SSA. However, there is inadequate knowledge on options for intensification of available practices in order to optimize systems productivity using intercrops [15]. It is used for food security, improving income from cereal-legumes field [16], risk reduction, and to maximize utilisation of land and labour [17]. Planting date, crop varieties and fertilizer to use, and whether to intercrop or not, are common decisions a farmer is faced with at farm level. Williams *et al.* [3] cautioned that CSA necessitates context-specific assessment of the ecological, social, and economic conditions in order to identify the most appropriate farming technologies and practices.

Cost Benefit Analysis (CBA) has been used to assess the viability of agricultural practices under climate change [18], the cost-effectiveness of climate-smart soil practices [19] and the viability of CSA practices [20]. In Tanzania, Karanja *et al.* [13] found that investments in CSA practices, such as crop rotation and intercropping of maize with soybean, have positive returns in short periods, and therefore can be promoted for adoption. However, for the case of ISFM, [21] found that highly profitable CSA practices may not necessarily be adopted. They attributed this to inadequate awareness about ISFM, labour intensiveness of some practices, and high cost of fertilizer, among others. Williams *et al.* [3] cautioned that although CSA approach is attractive and compelling in principle, its application under Africa's diverse agro-ecologies and highly heterogeneous farming systems, socio-economic conditions and policies still requires concrete examples of success and research-based evidence. The objective of this study was to determine on-farm yield, profitability and farmer acceptability of different CSA approaches, so as to identify the most feasible approaches to promote in drought-prone areas.

2. Materials and Methods

2.1. Field Procedures

The study was conducted in Nakasongola district (Kalungi & Lwabiyata sub counties) and Rakai district (Kagamba sub county), Uganda during 2020 and 2021. Nakasongola district is located in the central plateau, 1.3490˚N, 32.4467˚E), and 1000 to 1400 m above sea level (asl) [22]. It lies in the pastoral rangelands agro-ecological zone within the cattle corridor area. It has undulating landscape, gently sloping towards L. Kyoga in the north. Vegetation is open deciduous savannah woodland with short grasses. Temperature ranges from 25˚C to 35˚C and rainfall from 500 to 1000 mm p.a., unreliable, bimodally distributed. The main rain season is from March to May and a second season from September to December. Rakai district is located in the Southern region, 0.7069˚S, 31.5370˚E,

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1280 m asl, with annual rainfall of 800 to 1400 mm p.a., bimodally distributed [23]. Rainfall peaks from March-May and October-November.

Following participatory planning with agricultural officers in each district, six gender-inclusive farmer groups were selected per subcounty. Researchers and agricultural staff engaged the selected farmer groups to understand their (farmers') practices, climate-related risks being faced, and coping strategies. A farmer field school (FFS) approach was used in the study [24]. Researchers introduced the planned research to farmers and in a participatory manner, explored how the study could help them identify possible adjustments and changes they can make to reduce the negative impacts or damages associated with climate change, and thus improve their farming practices. Using mutually agreed criteria (willingness to spare about 0.8 ha of land and manage the trial; easily approachable, trainable and able to train others), one farmer was selected from each group to host the trial demonstrating the different adaptation practices. Group members agreed to work with the host farmer in planting and managing the trial. Soil was sampled from the selected farmer's field for laboratory testing, followed by field preparation, under a cost-sharing arrangement. Using the group field, researchers demonstrated to members, the construction of contour bunds and trenches for soil erosion control and water conservation. However, only 2 out of 32 participating farmer groups took up this practice, with most of them citing high labour demand, cost and busy schedules. For this reason, water conservation was dropped from the variables considered in this study. The experimental variables included: planting date *i.e.* early (onset of rain) vs delayed/late planting (two weeks from rainfall onset); soil management options; maize and beans varieties; and planting pattern (pure stand vs intercrop). Soil management options included: use of cattle manure, DAP and/or a combination at planting. Manure was applied at 2500 $kg \cdot ha^{-1}$, DAP at 125 $kg \cdot ha^{-1}$ and urea at 60 $kg \cdot ha^{-1}$, as recommended for maize in central Uganda. However, for sole beans, the DAP and manure rates were reduced to half and no urea applied.

Bean (*Phaseolus vulgaris* L.) varieties tested included NABE 4 and NAROBEAN 2, both bush types, developed by NARO and released in 1999 and 2016, respectively. NABE 4 is a large, red-mottled seed variety, resistant to major diseases, tolerates low soil fertility; matures within 80 to 95 days, with a yield potential of 2.0 to 2.5 $t \cdot ha^{-1}$ (http://www.fao.org/3/CA2552EN/ca2552en.pdf). NAROBEAN 2 is a medium-sized, red variety with mottled cuboidal-shaped seed, fortified with iron and zinc; matures within 60 - 75 days, having a yield potential of 1.6 to 2.2 $t \cdot ha^{-1}$ (http://www.sunrise.ug/news/201904/naro-releases-drought-tolerant-beans-with-power-bank-effect.html). Maize (*Zea mays* L.) varieties were: Longe 5 and Bazooka, developed by NARO and released in 2010 and 2016, respectively. Longe 5 is an open pollinated, drought tolerant variety, quality protein with double lysine and tryptophane. Resistant to Grey Leaf Spot, Maize Streak Virus, and moderately resistant to Northern Leaf Blight. Matures within 115 days, with yield

potential of 3 to 4 t·ha^{-1}
(http://dtma.cimmyt.org/index.php/publications/doc_view/186-dt-maize-vol-2-no-3-september-2013). Bazooka (Hybrid) is resistant to drought and moderately tolerant to Maize Lethal Necrosis (MLN) disease. Matures in 130 days, with yield potential of 9 - 10 t·ha^{-1}
(https://www.cimmyt.org/news/bazooka-maize-makes-a-bang-in-uganda/).

