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Abstract

This paper analyses the financial cost and benefit of adopting two different bundles of climate-smart agriculture (CSA) practices, which are tailored for the diverse conditions that prevail in southern Malawi. The results show the integration of CSA practices, including soil conservation, agroforestry, and livestock diversification, into conventional maize-legume and maize monocrop systems is profitable for farmers. Moreover, the profitability of these systems increases under extreme weather conditions that occur with increasing frequency in the region. However, the upfront costs and cost variability associated with the adoption of these CSA scenarios is high relative to conventional practices. In addition, while the Net Present Value is positive for the CSA scenarios, the monetary returns are small and are spread over a long investment period. These factors act as significant barriers to adopting CSA practices. Supporting farmers through climate financing or other mechanisms to make long-term private investment in CSA, based on the public benefits these investments generate for the environment, is critical for achieving widespread adoption.

Keywords: climate change, adaptation, climate smart agriculture, cost benefit analysis, Malawi.

JEL codes: D61, Q12, Q18, Q54, N57.

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1 Introduction

Malawi's economy, and the livelihoods of its people, are extremely vulnerable to the adverse effects of climate change. Climate-dependent sectors, such as agriculture and agriculture-related industries, are the backbone of the country's economy. The agricultural sector contributes approximately 30 percent to national gross domestic product (GDP) and provides employment for over 80 percent of the population (World Bank Development Indicators, 2020). More than 90 percent of all agricultural production in the country is rain-fed and only 4 percent of the total cultivated land in the country is irrigated (Murray *et al*., 2016).

The vulnerability of rain-fed production systems to adverse rainfall patterns is compounded by the limited capacity of rural populations in Malawi to cope with and adapt to these events. This is due to the deep and widespread poverty in rural areas, where over 80 percent of the poor in Malawi live (World Bank, 2020). For many poor rural households, agricultural production is geared primary toward meeting short-term household food consumption needs, which may limit their capacity to make longer-term, and more risky investments in their farms.

The vulnerability of resource constrained rural households in Malawi is likely to intensify in coming years as a result of climate change. The latter is increasing the frequency of adverse weather events in Malawi, such as droughts and floods, and is directly linked to rising temperatures. Between 1960 and 2006, mean temperatures in Malawi have increased by 0.9 °C, and it is likely that they will increase by an additional 2.3 °C by 2070 (CIAT and World Bank, 2018). Rainfall projections for Malawi are more uncertain, but averages across different projection models show a reduction in precipitation of 3.2 percent by 2070 (Global Facility for Disaster Reduction and Recovery, 2011). Without significant investments to improve the capacity of smallholders to adapt to these changing conditions, opportunities for economic growth, poverty reduction and better food security and nutrition in Malawi will be further constrained.

Policymakers in Malawi recognize the challenges posed to the country by climate change. As part of its response, the government prioritizes the adoption of farm practices and farm technologies that are in line with the concept of "climate-smart agriculture" (CSA). While the specific practices and technologies vary by agro-ecological and socio-economic context, in general CSA practices are intended to increase the productivity and resilience of agriculture to climate change, while also contributing to mitigation benefits where feasible.

However, despite a significant policy commitment to advancing CSA in Malawi, the adoption of farm practices associated with CSA in the country remains low (Dougill *et al*., 2017; Maggio and Asfaw, 2020; CIAT and World Bank, 2018). Understanding the costs of adopting CSA practices to farmers and the benefits that may accrue as a result of adoption is critical for designing policies and programmes to promote CSA in Malawi. A robust financial analysis of CSA practices can provide valuable insights into their profitability, upfront investment costs, and the sensitivity of the investments to exogenous shocks, such as market and weather elated shocks. These insights can help to shed light on potential adoption barriers and project interventions to address these.

In this paper, we conduct an in-depth cost benefit analysis of two CSA scenarios that are tailored for different production systems found in the southern Malawian districts of Blantyre, Neno, Phalombe, and Zomba. The first scenario is adapted to hot and arid conditions and marginally larger land-holdings, which prevail in Neno and segments of Zomba district. This CSA scenario entails the integration of maize monocropping systems with agroforestry trees, goat raising, and soil erosion prevention practices. The second scenario is compatible with small landholdings, typical of Blantyre, large parts of Zomba, and Phalombe Districts. It involves the integration of legume intercropping systems with agroforestry trees and soil erosion-prevention practices.

The analysis shows that relative to business-as-usual practices in these districts, the CSA scenarios are profitable under a range of market and weather related risks. However, they also entail substantial upfront costs to farmers, which limit their adoption. Moreover, while the CSA scenarios analysed are profitable, the profits per hectare are relatively small and may not be sufficient to prompt farmers to autonomously change their farming practices. Policy and programmatic interventions to diffuse the adoption costs and risks of transitioning to the CSA practices are, therefore, needed for achieving more widespread adoption.

2 Study setting

The present analysis focuses on the southern Malawian districts of Blantyre, Neno, Phalombe, and Zomba. Despite their geographical proximity, these districts are heterogeneous in terms of their biophysical characteristics, population pressures, and land availability (see Table 1). These conditions shape the types of agricultural activities and farm practices that prevail in the districts, and subsequently the range of feasible and appropriate CSA scenarios that can be adopted. Blantyre, for example, has a total population of 417 433 persons distributed in an area of 2 012 km^2, with a population density of 189 persons per km^2. Farmers in Blantyre have average land-holding size of 0.4 hectares, which push them towards land management practices that can maximize output per scarce unit of land. The district capital (Boma) is the economic centre of southern Malawi. This creates market opportunities in the district for a wide range of agricultural products. Indeed, Blantyre is home to numerous agricultural trading firms, which purchase maize, legumes, and other products for local and international markets. Small land sizes combined with good market conditions explains the high rate of adoption of maize-legume intercropping in the district (Table 1).