For a given farmer the experimental field was divided into two: one half was planted at rainfall on-set (early planting) while the other half was delayed/late-planted. Each plot of 11 m × 10 m was split into two, 5 m by 10 m sub plots, separated by a one-meter space. The two split sub plots were planted to different crop varieties. The experimental design was a split-split plot, with the main factor as planting date (early vs late); sub plot as fertilizer treatments; sub – sub plots as 2 maize and 2 bean varieties, factorially arranged over each fertilizer treatment. Three sub counties served as the blocks, six farmer groups per sub county as the replicates. In pure stand, beans were planted at 50cm by 20cm while for maize it was 75 cm by 60 cm. In intercrop, spacing was 90 cm between two maize rows, with one bean row in-between. Two seeds were planted per hole for both maize and beans. Early planting started at the onset of rains which was 4th March for Rakai in 2020 and 12th March for Nakasongola. During 2021, rainfall onset was 15th March in Rakai and 23rd March in Nakasongola. Late planting was done two weeks after rainfall onset. This is considered the minimum delay period though may extend up to a month or 45 days. Group members participated in planting the trials and were encouraged to regularly visit the trial field for on-spot checks, participatory monitoring, discuss emerging observations, experiential joint learning and evaluation.

Normal crop management practices (weeding, spraying) were carried out by the host farmer whenever required. From each 5 m × 10 m sub sub-plot, harvesting was performed from a 2 m × 10 m and 3 m × 10 m portion for beans and maize, respectively, by both the research team and farmer group members. The harvested beans and maize were hand-threshed and winnowed, then weighed, and 200 g sampled, labelled and taken to the laboratory for further processing, while the rest of the produce was left for the host farmer. For maize, the number of plants harvested was first counted to obtain the actual number of plants harvested, cobs removed from the marked portion then threshed. Data on actual maize plants harvested were later used to correct for a uniform plant population during yield computations. The trial host farmer was interviewed to obtain information on costs incurred from land opening to harvesting. In addition, information on practices admired, lessons learnt, and possible practices farmers were to adopt were recorded. Information obtained was compared with the farmer's record book and where costs data were not consistent, an average with the farmer's record was considered. In addition, anticipated farm gate price of beans and maize in the area was obtained so as to calculate the projected revenue from their sale.

2.2. Profitability Analysis

Profitability analysis of different CSA strategies was done using partial budgeting technique [25]. Partial budgeting relies on the ability to isolate costs and benefits that vary with introduction of new technologies. It assumes that as technology users make a switch from the business-as-usual practice, they anticipate to make savings either in terms of reduced costs, increased benefits or reduced use of resources to attain the same or more output per unit area. Partial budgeting was employed to determine the various costs that vary with technologies and their corresponding benefits. Items considered under the partial budget are listed in Table 1. The Gross Benefits (GB) and Benefit to Cost ratio (B/C) were estimated as shown in Table 1, item 5 and 7, respectively. The B/C ratio is an indicator of the profitability of a given strategy. A B/C ratio of one (1) is the break-even point implying that farmers recover all the total variable costs incurred. A B/C above one (1) implies that farmers recover the total variable costs and earn some profits. Below one (1) indicates that the practice is not economically viable and farmers are incurring losses.

2.3. Land Equivalent Ratio

In order to evaluate the most appropriate land saving method, land equivalent ratio (LER) was calculated for the intercrops across the different practices, as per [26]:

$$\text{LER} = Y_{Bi}/Y_{Bp} + Y_{Mi}/Y_{Mp}$$

Y_{Bi} = Yield of beans in intercropping (kg·ha^{-1}).

Y_{Bp} = Yield of beans in sole/pure stand (kg·ha^{-1}).

Y_{Mi} = Yield of maize in intercropping (kg·ha^{-1}).

Table 1. Items used in the partial budget used to determine the economic benefits of alternative CSA strategies.

Item	Description	Notes
1	Total variable costs	Cost of land rental (if any), ploughing; purchase of maize and bean seeds, fertilizers, manure, herbicides, pesticides, fungicides; labour for applying fertilizers, weeding, spraying, harvesting, transportation of produce from the garden, drying, threshing and winnowing
2	Farm gate prices[1] for 50-kg bags DAP, Urea, and 2.5 ton of cow manure	DAP = Ug. Shs. 150,000 (US$41.09); Urea = Ug. Shs. 130,000 (US$35.52); manure = Ug. Shs. 200,000 (US$54.79) per 2.5-ton truck including transport
3	Average yield (kg·ha^{-1})	As measured in the field for different treatments
4	Field price	Farm gate price of maize and beans per kg at time of harvest
5	Gross benefits	Adjusted yield × field price
6	Gross margins = Gross field benefits-total variable costs	Gross margins are not the same as net profit, because not all production costs are considered under the partial budget
7	$\left(\frac{\text{Benefit}}{\text{Cost}}\right) = \left(\frac{\text{Gross benefits}}{\text{total variale costs}}\right)$	A benefit to cost ratio equal to one (1), implies that for each 1 US$ invested in the total variable costs, farmers recover their 1 US$.

[1]Conversion rate: 1.0 US dollar equivalent to Ug. Shs. 3650/ = .

Y_{Mp} = Yield of maize in sole/pure stand (kg·ha^{-1}).

Land equivalent ratio is defined as the relative land area under sole crops that is required to produce the yields achieved by intercropping [27]. It is an important tool used to evaluate the advantages of intercropping systems; it measures the yield advantage obtained by growing two or more crops or varieties as an intercrop compared to growing the same crops as separate monoculture [28]. It shows the efficiency of intercropping for using the environmental resources compared with monocropping. Land equivalent ratio (LER) can be used to assess land returns from the pure stand yields and from each separate crop within the mixture [29]. A LER greater than 1.0 implies that for that particular crop combination, intercropping yielded more than growing the same number of stands of each crop as sole crops. A LER of less than 1.0 implies that intercropping was less beneficial than sole cropping [30].

2.4. Farmers' Acceptability of Different CSA Technologies and Practices

Action research approach [31] was used to assess farmer acceptability of different CSA options in this study. Besides participation of all stakeholders during the planning, conceptualisation and execution of the trials, we used a checklist to assess farmers' technology adoption process at different stages including awareness, experimentation, lessons learnt and technologies/practices to adopt. This would ultimately improve farmers' decision making and facilitate change in farmers' practices [32]. Working in groups, farmers willingly participated in all farm operations right from land preparation, planting, weeding, spraying and harvesting. They also paid regular visits to host farmers to check on the progress of trial field and discuss any emerging observations.