Phalombe is the second smallest district in southern Malawi, with an area of 1 323 km^2, equal to about 1.4 percent of the total size of the country. Despite its small area, Phalombe District has a large population and thus a high population density. In Phalombe the population density is 325 persons per km^2, well above the national average of 139 persons per km^2. As a result, Phalombe district has the second smallest average land-holding size in the region, with an average land-holding of 0.5 hectares. Similarly to Blantyre, farmers in Phalombe frequently adopt legume intercropping to maximize returns to their small land areas.

Zomba district is also densely populated district, with a population of about 685 700, distributed along an area of 2 363 km^2, and a population density of 230 persons per km^2. Again, population pressure plays a key role in reducing the availability of land to farmers, who farm on average to 0.5 hectares of land. However, Zomba exhibits a different prevalence of cropping system compared to Blantyre and Phalombe (see Table 1). Maize monocropping is more dominant in the district (45 percent) than intercropping (17 percent). In small pockets of Zomba livestock is feasible.

Finally, Neno observes a slightly different pattern compared to the three districts above. Neno District has a lowest population density, 81 persons per km^2, compared to the other districts included in this study. As a result, average land holdings are larger, averaging 1.3 hectares. Low population densities in the district create opportunities for livestock rearing. Indeed, large parts of the land of the district (56.97 percent) is under grassland which can be used for grazing. Maize is the prevalent crop grown in 90 percent of the small landholding and 70 percent of the large landholdings. This is done mostly in monocrop, with 46 percent of farmers growing maize as a monocrop. By contrast, only 5 percent of households adopt maize-legume intercropping.

Table 1. Population density, farm size, and farm systems in Blantyre, Phalombe, Neno and Zomba

District	Population	Total surface (km^2)	Population density (pop/km^2)	Average land-holding (ha)	Share of maize monocropping	Share of maize-legume intercropping
Blantyre (rural)	417 433	2 012	189	0.4	0.43	0.46
Phalombe	429 450	1 323	325	0.5	0.09	0.22
Zomba	685 700	2 363	230	0.5	0.45	0.17
Neno	138 300	1 561	81	1.3	0.46	0.05

Source: District's socio-economic profile (2017) and IHPS (2013).

The promotion of CSA has increased substantially in recent years throughout Malawi. According to a study commissioned by the Malawi Climate Smart Agriculture Alliance (MCSAA), more than 308 stakeholders implemented CSA projects in the country between 2013 and 2016. These projects targeted more than 900 000 household, or about 30 percent of the rural population. However, there is an observed lack of coordination among various CSA stakeholders, and there is a recognized need for a coherent CSA policy framework to guide implementation of CSA technologies and approaches, as well as linking these with the climate change policy framework.

The districts considered in this paper have observed an influx of agricultural projects that include specific CSA components. Among others, the European Union has funded the GCCA project, which provided EUR 6.8 million to strengthen community resilience to climate change in Blantyre, Neno, Phalombe and Zomba. The project utilizes farmer field school approaches to transfer knowledge on a range of CSA practices to 172 800 individuals, including practices included in the CSA scenarios analysed in this report: soil and water conservation, conservation agriculture (including legume intercropping), and agroforestry.

3 Selection of scenarios

Two prevalent baseline production scenarios have been identified, which are representative of the conventional farming systems in the research area and of the contextual factors discussed in the background section above. The first scenario (BAU1) is found in Neno District, and pockets of Zomba District. In these areas, farmers typically practice extensive maize monocropping (mostly for home consumption), with very sporadic low input small livestock rearing. The second baseline scenario (BAU2) is a maize-legumes intercropping system, where maize and legume seeds are sown in the same planting station, rather than in intercropped rows. This system requires less management and is less labour intensive than row intercropping, but also leads to competition between plants for soil moisture and results in lower yield for both crops. This "traditional intercropping system" is common in Blantyre, Phalombe, and in part of the Zomba district. In these areas, land constraints limit the ability of farmers to own livestock, and market access conditions are less constrained.

The prevalence of these two distinct baseline scenarios is a function of local contextual factors, including variation in market accessibility, and labour and land availability. Due to the context specificity of the two systems, major departures from these baselines are very unlikely in both areas. Based on this, context appropriate, climate-smart alternatives to the baseline scenarios were identified. These alternative scenarios (CSA1 and CSA2) build on the existing baseline production scenarios, the CSA practices being promoted in the districts, and respect the localized constraints that farmers face in their areas of operation.

The first CSA system (CSA1) is compatible with larger land holdings of 1 hectare and above. This system improves the resilience and performance of maize monocropping by including leguminous trees (*gliricidia trees*) on the plot, adding contour ridges during lands preparation to capture rainfall and limit erosion, and by diversifying household income through the integration of more intensive goat raising into the system. Based on discussions with local agricultural extension officers and other CSA experts, the specific elements of this system were selected to fit within the specific opportunities and constraints faced by farmers in the district. For example, integrating leguminous agroforestry trees into maize monocropping systems was selected instead of legume intercropping, because legume production is not common in the district, and agroforest trees can provide additional feed sources for goats, while contributing to improvements in maize production through atmospheric nitrogen fixation. Goat raising was selected for their tolerance to high temperatures which prevail in the district, and the existence of local markets for goats. Finally, contour ridges can help improve the productivity and resilience of maize system by enabling long term improvements in soil quality and moisture retention capacity. These ridges involve significant additional labour during the first year of adoption, but under normal conditions they can be restored before the new planting season with lower investment than other land-management techniques.

The second alternative system (CSA2) is tailored for farmers with smaller land holdings, usually around 0.4 hectare or 1 acre, and improves maize-legume intercropping system through the integration of a leguminous tree belt around the plot, and the preparation of contour ridges to improve resilience to low and high rainfall conditions. As with CSA1, these practices were selected to fit within the existing baseline systems in the districts, while being attentive the challenge of limited land available for field expansion or livestock rearing.