A first prerequisite for a farmer to apply a new technology is to be aware about its existence. More recently introduced technologies are often less well known than technologies that have been spreading over a longer period of time. Farmer awareness depends on the type of technology, the specific context, and farm and farmer characteristics. The supply, diffusion, and demand for information matters in increasing awareness. Willingness to learn even within a group varies, with the more eager members ready to actively engage in the search for information about farming. As part of awareness, we collected information on the lessons learnt about the technologies applied in the trial. Experimentation involved joint evaluation of the technologies and practices for farmers to decide if and when to use the technology. Farmers may also be constrained in their ability to apply a new technology, especially if capital and/or labour intensive [21]. In our trials, only two (out of 32 host farmers) managed to construct trenches and bunds, which had been demonstrated during the preparatory activities. For this reason, trenches and bunds were eliminated from the study design. After experimentation, farmers rely on their own experience and lessons to decide whether or not to take up the technology/practice. During the assessment we identified farmers group members who had started practicing the technologies/practices demonstrated (e.g. line planting) and those who are willing to continue using the various technologies.

2.5. Laboratory Procedures

Soil testing was done from the Soils Analytical laboratory of the National Agricultural Research Laboratories (NARL)-Institute, Kawanda according to [33]. Maize and beans grain samples were oven-dried at 70˚C in a paper bag to a constant weight so as to obtain percent moisture loss, which was used to adjust the field plot grain weights, and yield reported as kilograms per hectare. For maize, the moisture-corrected field weights were first adjusted for plant population before conversion to $kg \cdot ha^{-1}$.

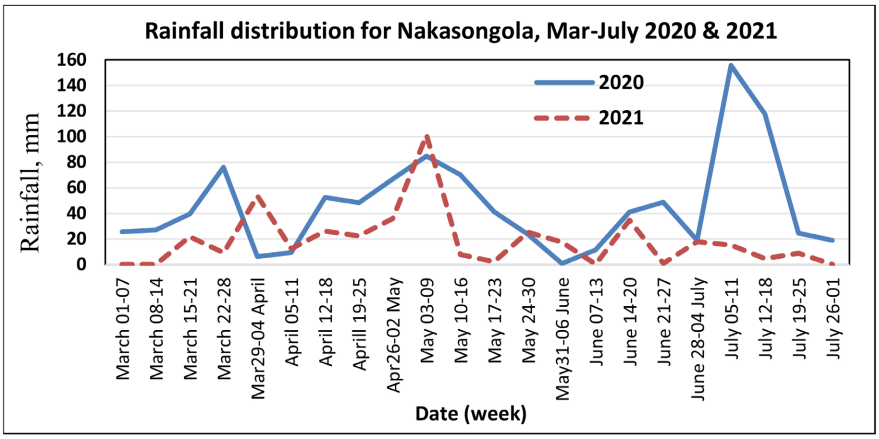
2.6. Statistical Analysis

The yield and profitability data were processed using Microsoft excel then exported to Genstat package, 11th Edition for statistical analysis using a generalised linear model (GLM) analysis of variance. Duncan multiple range test at 0.05 probability level was used to separate means when significant differences were evident. General linear regression was used to identify the most responsible yield influencing factor. Stepwise regression was used to obtain a better summary of the regression, *Mallow's* Cp was best selected for presentation of both the R^2 value and level of significance (p values). For qualitative data, IBM SPSS Statistics 20 software was used to analyze the farmers experience, technologies applied they still recorgnised, perceptions, lessons learnt, practices they accepted to continue to practice (adopt) and the various reasons towards the different technologies.

3. Results

3.1. Rainfall Distribution for Nakasongola and Rakai during the Two Growing Seasons

The first rain season started during mid-March during both years. In general, rain was more favourably distributed during 2020 than in 2021, especially during the mid-April to late May period, which is the peak of the growing season (**Figure 1**). On the other hand, very low rainfall was received during early to end of April; dry spells were also experienced in mid-May, early June, and from late June to late July. The data also shows that between March and July, the area received 1009 mm rainfall in 2020 compared to 418 mm during 2021. Apart from the poor distribution in 2021, the huge difference in total rainfall received could have greatly contributed to differences in crop performance during the two seasons. Similarly, for Rakai, the area received heavier and more favourably distributed rainfall between early April and mid-May of 2020 than 2021. In total 701 mm or rain was received during March to July of 2020 while in the same period, 429.8 mm was received in 2021 (**Figure 1**).



Rainfall distribution in Nakasongola

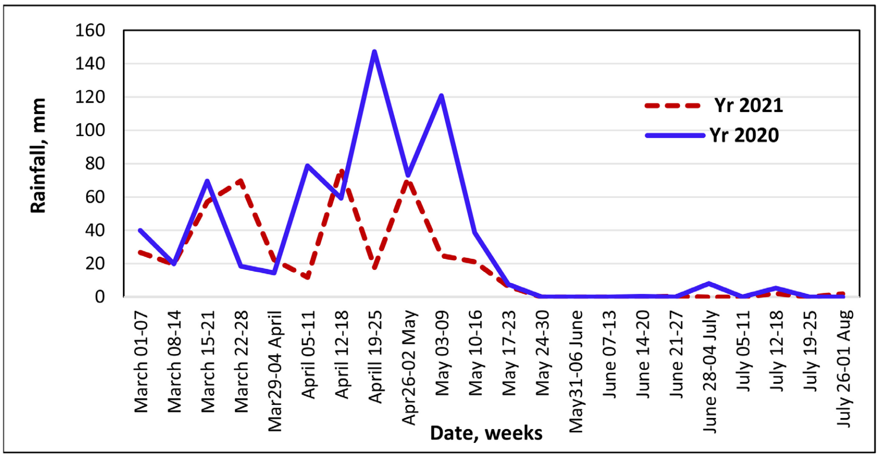


Figure 1. Rainfall distribution for Nakasongola and Rakai during the 2020A and 2021A growing seasons.

3.2. Soil Characteristics

Laboratory results indicated soil in Rakai to be moderately acidic, with medium organic matter content. Soil is low in P and Ca. Texture is predominantly sandy loam (**Table 2**). Nakasongola soil is sandier than Rakai, especially in Lwabiyata sub county, slight to moderately acidic, with pH levels generally within the optimum range for maize (pH 5.5 to 7.0) and beans (pH 6.0 to 6.5) growth. Organic matter content is low in both sub counties, but worse in Lwabiyata. Phosphorus is deficient in both sub counties; Potassium, Ca and Mg levels are also low.