Table 2. Baseline and alternative scenarios of the analysis

Baseline scenario 1 (BAU1) in Neno and Zomba	Alternative scenario 1 (CSA1) in Neno and Zomba	Baseline scenario 2 (BAU2) in Blantyre, Phalombe and Zomba	Alternative scenario 2 (CSA2) in Blantyre, Phalombe and Zomba
Maize monocropping	Maize monocropping with gliricidia tree on the plot (agroforestry), goat raising, and soil erosion-prevention practices (contour ridges)	Legume intercropping: maize+pigeon pea	Legume intercropping (maize+pigeon pea) with gliricidia tree belt around the plot (agroforestry) and soil erosion-prevention practices (contour ridges)

Source: Authors' own elaboration.

4 Research design and analysis

The cost benefit analysis contained in this study is based on data collected through interviews carried out with farmers and other key informants in the districts of Blantyre, Neno, Phalombe and Zomba in October 2019. These districts were selected in agreement with the Ministry of Agriculture based on two criteria: 1) their frequent exposure to weather shocks; and 2) the existence of several projects aimed at addressing farmers' sensitivity and resilience to weather shocks through the promotion of climate-smart agriculture practices.

In total 53 interviews were conducted with randomly selected farmers in the four districts. A structured questionnaire was administered to collect information on household demographic characteristics, wealth, land endowments, livestock owned, levels of erosion, experiences with weather shocks, types and levels of agricultural production, access to the output market, market prices, and the costs and benefits associated with the adoption of climate-smart agriculture practices. This farm household information was complemented with key informant interviews carried out with local agricultural extension officers, project implementers, and private sector actors.

The information collected through interviews is integrated with secondary crop price data[1] to build two cost-benefit models to compare conventional, baseline production systems and climate-smart alternative systems. These models provide annual cash flow estimates in real financial terms over a 15-year period,[2] using World Bank and International Monetary Fund exchange rates and inflation data. This information is used to calculate two key measures of profitability:

1) The Net Present Value (NPV): The difference between all future cash inflows and outflows, discounted to the present using a discount rate of 11 percent.
2) The Internal Rate of Return (IRR): The discount rate at which the NPV of all cash flows is equal to zero. IRRs larger than the economy discount rate, set at 11 percent, are considered profitable to farmers relative to other investments.

In addition, a range of sensitivity analyses are conducted, to assess the impacts of climate and market related shocks on the returns associated with the adoption of the CSA scenarios relative to the baselines.

[1] This information was collected during the interviews and also retrieved from the Integrated Household Panel Survey data in Malawi (World Bank, 2019).

[2] We select a 15 years period for analysing the return from the investment in long term. The results are consistent to alternative long periods, such as 20 years.

5 Cost and returns associated with monocropping systems in Neno and parts of Zomba Districts (BAU1 and CSA1)

This section summarizes the key assumptions related to the costs and returns of adopting the two maize monocropping scenarios (BAU1 and CSA1) in Neno and parts of Zomba Districts. The costs, prices and returns are computed based on average values from the farm household survey data collected in the field, unless otherwise specified, and are validated through expert consultation with agriculture and livestock extension officers in the districts.[3]

The analysis assumes a time horizon of 15 years to assess returns and costs of adopting the CSA1 scenario relative to the baseline maize monocropping scenario (BAU1). Both BAU1 and CSA1 are assumed to be adopted on a one-hectare farm. The analysis assumes the yield of maize in the BAU1 monocropping systems is 1 762.5 kg/ha under average weather conditions. The value of maize production is based on an average farm-gate price of 170 MWK per kg, slightly below the government minimum floor price of 175 MWK.

To account for weather variability over the 15 seasons in the analysis, the maize yield is multiplied by a random seasonal coefficient that can improve or reduce the seasonal production within certain limits, taking values between 0.5 and 1.5.[4] In addition to receiving revenues by selling maize to market intermediaries at the observed price, farmers may trade the crop residue for the production of organic fertilizer. The observed market price for crop residue is not flexible, usually 5 000 MWK per ox-cart of product,[5] and the demand is quite small. Farmers in CSA1 complement these sources of revenues by periodically selling livestock.

In terms of input use, the average farmers in both scenarios utilizes 22.4 kg/hectare of maize seeds, a fixed amount of basal and trop dress fertilizer, equal to 71.4 kg and 69.3 kg per hectare respectively, and a larger quantity of organic fertilizer (596.2 kg per hectare).[5] These inputs are priced at their market value. In both scenarios, we utilize the market price of inputs, rather than the subsidy price received through the Farmer Input Support Programme. Price of maize seeds has been set equal to 250 MWK/kg, while price of basal and top dress fertilizers is equal to 523 and 493 MWK/kg, respectively. Organic fertilizer costs 30 MWK/kg.

All the labour-related activities, including land clearing and preparation, fertilizer and manure application, planting, weeding, harvesting, transporting, shelling and packing, are calculated as person-day costs using the average time for conducting all these activities and considering the initial costs of the tools necessary for their implementation. According to what was observed in the field, the average day rate for *ganyu* day labour is 940 MWK. Land clearing and preparation is the most expensive activity, at a cost of 47 000 MWK/ha. Construction of contour ridges, involves an additional labour costs of about 39 000 MWK, to which the cost of acquiring a shovel necessary for the work is added. The cost of transport is linked to the purchase of inputs from the agro-dealer and they are about 500 MWK per 50 kg of fertilizer bag. The model also

[3] Where specified, this information has been also complemented with the LSMS survey data (World Bank, 2019).

[4] The sensitivity analysis tests the robustness of this assumption by changing the distribution of simulated weather and finds very similar results.

[5] Refers to Tables A1 and A2 in the Annex for a full list of variables, average costs and benefits included in the model and measured for the first year of operation.

accounts for the opportunity costs of the land used, which is set at the average value at which a farmer can lease land, equal to 17 887 MWK/ha per year. Farming practices in these areas is primarily done manually and the model includes the initial cost of agricultural tools required.