3.3. Effect of Planting Date on Maize and Bean Yields and Profitability

Planting maize early resulted in significantly ($P < 0.001$) higher grain yields compared to late planting during both years (**Figure 2**). Maize yields dropped by 16% due to late planting in both years ($P < 0.001$). For beans, early planting resulted in significantly higher grain yield during 2021 season. There was 11% decline in grain yields during 2020 as a result of late planting. However, in 2021

Table 2. Selected soil characteristics for Rakai and Nakasongola districts.

	pH	OM	P	Ca	Mg	K	Sand	Clay	Silt	Textural
		---%--	-----------------------ppm--------------------				-----------------%-------------			Class
Rakai district, Kagamba sub county										
	6.0 ± 0.4	4.4 ± 2.1	5.3 ± 2.2	415 ± 206	144 ± 40	155 ± 77	66.6 ± 8.9	15.8 ± 3.7	17.6 ± 5.4	Sandy loam
Nakasongola district, Kalungi sub county										
	6.1 ± 0.5	1.64 ± 0.6	19.6 ± 18.1	444 ± 220	200 ± 96	274 ± 187	66.8 ± 9.9	17.2 ± 5.3	16.0 ± 4.6	Sandy loam
Nakasongola district, Lwabiyata sub county										
	6.3 ± 0.3	1.08 ± 0.4	3.30 ± 2.0	330 ± 110	150 ± 22	151 ± 21	78.5 ± 5.6	11.7 ± 2.8	9.8 ± 2.8	Sandy loam
Critical values	5.5	3.0	36.0	1640	87	73				

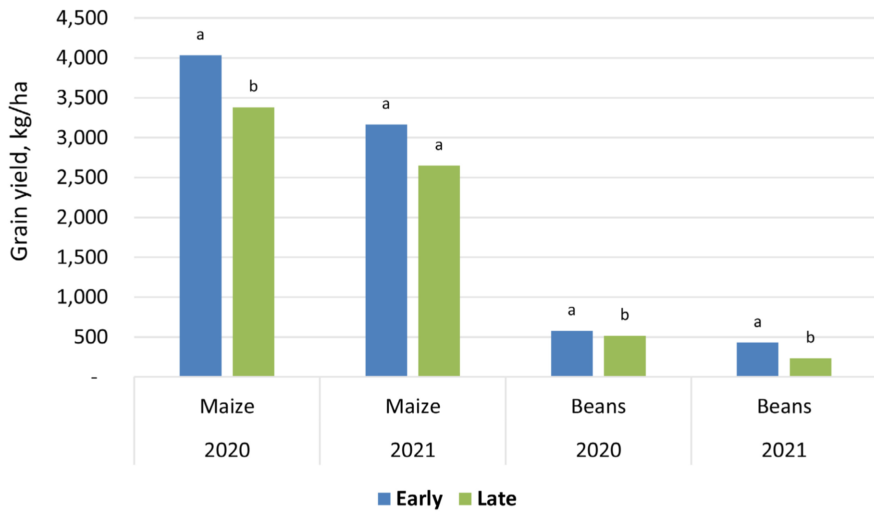


Figure 2. Maize and bean yield as affected by planting date, 2020-2021. [a,b]Grain yield of the same crop followed by same letter within the same year, are not significantly different (p = 0.05).

bean grain yields dropped sharply by 46% due to late planting, which was highly significant ($P < 0.001$) (Figure 2). Planting beans late caused an 18% and 43% drop in B/C ratio during 2020 and 2021, respectively. There was however an economic loss (BC = 0.826) during 2021. For maize, late planting resulted in a significant ($P < 0.001$) 14% and 28% drop in B/C during 2020 and 2021, respectively (Table 3).

3.4. Effect of Fertilizer Application on Maize and Beans Yield and Profitability

During 2020, fertilizer application increased maize grain yields significantly ($P < 0.001$), more so with manure compared to DAP or manure + DAP combination. During 2021, however, fertilizer application had no effect on maize yield (Table 4). On the other hand, bean yields significantly increased with application of DAP during 2020 and 2021, but not manure or manure + DAP combination.

Table 3. Effect of planting date on maize and beans profitability.

Plating date	Beans		Maize	
	2020	2021	2020	2021
	B/C ratio			
Early	1.656 ± 0.055[a]	1.446 ± 0.061[a]	1.772 ± 0.056[a]	1.675 ± 0.056[a]
Late	1.353 ± 0.046[b]	0.826 ± 0.039[b]	1.517 ± 0.050[b]	1.208 ± 0.050[b]
% drop in B/C	18.3%	42.9%	14.4%	27.9%

[#]Means within the same column followed by the same superscript are not significantly different (P = 0.05).

Table 4. Effect of fertilizer application on maize and beans yield.

Fertilizer treatment	Maize yield, kg/ha		Bean yield, kg/ha	
	2020[#]	2021	2020	2021
Control	3467 ± 104[bc##]	2848 ± 77[a]	515 ± 28.7[b]	288.5 ± 20.7[bc]
DAP	3958 ± 200[b]	2987 ± 132[a]	717 ± 56.6[a]	463.4 ± 36.6[a]
Manure	4904 ± 302[a]	3026 ± 157[a]	580 ± 68.5[b]	245.2 ± 27.8[c]
Manure + DAP	3369 ± 201[c]	2800 ± 213[a]	392 ± 40.2[c]	374.8 ± 71.1[ab]

[#]Means within the same column followed by the same superscript are not significantly different (P = 0.05); [##]±value indicates standard error of the mean.

During 2020, use of DAP increased B/C ratio for beans, although not significantly ($P > 0.05$). Use of manure on beans reduced the beans B/C, more so when combined with DAP ($P < 0.05$). Similar results were obtained during 2021 (Table 5). For maize, application of DAP or manure did not improve B/C; in fact, combined use of manure and DAP on maize significantly ($P < 0.05$) reduced the B/C ratio during both years.

3.5. Maize and Bean Yield and Profitability for Different Varieties

Maize yields were significantly ($P < 0.05$) higher for variety Bazooka than Longe 5 during both years, resulting in higher B/C for Bazooka than Longe 5 (Table 6). Bean yields and B/C were higher for NAROBEAN 2 than NABE 4, although not significantly different ($P > 0.05$).

3.6. Effect of Intercropping on Maize-Bean Yield, Land Equivalent Ratio (LER) and Profitability

Maize and beans yields were higher in pure stand compared to intercrops during both years. Results show that intercropping reduced maize yields by 25 and 16% during 2020 and 2021, respectively. On the other hand, bean yields dropped by 57 and 52% during 2020 and 2021, respectively due to intercropping (Table 7). These yield reductions were highly significant ($P < 0.001$). Land equivalent ratio (LER) values were significantly ($P < 0.001$) greater than 1.0 for the intercrops

Table 5. Effect of fertilizer application on maize and beans profitability.