Several additional costs and benefits are derived from the CSA1 scenario relative to the baseline. The analysis includes the costs of purchasing *gliricidia sepium* trees, which are planted every 3 meters in the field, for a total of 1 100 trees. These tree begin to affect crop production after 1 year, through various channels, including the fixation of atmospheric nitrogen, reductions in soil erosion, and reductions in crop evapotranspiration.[6] Implementing agro-forestry is associated to additional initial costs of establishing a tree nursery,[7] which is divided across the community and assumed to be 9.4 MWK per tree, as well as to the costs of seeds, which is 625 MWK for CSA1, and to the labour costs to raise these trees seedlings in the nursery and plant and maintain them in the field. Tree growth and maintenance is about 32 000 MWK for CSA1 in the first year and reduces to 30 636 in the following ones. The adoption of this agro-forestry system is assumed to increase maize yields 387.5 kg per hectare, relative to the baseline, which is an average of what was found in the field and in the literature (Mng'omba and Akinnifesi, 2019). The CSA1 model, in addition, assumes that the adoption of the agro-forestry induces a marginal reduction of 10 percent of use in the basal and top inorganic fertilizer applied after from the third year onwards, because of the natural fertilization from the trees.

Finally, the CSA1 scenario includes the incorporation of a well-managed goat production operation into the system. To this end, the model accounts for the cost of improved dry season feeding, equal to about 1 200 MWK per goat, annual vaccination (336 MWK per goat), and labour associated to grazing, estimated at 4 000 per month for about 12 goats. Diversification into small ruminant livestock is expected to help households increase incomes and provide more stabilize income sources under conditions of weather shocks. The analysis of the CSA1 scenario assumes that farmers initiate goat production by purchasing two juvenile female goats and one male goat at local market prices (15 250 MWK per head). Since they are juvenile, these goats start to reproduce after two years. To account for the mortality rate of new-born goats, the analysis hypothesizes that each female goat may give birth to an average of one goat twice a year after the first two years of life, and the new-born holds an equal probability of being female or male.[8] The farmer sells the male goat after the first year of life, while female goats are sold after kidding four times.

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[6] To account also for the potential failure rate of tree plantation in the tree nursery, the exercise considers the initial plantation of 1665 seeds.

[7] As observed in the field, the annual supply of the tree nursery is assumed to be 20 000 trees.

[8] In a sensitivity analysis we test for a lower level of reproduction or high level of mortality for new-borns, considering a female goat reproducing once a year after the first two years of life. The results are consistent and available upon request.

6 Cost and returns associated with maize-legume intercropping systems in Blantyre, Zomba, and Phalombe Districts (BAU2 and CSA2)

This section summarizes the key cost and return assumptions that underlie the cost benefits analysis of the baseline (BAU2) and climate-smart alternative (CSA2) scenarios involving the maize-legume intercropping systems that are found in Blantyre, Zomba and Phalombe Districts. As with the previous discussion, also in this case the costs, prices and returns are computed based on average values from the on-field interviews *unless otherwise specified* and verified through key informant interviews with District extension officers and other local experts.

This maize-legume system exists in areas where population densities are relatively high and average land sizes small. As such, it is assumed that the two scenarios, BAU2 and CSA2, are adopted and implemented in a land size of 0.4 hectare, or 1 acre. The distribution of weather and a farm-gate prices do not vary from the scenarios above.

The intercropped system considered in the analysis is a combination of maize and pigeon peas which, according to our data, is the most common legume adopted in the districts under analysis. Following the extant literature and the field visits, the expected maize yield for the BAU2 scenario is slightly higher than the BAU1 monocropped systems. The analysis also accounts for the yield penalty associated with plant competition that results for the traditional practices of planting maize and legumes in the same rows. We therefore set the yield of BAU2 to be 10 percent lower than the CSA2 system, which averages at 1 919.25 kg/ha under normal weather conditions. This yield varies in the model over the 15-year adoption period to account for weather variability based on the random yield coefficient explained above.

The labour costs linked to land preparation, planting, harvesting and agro-forestry are assumed to be slightly higher than in the maize monocropping scenarios per hectare, as labour cost is non-linear on land size, and it decreases per unit of land, advantaging larger land holdings compared to smaller ones. The cost of pigeon pea seeds derived by the interviews and market observation is equal to 320 MWK/kg. Following the same approach for maize, the expected pigeon pea production for the CSA2 is assumed to be between what is found in the literature (Thierfelder *et al.*, 2013; Waddington *et al.*, 2013; Waldman *et al.*, 2017) and what was found in the field visits, equal to 616.5 kg/ha. The vast majority of the interviewed farmers sell at the farm gate, with almost zero cost of transportation. Therefore, the model assumes that farmers sell at the observed average farm-gate price of pigeon peas, which is equal to 275 MWK/kg.[9]