Fertilizer treatment	Beans		Maize	
	2020#	2021	2020	2021
	B/C			
Control	1.553 ± 0.054ab##	1.664 ± 0.054a	1.774 ± 0.054a	1.386 ± 0.060a
DAP	1.756 ± 0.072a	1.765 ± 0.074a	1.774 ± 0.077a	1.232 ± 0.072a
Manure	1.493 ± 0.108b	1.567 ± 0.102a	1.641 ± 0.097a	1.273 ± 0.083a
Manure + DAP	1.012 ± 0.058c	1.045 ± 0.061b	1.078 ± 0.063b	0.961 ± 0.122b

#Means within the same column followed by the same superscript are not significantly different (P = 0.05); ##±value indicates standard error of the mean.

Table 6. Maize and bean yield and profitability as affected by difference in varieties.

	2020	2021	2020	2021
	Yield, kg·ha^{-1}		B/C	
	Maize			
Bazooka	4002a	3075a	1.727a	1.456a
Longe 5	3407b	2735b	1.562b	1.427a
	Beans			
NAROBEAN 2	568.0A	345.3A	1.511A	1.161A
NABE 4	529.0A	316.1A	1.498A	1.111A

#Means within the same column followed by the same superscript are not significantly different (P = 0.05).

Table 7. Effect of intercropping on maize-bean yield, land equivalent ratio (LER) and profitability.

	Maize yield#	Bean yield	LER	B/C	
	2020				
Sole crop	4440 ± 159a##	882 ± 45.3a	1.000b	Sole maize	1.743a
Intercrop	3337 ± 93b	381 ± 15.8b	1.241a	Intercrop	1.596b
				Sole beans	1.322c
	2021				
Sole crop	3242 ± 116a	504 ± 35.2a	1.000b	Sole maize	1.667a
Intercrop	2737 ± 66b	244 ± 14.1b	1.497a	Intercrop	1.328b
				Sole beans	0.750c

#Means within the same column and year, followed by the same superscript are not significantly different (P = 0.05); ##±value indicates standard error of the mean.

during both years. The B/C ratios were consistently higher for sole maize than intercrop and lowest for pure beans (P < 0.001).

3.7. Interactive Effects

3.7.1. Effect of Planting Date and Fertiliser Treatment on Bean Yield and Profitability, 2020

A significant (p = 0.002) interaction was observed between time of planting and fertilizer application during 2020. Application of DAP significantly (p = 0.002) increased the grain yields of early-planted beans over the control. When late planted, grain yields were significantly increased by application of manure without DAP (Table 8). Regarding profitability, results show that during a wet season (2020A), application of DAP increased B/C for the early-planted but not the late-planted crop. Manure use reduced the B/C for early planted beans, while for the late planted crop, a slight increment in B/C was observed. Combined application of DAP and manure further reduced B/C significantly, whether early or late-planted.

3.7.2. Interactive Effects of Fertilizer Application and Planting Pattern on Bean Yields

Application of DAP increased bean grain yields, more so in pure stand. Manure use slightly improved bean yields both in pure stand and in intercrop, but not significantly. Combined use of manure with DAP reduced bean grain yields, especially in pure stand (Table 9). Regarding profitability, application of DAP significantly increased bean production B/C especially for the pure bean stand (P < 0.05). Manure application had no effect on B/C whether in pure stand or intercrop. In fact, combined application of manure and DAP on beans, whether as intercrop or pure stand, decreased B/C.

3.7.3. Interactive Effects of Fertilizer Application and Planting Pattern on Maize Yield and Profitability

Table 10 presents results on the interactive effects of fertilizer use and planting pattern on maize yield and profitability. Results show that during a low rainfall season (2021), maize yields were not significantly (P > 0.05) improved by DAP or manure use, both in pure stand and in intercrop. Combined use of manure and DAP significantly (P < 0.05) reduced maize yields in pure stand, but not in

Table 8. Bean yield and profitability as affected by time of planting and fertilizer application, 2020.

	Bean yield, kg/ha		B/C ratio beans	
	Early[#]	Late	Early	Late
Control	545 ± 44.8[b##]	486 ± 35.8[b]	1.695 ± 0.083[ab]	1.412 ± 0.067[a]
DAP	795 ± 88.0[a]	639 ± 70.7[ab]	2.005 ± 0.112[a]	1.507 ± 0.073[a]
Manure	420 ± 61.0[b]	740 ± 112.1[a]	1.369 ± 0.135[c]	1.617 ± 0.166[a]
Manure + DAP	479 ± 62.6[b]	304 ± 45.7[c]	1.223 ± 0.067[c]	0.801 ± 0.080[b]

[#]Means within the same column followed by the same superscript are not significantly different (P = 0.05). [##]±value indicates standard error of the mean.

Table 9. Effect of fertilizer application and planting pattern on bean yields and profitability, 2020.

Fertilizer treatment	Bean yields, kg/ha		B/C	
	Pure stand	Intercrop	Sole/pure stand	Intercrop
Control	800 ± 61.2[b]	373 ± 20.4[ab]	1.236[bc]	1.712[b]
DAP	1181 ± 100.1[a]	482 ± 40.5[a]	1.768[a]	1.750[a]
Manure	969 ± 124.4[ab]	386 ± 45.4[ab]	1.356[b]	1.561[b]
Manure + DAP	659 ± 79.2[c]	260 ± 26.7[b]	0.938[c]	1.049[c]

[#]Means within the same column followed by the same superscript are not significantly different (P = 0.05).

Table 10. Interactive effects of fertilizer application and planting pattern on maize yield and profitability during 2021.

Fertiliser treatment	Maize, kg/ha		Maize B/C	
	Intercrop	Sole	Intercrop	Sole
Control	2685[a]	3174[ab]	1.425[a]	1.905[a]
DAP	2817[a]	3328[ab]	1.298[ab]	1.292[b]
Manure	2683[a]	3713[a]	1.307[ab]	1.860[a]
Manure + DAP	2905[a]	2590[b]	0.953[b]	1.036[b]

[#]Means within the same column, followed by the same superscript are not significantly different (P = 0.05).

intercrops (Table 10). On the other hand, B/C ratio was reduced when DAP and/or manure were applied, both in sole/pure stand and in intercrop.