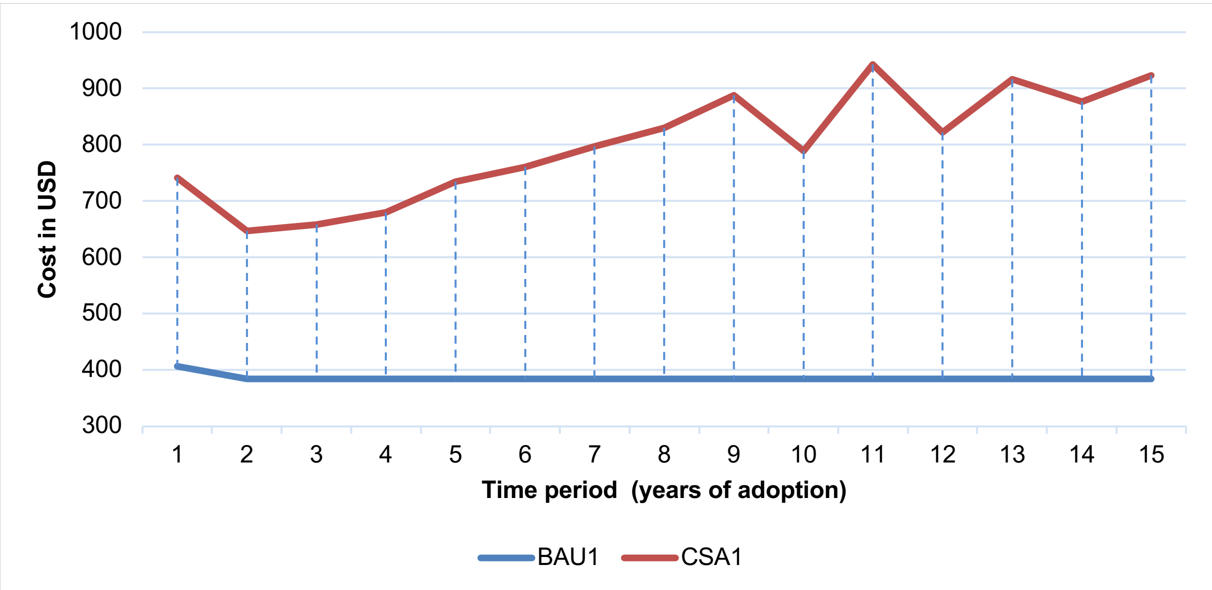
In BAU2, the agroforestry intervention involves a tree belt with trees planted every 3 meters, making up a total of 84 trees. As with the previous case, costs of agro-forestry implementation enters into the model as cost of tree nursery establishment, labour cost to growth, and costs for maintaining the trees in the field. Total cost of agroforestry, in this case, is about 16 500 MWK for the first year and less than 15 500 MWK for the following years. The effect of agro-forestry on yield is assumed to take place after two years of planting, to deliver benefits only on maize yield with an additional production of 135 Kg in CSA2. This is justified by the disposition of the trees as tree belt and because of the presence of legumes in the field. Farmers in CSA2 and BAU2 profit by trading maize and pigeon pea to intermediaries in the market, and by selling crop residue for compost.

[9] For more information of pigeon peas price, refer to IFPRI (2019).

7 Is it profitable to integrate climate-smart agriculture practices in a maize monocropping system?

As Figure 1 shows, the costs linked to the CSA1 system are higher and more volatile than the baseline scenario. This is due to the costs of adopting and maintaining the three practices that comprise this scenario, namely the integration of agroforestry, building and maintaining contour ridges, and acquiring and managing goats. According to this analysis, costs incurred by farmers during the first year of CSA1 adoption amount to about USD 740, approximately USD 335 more than the baseline. This is a significant cost for farmers in the area and is nearly the average yearly revenue of a farmer in southern Malawi (Anker and Anker, 2014). The baseline BAU1 scenario, on the other hand, is more financially accessible and less volatile, with average yearly cost of about USD 400, less than half of the yearly cost of CSA1 (USD 822). This cost difference points towards the existence of a significant barrier to the adoption of the CSA system for resources constrained households facing high discount rates.

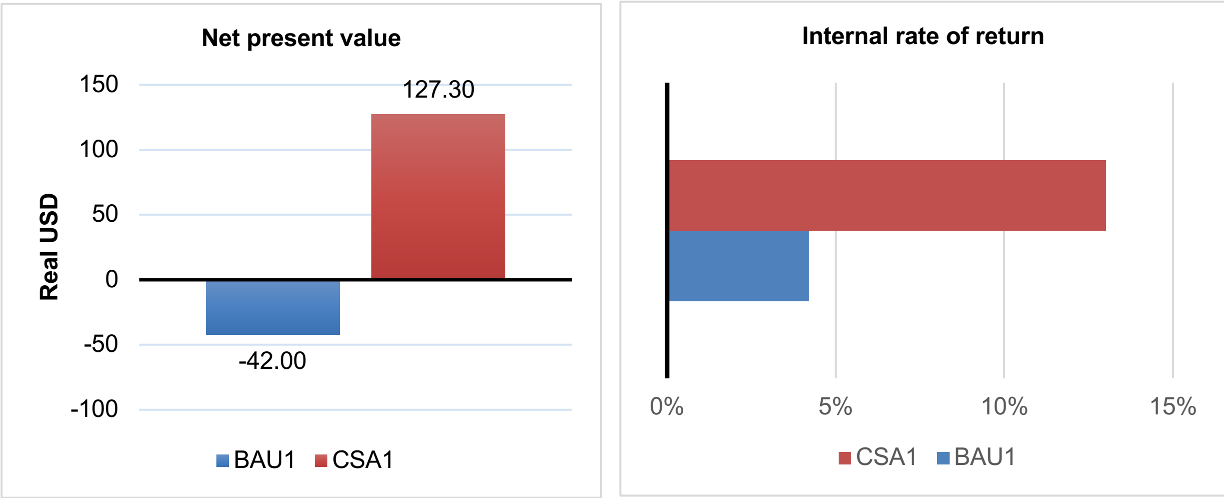
Figure 1. The CSA1 system is associated to higher and more volatile costs than the baseline scenario



Source: Authors' own elaboration.

Despite the relatively higher cost of the climate-smart alternative system (CSA1, the financial analysis shows that the system is significantly more profitable than the baseline scenario. As shown in Figure 2, under current markets, the IRR of the CSA1 scenario (13 percent) is more than three times above that associated to the monocropping system without intervention (4 percent), and higher than the financial discount rate of 11 percent. These figures suggest a higher profitability for CSA1 with respect to both BAU1 and the financial discount rate. However, this profitability is conditional to a substantial initial level of investment and to the capacity to withstand higher cost volatility during the entire period of implementation.