3.8. Multiple Regression and Model Selection for Predicting Bean Grain Yield and Profitability

3.8.1. Multiple Regression and Model Selection for Bean Yield, 2020

All regression subsets for bean yield were positive, weak with varying levels of significance. When all factors were considered individually, planting pattern (sole vs intercropped) accounted for the highest percent contribution to bean yield (Table 11). With two factors considered simultaneously, R^2 value improved, and was best when planting pattern was combined with fertilizer treatment. Adding planting date and bean variety improved the R^2 slightly but not significantly. Maximum R^2 value of 37.73 was obtained when the four factors were considered. Meanwhile, the Cp value reduced with increase in the number of factors simultaneously combined.

The R^2 value for B/C was higher for fertilizer treatments when each factor was individually considered and this was followed by planting date and planting patterns, all of which were weak, positive but significant (Table 12). There was a general increase in the R^2 value when two factors are combined. Combining more factors increased the R^2; the best regression coefficient was observed with three factors excluding bean variety.

Table 11. Regression coefficients for bean yield, 2020.

Adjusted R^2	Cp	df	Planting date (1)	Fertiliser treatment (2)	Bean variety (3)	Planting pattern (4)
Subset with 1 item				p values		
31.00	37.53	2	-	-	-	0.000
5.61	186.11	4	-	0.000	-	-
0.25	215.69	2	0.168	-	-	-
<0.00	217.40	2	-	-	0.361	-
Subset with 2 items						
37.30	7.46	5	-	0.000	-	0.000
31.83	36.57	3	0.101	-	-	0.000
31.53	38.25	3	-	-	0.281	0.000
5.93	184.77	5	0.138	0.000	-	-
5.57	186.82	5	-	0.000	0.357	-
0.21	216.35	3	0.169	-	0.362	-
Subset with 3 items						
37.7	6.22	6	0.073	0.000	-	0.000
37.34	8.23	6	-	0.000	0.27	0.000
31.86	37.29	4	0.101	-	0.282	0.000
5.89	185.49	6	0.139	0.000	0.359	-
Subset with 4 items						
37.73	7	7	0.073	0.000	0.271	0.000

Table 12. Regression coefficients for bean B/C, 2020.

Adjusted R^2	Cp	Df	Planting date (1)	Fertiliser treatment (2)	Bean variety (3)	Planting pattern
Subset with 1 item				p values		
10.69	36.2	4	-	0.000	-	-
4.39	61.93	2	0.000	-	-	-
3.09	67.59	2	-	-	-	0.000
<0.00	82.29	2	-	-	0.852	-
Subset with 2 items						
15.15	17.79	5	0.000	0.000	-	-
13.84	23.45	5	-	0.000	-	0.000
10.45	38.15	5	-	0.000	0.843	-
7.50	49.18	3	0.000	-	-	0.000
4.13	63.88	3	0.000	-	0.848	-
2.83	69.54	3	-	-	0.849	0.000

Continued

Subset with 3 items						
18.32	5.04	6	0.000	0.000	-	0.000
14.92	19.75	6	0.000	0.000	0.839	-
13.61	25.41	6	-	0.000	0.840	0.000
7.25	51.14	4	0.000	-	0.846	0.000
Subset with 4 items						
18.1	7	7	0.000	0.000	0.836	0.000

3.8.2. Regression Models for Maize-Bean Yield and Profitability under Different CSA Approaches

During both seasons (2020 & 2021) beans yields were most influenced by planting pattern (intercropping vs sole cropping), fertilizer treatment (use of DAP) and planting date (early vs delayed/late, Table 13). Results also show that during a normal rainfall season (2020), planting pattern, fertilizer use (DAP) and planting date significantly influenced beans profitability. However, in case of a *predicted* low rainfall season (2021), bean profitability is most influenced by planting date and planting pattern; fertilizer use on beans is not profitable. It is worth noting that difference in varieties had no significant influence on bean yield and profitability during both years.

For maize, all four factors (planting date, fertilizer use, varieties and planting pattern) influenced yield and profitability during 2020. However, during a low rainfall season (2021) maize yield was most influenced by planting date, variety planted and planting pattern, and not fertilizer management. On the other hand, maize profitability depended on planting date, fertilizer management and planting pattern, but not on variety planted.

3.9. Farmer Acceptability of the Different CSA Technologies and Practices

3.9.1. Farmers' Lessons

There were many lessons learnt by farmers on different technologies and practices covered in this study and these varied significantly ($P < 0.05$) from each other. Most farmers (40%) indicated that they had learnt the importance of timely planting, 24% indicated advantages of the varieties used in the study, 21% had learnt the use of fertilizers, while 14.7% mentioned cropping arrangement (intercrop vs sole crop) (Figure 3).

Farmers gave a number of reasons for the lessons learnt. For most farmers (42%) timely planting results in higher yields for the early planted crops and reduced risks of pest damage (15.8%); late planted crops are also affected by extreme weather events (15.8%) (Table 14). On varieties, 29.4% of farmers learnt that they should plant Bazooka under good rains and Longe 5 if a drought is expected. Secondly, Bazooka produced two cobs, while Longe 5 produced one bigger cob, as noticed by 23.5% of the respondents. In addition, 17.6% of respondents

Table 13. Summary of best-fit multiple regression models for maize-bean yield and profitability under different CSA approaches.

Parameter	Combination	Adjusted R^2	Cp	Planting date	Fertilizer treatment	Bean variety	Planting pattern
				p values			
2020							
Bean yield	A[#]	31.5	37.5	-	-	-	0.000
	B[##]	37.7	7.0	0.073	0.000	0.271	0.000
B/C	A	10.7	36.2	-	0.000	-	-
	B	18.1	7.0	0.000	0.000	0.836	0.000
2021							
Bean yield	A	15.4	86.2	-	-	-	0.000
	B	31.5	7.0	0.000	0.000	0.477	0.000
B/C	A	16.8	70.5	-	-	-	0.000
	B	30.1	7.0	0.000	0.122	0.656	0.000

Parameter	Combination	Adjusted R^2	Cp	Planting date	Fertilizer treatment	Maize variety	Planting pattern
				p values			
2020							
Maize yield	A	9.9	68.1	-	-	-	0.000
	B	24.0	7.0	0.000	0.000	0.000	0.000
B/C	A	12.0	24.2	-	0.000	-	-
	B	16.7	7.0	0.000	0.000	0.018	0.046
2021							
Maize yield	A	4.9	26.0	0.000	-	-	-
	B	10.9	7.0	0.000	0.546	0.003	0.000
B/C	A	13.6	27.0	0.000	-	-	-
	B	19.7	7.0	0.000	0.000	0.685	0.000

A = Best model with single explanatory variable, B = Subset with four variables.