Figure 2. CSA scenarios are profitable, however they require upfront investment capital

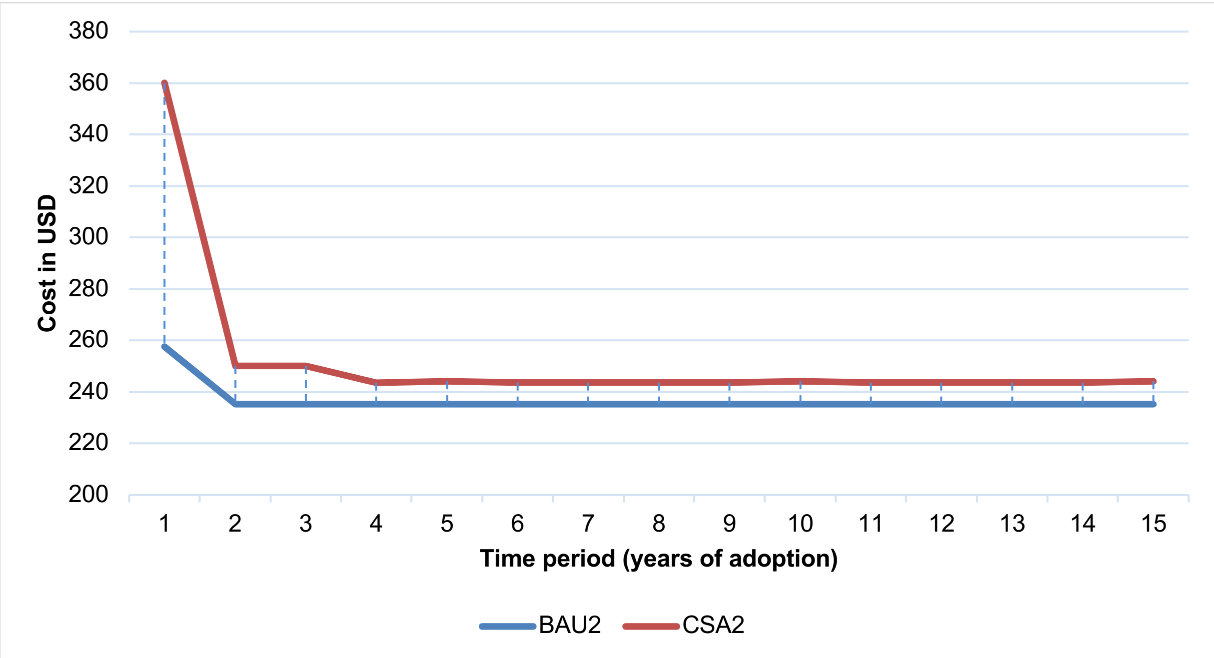


Source: Authors' own elaboration.

8 Is it profitable to integrate climate-smart agriculture practices in a maize-legume intercropping systems?

In contrast to what was observed under the previous scenarios, CSA2 and BAU2 show very similar costs of investment across the entire period, with a substantial divergence only in the initial year, where the cost of implementing CSA2 is 40 percent higher than that of investment in BAU2. This difference is driven by the investment in tree seedlings, the initial cost of installing the tree belt around the plot, which requires an average initial investment of 156 USD per acres (0.04 hectares), and additional labour costs associated with installing contour ridges. This represents a significant adoption barrier for farmers. However, once this initial investment is made, maintenance costs and cost volatility between the baseline and alternative scenario are very similar (see Figure 3).

Figure 3. Intercropping intervention is associated to higher initial costs than the baseline scenario

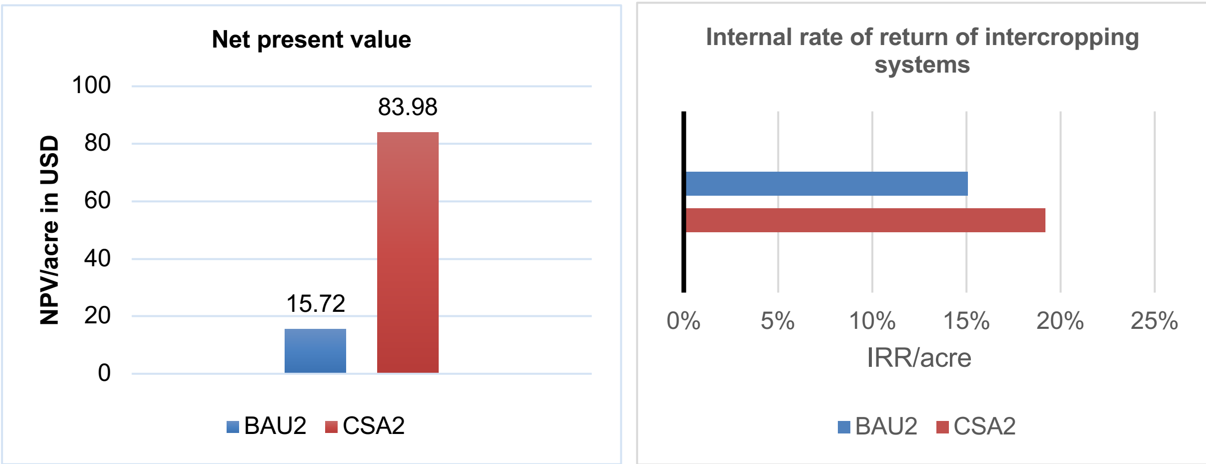


Source: Authors' own elaboration.

Is it profitable to shift from the traditional maize-legume intercropping system to the system of CSA2? The analysis presented in Figure 4 shows that the NPV and IRR of the climate-smart alternative system is higher than in the baseline BAU2 scenario. Notice also that the returns from the legume intercropping scenarios are, in general, more profitable than maize monocropping counterparts. This likely derives by the higher income linked to the commercialization of pigeon pea, as well as the benefits from the fertilizing effects associated to the cultivation of a staple crop in combination with a leguminous crop.

In terms of magnitude, the BAU2 system and CSA2 system are associated to a NPV of USD 15.72 and USD 83.98 per acre (0.4 hectares), respectively, while the IRR of CSA2 (19 percent) is 8 points higher than the financial discount rate and 4 percent higher than the internal rate of return from the baseline scenario (15 percent). These results suggest that while the difference in NPV is high in percentage terms, the monetary difference between the two scenarios when discounted over 15 years is limited (68.26 real USD). Taken together, the results of this section suggest that in both cases the adoption of the climate-smart alternative production systems is more profitable than the baseline case. However, initial investment costs, and relatively small marginal difference in profits are likely hindering adoption.

Figure 4. The scenario integrating CSA into maize-legume is slightly more profitable both in terms of internal rate of return and net present value



Source: Authors' own elaboration.

9 Testing the sensitivity of the analysis

In the sub-sections below, we explore the sensitivity of the results to alternative assumptions. In particular, we analyse the sensitivity of the NPV and IRR to the assumptions related to weather shocks and market conditions.

9.1 Are these scenarios effective under alternative “normal” climate conditions?

In the main analysis presented above, weather variability, consistent with Malawi’s historical weather pattern, is built into the analysis through a randomly generated coefficient ranging between .05 and 1.5, which is multiplied by the average crop yield in any given year. To test the sensitivity of the outcomes to this assumption, we re-run the model under two different variability scenarios. The first is built randomly as before and constrained between 0.5 and 1.5, and the second is the average of three random distributions.

These results show that for the maize mono-cropping scenarios, the difference between the baseline (BAU1) and the climate-smart alternative (CSA1) is similar to the results of the main analysis presented earlier. In particular, the BAU1 scenario has a negative net present value in both cases, -60.00 and USD -64.27 respectively, while the CSA1 scenario reports a positive net present value. Thus, the key finding of this analysis—that the adoption of agro-forestry and the integration of goat rearing into maize monocrop systems is more profitable than monocropping alone—is robust under a range of different weather variability scenarios. A similar result emerges for maize-legume intercropping systems, where the difference between the baseline and the alternative scenario is positive and equal to 9.42 and 41.76 real USD, under the two sensitivity scenarios. Also, in this case, therefore, the adoption of agro-forestry as tree belt and use of contour ridges provides a tangible advantage compared to the baseline scenario.

9.2 How smart are these systems under weather shocks?

As a result of climate change, it is anticipated that the frequency and intensity of extreme weather events will increase (IPCC, 2007). This can have important implications for the profitability of long-term land use investments. It is, therefore, important to assess the financial performance of climate-smart production systems, relative to conventional baseline systems under conditions of weather shocks, such as droughts and floods.

The proposed climate-smart systems are expected to reduce the vulnerability of farmers’ production systems to extreme weather in several ways. For CSA1, it is expected that the integration of agro-forestry and contour ridges into maize-mono-cropped systems will help reduce the impact of flood shocks by limiting erosion. Agroforestry, in particular, may prevent soil erosion and crop losses by reducing water run-off speed under heavy rainfall conditions. Under drought and/or high temperature conditions, agroforestry systems can also reduce soil evapotranspiration by providing shade to crops, and thus reduce water stress. These benefits are combined with income diversification benefits derived from goat production. Goats are able to make use of natural vegetation, which tends to more resistant to droughts and floods. As such, goats tend to be less sensitive to weather shocks than crop production systems, and they represent a good stock of saving when farmers face extreme weather conditions.

For the CSA2 system, the benefits associated with agro-forestry and contour ridges described above are complemented by the additional benefits derived from the integration of pigeon peas into the system. Pigeon peas are a drought tolerant legume, with deep rooting system (Priyanka *et al*., 2010). As a legume, they also help to fix atmospheric nitrogen, which enhances soil nutrient composition and can contribute to more vigorous maize growth. This, in turn, can enable maize plants to better withstand weather shocks. Moreover, legume intercropping can help to shade soil and create local micro-climate that is beneficial to other cereal crops under drought shocks (Raseduzzaman and Jensen, 2017; Rusinamhodzi *et al.*, 2012).

To test the benefits of these practices under weather shocks, we focus on the extreme events occurring during the first 5 years of adoption. In this sensitivity analysis, the assumption is that the extreme event fully nullifies the production during the year of occurrence for the baseline scenarios, consistent with the impacts of the devastating floods that affected Malawi in recent years. For the alternative scenarios, the model assumes heterogeneous impacts of the shocks. These impacts are based on the existing literature that associates shock occurrence to maize yield and other outputs (Asfaw and Maggio, 2018). In particular, following Arslan, Belotti and Lipper (2017), we model crop loss due to weather shocks in the CSA scenarios as 62 percent lower than under normal conditions. To this loss, we assume that the adoption of soil and water conservation systems, such a contour ridges, reduces the negative impact of the shocks by 27 percent. We hypothesize that agro-forestry has a linearly decreasing effect on the impact of weather shocks, meaning that a shock will reduce the detrimental impacts as the density of leguminous trees on the plot increases (Coulibaly *et al*., 2017; Thhorlakson and Neufeldt, 2012).[10] Finally, we assume that also goat production is negatively affected both in terms of fertility and in terms of weight of sold production. This is translated in a reduction of the value sold by 25 percent during a shock.

As shown in Table 3, the alternative scenarios generate higher returns than the baseline ones under all scenarios. However, CSA2 is the only scenario associated with positive financial returns even under shock, while CSA1 is less likely to bring positive returns under shock. This result is due to the higher level of climate resilience associated to CSA2 compared to CSA1, due to its contemporaneous adoption of three CSA practices which are able to double the efficacy of CSA2 compared to CSA1 under weather shocks.

An important finding from this analysis is that the benefits of adopting the alternative climate-smart systems, relative to their baseline counterparts, are larger under weather shock conditions than under normal conditions. In particular, CSA1 is associated with revenue that is between 2.87 and 123.3 times higher than under BAU1.[11] CSA2 shows returns relative to its baseline scenario that are between 2.31 and 4.43 higher. Adoption, in both cases, appears particularly significant in reducing vulnerability during the first five years of investment, a period that farmers discount more because closer to the present.