Table 14. Reasons given for the farmers lessons learnt.

Reasons	Planting time	Variety	Fertilizer	Sole vs intercrop
Higher yields for early planted crops	42.1	-	-	-
Timely planting reduces risks like pest damage	15.8			
Late planted crops affected by extreme weather events	15.8			
Early land preparation	10.5			
Early planted crops fetch higher prices	10.5			
Intercrop when early planted and not for late planting	5.3	-	-	-

Continued

Plant Bazooka under good rains and Longe 5 in drought prone conditions	-	29.4		
Two cobs for Bazooka but bigger for Longe 5	-	23.5	-	-
NAROBEAN 2 grows faster	-	17.6	-	-
Higher growth vigor with Bazooka	-	17.6		
All maize varieties good provided sufficient rainfall distribution	-	5.9	-	-
All varieties equally affected by drought	-	5.9	-	-
Fertilizer use leads to higher yields	-	-	63.0	
Manure use is good and gives higher yields	-	-	18.5	-
Fertilized plots less affected by drought	-	-	7.4	
Farmer to stop selling manure but apply in his garden	-	-	3.7	-
Bigger seed size with manure followed by DAP and least in unfertilized	-	-	3.7	-
Not beneficial to fertilize fertile fields	-	-	3.7	-
Sole cropping of beans is better than intercropping	-	-	-	61.1
Intercropping is better due to double benefits	-	-	-	22.2
Intercropping reduces bean growth	-	-	-	5.6
Appropriate spacing of maize and beans in mono and intercropping	-	-	-	5.6
Intercrop if early planted and vice-versa	-	-	-	5.6
Total	**100**	**100**	**100**	**100**

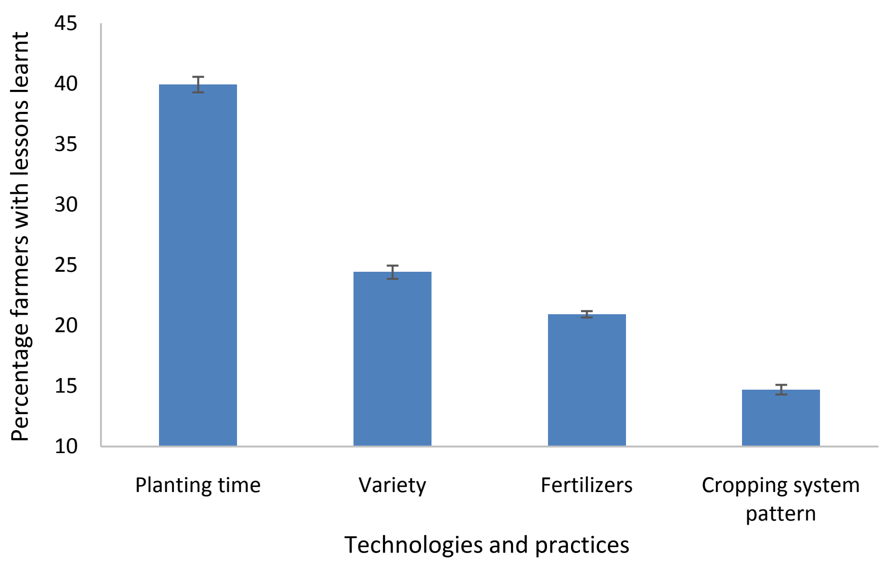


Figure 3. Farmers' lessons learnt from different climate smart technologies and practices.

reported a higher growth vigor with Bazooka, and that NAROBEAN 2 grows faster. On fertilizers, 63% of farmers recognized that fertilizer use leads to higher yields, with 18.4% reporting manure use to be a good practice (3.7% indicated they would stop selling manure and use it in their gardens instead). Interestingly, 7.4% of famers recognized that fertilized plots are less affected by drought.

Most farmers (61%) learnt that monocropping of beans is better than intercropping. However, 22.2% learnt that intercropping is better due to the double benefits it gives, while 5.6% indicated that intercropping is better when the crop is early-planted.

3.9.2. Technologies and Practices That Farmers Accepted to Adopt

Many (58%) of the farmers accepted to adopt early planting, use of fertilizers (47%) especially manure (41.2%), improved varieties (40%), and sole cropping (40%). However, 45.8% of respondents indicated that they were to adopt more than two of the above practices combined (**Table 15**).

4. Discussion

Generally maize and bean yields were higher in 2020 compared to 2021, attributed to higher rainfall received in 2020 than in 2021 (**Figure 1**). Early planting produced significantly (P < 0.001) higher maize and bean yields compared to late planting (**Figure 2**). Results also show that both maize and beans are better grown when early planted, supplemented with DAP. This translated into higher

Table 15. Technologies and practices that farmers accepted to adopt.

Practices to adopt	Planting time	Variety	Fertilizer	Sole vs intercrop	Other practices
Early planting	58.1	-	-	-	-
No mention of early planting	41.9	-	-	-	-
Improved varieties	-	40			
Longe 5	-	20	-	-	-
Bazooka	-	20	-	-	-
NAROBEAN 2	-	20	-	-	-
Fertilizers	-	-	47.1	-	-
Manure	-	-	41.2	-	-
DAP	-	-	11.8		
Sole cropping	-	-	-	40	
Monocrop beans	-	-	-	30	-
Intercropping	-	-	-	30	-
More than two of the above practices	-	-	-	-	45.8
Line planting and proper spacing	-	-	-	-	25.0
Line planting	-	-	-	-	12.5
Ploughing using a tractor	-	-	-	-	8.3
Timely and appropriate weeding	-	-	-	-	4.2
Planting using a peg	-	-	-	-	4.2
Total	**100**	**100**	**100**	**100**	**100**

B/C for the early-planted compared to the late-planted crops (**Table 8**). The observed decline in maize yield and profitability due to delayed planting is consistent with findings by [34] in Zambia. Baum *et al.* [35] observed that optimal fertiliser application has economic benefits to the farmer where it led to increased productivity at early-planting. Results also show that in case of delayed planting or during a predicted low rainfall season, use of manure is beneficial, but may not be profitable for short-season crops possibly due to its slow mineralization rate [36] and relative high cost if purchased. This cost can be reduced if a farmer can use home-generated manure. In the case of the sites of this study, cattle grazing is a common activity and farmers can either freely or cheaply obtain manure at their farms. The beneficial effects of using organic materials (compost, animal and chicken wastes, etc.) in improving soil moisture, fertility and crop drought survival has been widely documented [37] [38] [39]. Furthermore, manure is a slow-release fertiliser material, so its benefits can last much longer than the short season annual crops do. Results also show that DAP is more beneficial on sole bean crop than intercrop (**Table 9**). Combined use of manure and DAP reduced bean yields and profitability in pure stand and intercrop, hence not advisable.

Intercropping reduced the yield of both maize and beans. The B/C ratio was highest for sole maize followed by intercrop and least for beans (**Table 7**). This is due to higher yields and reduced input use in case of pure maize compared to pure beans or intercrop system. In Tanzania on the contrary, [40] reported that maize-bean intercrop was more profitable than sole maize. According to [41] although intercropping reduces the yield of individual crops, the reduction is compensated by the collective yield and further increase in net profit to the farmer. Results also show that LER values were greater than 1.0, indicating that intercropping is a more effective system for utilizing the same piece of land, compared to pure stand. Similarly, [42] found LER for maize-bean intercrop of greater than 1.0. Amanullah [41] and [43] reported that intercropping leads to better use of physical resources (solar radiation, mineral nutrients and water), provide higher labour productivity than sole cropping and reduces risk as compared with sole cropping. Intercropping also offers advantages in weeds, pests and disease management, transfer of the biologically fixed N to maize, insurance against crop failure to small holders, and control of erosion by covering a large extent of ground area [44].

In Ethiopia, [45] reported a yield advantage when maize and beans were intercropped as opposed to sole cropping; while bean yields were significantly reduced by intercropping, maize was not. Getahun and Seltene [45] recommended that there is need to find a compatible bean variety to increase production in the bean-maize intercropping. Results of present study show that profitability of a maize-bean intercrop was highest with variety Bazooka compared to Longe 5 (**Table 6**). Based on this, intercropping Bazooka with any of the two bean varieties would be feasible, but NAROBEAN 2 presents a slightly better option in terms of yield (Table 6) as well as marketability (as indicated by farmers). For highest financial benefit under the weather, market and other factors prevailing during the study period, a farmer would be better off planting Bazooka in pure stand, while for food security, intercropping Bazooka with beans would be most preferred.

Multiple regression analysis showed that bean yield was most influenced by planting pattern (sole or intercropped), followed by fertilizer use, then planting date. On the other hand, R^2 value for B/C showed that bean profitability was most influenced by fertilizer use, followed by time of planting and planting patterns (Table 13). The best R^2 value was observed with 3 factors excluding bean variety. Thus, a farmer may plant any bean variety together with all the tested technologies/practices. For maize, all four factors (planting date, fertilizer use, varieties and planting pattern) influenced yield and profitability during the good rainfall 2020A season. However, during a low rainfall season (2021) maize yield was most influenced by planting date, type of variety planted and planting pattern, and not fertilizer management (Table 13). Solubility, sorption and uptake of fertilizer nutrients is highly affected by soil moisture. On the other hand, maize profitability depended on planting date, fertilizer management and planting pattern, but not on variety planted. Overall, results show that planting date and planting pattern influence maize-bean yield and profitability. Seasonal differences affect fertilizer use benefits due to its influence on yield and profitability. Unlike beans, difference in varieties affect maize yield and may also influence profitability. For decision making, this means that farmers need timely field preparation, and timely acquisition of the right inputs, to facilitate planting at the onset of rains using the appropriate planting arrangement.

Results of this study also emphasize the need to promote the different CSA approaches in combination rather than singly. Indeed, based on their experiences and lessons learnt during this study, 46% of farmers indicated that they were to adopt more than two of the practices tested. Corner-Dollof [46] suggested that introduction of multiple CSA approaches might be more effective than providing a singular path for farmers. This would allow them to pick and choose what works for them and their communities and provide more opportunities for uptake. In South Africa, [47] reported that during wet season, optimal fertiliser application on early-planted maize increased productivity, resulting in economic benefits to the farmer. Net farm income responds positively to improved crop variety or fertilizer when they are adopted in isolation as well as in combination, but the effect is greater when these practices are combined. From a study of the adoption of complementary CSA technologies in Tanzania, [48] concluded that "inter-related technologies should be promoted as a package or bundled while taking into consideration household and farm-level constraints to adoption".

5. Conclusions

Early planting of maize and beans increases yield and profitability, especially when DAP is applied. In case of delayed planting or during a predicted low rainfall season, manure use is beneficial and likely more profitable using cheap home-generated manure. Planting Bazooka in pure stand is as profitable as intercropping it with beans, meaning that for food security, a farmer is better off intercropping. Although intercropping reduces yields of both maize and beans, it is more profitable than beans grown in pure stand. Profitability was higher when CSA practices (early-planting, fertilizer use and intercropping) are used in combination, rather than singly. Thus, in upscaling CSA practices, we need to be mindful of the costs associated with different technologies and practices, the target enterprise, its intended purpose, as well as the market dynamics, so that the farmer does not incur losses. A combination of CSA practices is always more profitable than the individual practices promoted singly. Farmers' lessons stressed the importance of early planting and fertilizer use; however, majority indicated they were to adopt more than two of the practices tested.

Recommendations

Farmers increasingly face a number of challenges with regard to farm-level decisions in the midst of climate change-related risks. This study has demonstrated that early planting is a critical decision that a farmer should make since it affects the resultant yield and profitability of maize and beans. Intercropping is another yield determining factor, especially for beans. For commercial production, farmers are better off planting maize as pure stand, but for food security, intercropping is more beneficial. Fertilizer (DAP) use is critical for both maize and beans, more so when the crops are early planted; however, in case of late planting, manure use is advisable. Profitability is better with higher-yielding varieties such as Bazooka. These technologies and practices should be promoted in combination rather than singly, for easier adoption.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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