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[10] We therefore hypothesize that agro-forestry reduces the shock impact by 5 percent in legume intercropping and by 10 percent in monocropping.

[11] Note that these results are conditional on the weather distribution employed in the first part of the analysis.

Table 3. Alternative maize-legume intercropping system is the only system reporting positive returns under shocks

	Net present value (real USD)					
	Maize monocropping			Maize legume intercropping		
Year of the shock\scenario	BAU1	CSA1	Proportional difference	BAU2	CSA2	Proportional difference
t=1	-404.23	-3.28	123.34	-132.34	70.69	2.87
t=2	-523.37	-82.71	6.32	-211.05	61.46	4.43
t=3	-395.55	-36.02	10.98	-132.75	68.57	2.93
t=4	-413.63	-75.25	5.49	-145.54	67.53	3.15
t=5	-235.38	-83.99	2.80	-96.53	73.31	2.31

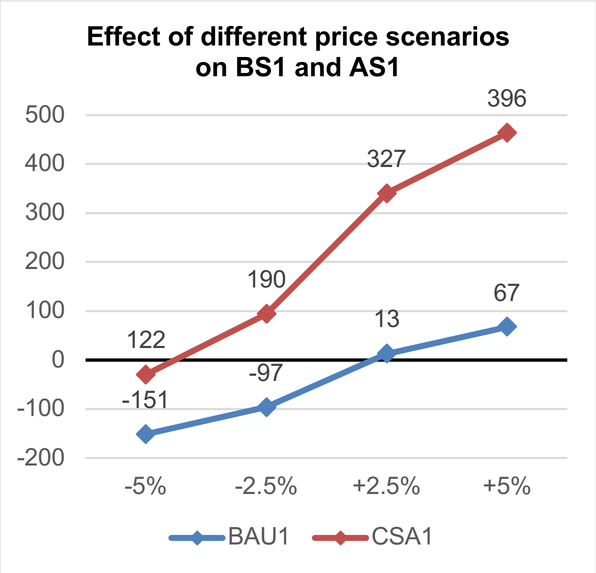
Source: Authors' own elaboration.

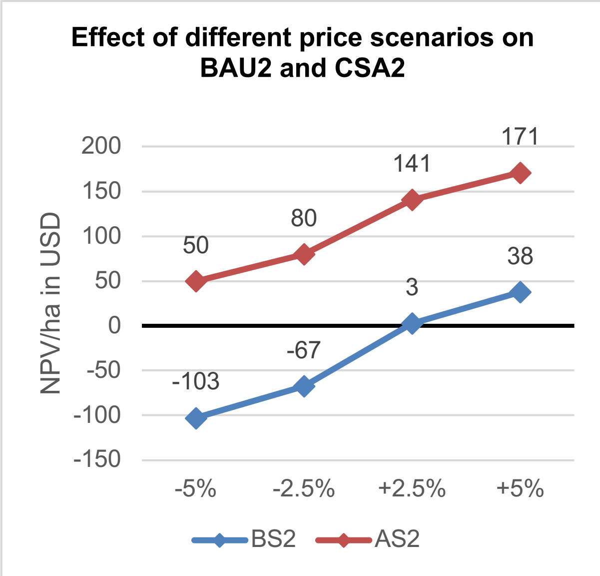
9.3 Would the adoption be still profitable under different market conditions?

We also tested how sensitive the results of the analysis are to variations in crop output prices. To do this, the scenarios are run with output prices that are adjusted by between -5 and +5 percent relative to the observed price. As shown in Figure 6, both alternative climate-smart scenarios remain profitable even when prices decrease by 5 percent. By contrast, for the baseline scenarios to become profitable, output prices must increase by 2.5 percent relative to current prices. This suggests that the adoption of these practices can enable farmers to better withstand fluctuations in market prices than farmers relying on conventional, baseline production systems.

The importance of marginal improvements in farm gate prices to farm profitability is highlighted in Figure 5. It shows that an increase of 10 percent in farm gate prices is associated with approximately a 3-fold increase in NPV for the two climate-smart systems. Improving farm-gate prices for producers is therefore important for capturing the benefits of climate-smart production systems and is therefore essential for supporting adoption. However, this must be done in such a way as to not crow out private investments in output markets or increase substantially the prices consumers pay for food. Investments in public goods, such as market infrastructure and market information for farmers may be effective policy tools for achieving this objective.

Figure 5. The baseline scenarios turn profitable only under higher prices but not as much as the alternative scenarios





Source: Authors' own elaboration.

10 Conclusion and policy recommendations

The climate-smart agriculture scenarios considered in this analysis for Malawi, under a range of climatic and market conditions, generate higher returns over a 15-year investment period compared with conventional production systems. With this in mind, what does explain low levels of adoption and how can this be remedied?

The analysis shows that the adoption of the climate-smart scenarios is associated with large initial investments for farmers, including livestock purchases, tree seedlings acquisition, and increased labour allocation. These adoption barriers are compounded by uncertainty over future benefits, lack of management information, and limited necessary infrastructure, such as tree nurseries and livestock services. In general, farmers lack the necessary knowledge to weight current cost and medium- or long-term returns from the above practices. Oftentimes, stakeholders do not have precise information on several aspects of the adoption of these practices, including the level of labour supply needed for their implementation and the local cost of inputs. Even when this information is available, communicating this to the farmers using an accessible language remains an open challenge in several parts of the country.

Addressing these constraints will require multiple and simultaneous policy and programmatic interventions. The analysis highlights the need to address liquidity and risk constraints that limit adoption of improved farm management practices among smallholder farmers. There are various options for doing this. One option is to modify existing social protection programmes to make them conditional on the adoption of improved, climate-smart practices or to bundle the distribution of social protection assistance with extension advice on climate-smart agricultural practices. Social protection support, in cash or in-kind, has been found to reduce the risk to farmers of adopting new farm practices and to address the liquidity constraints that prevent them from making new investments (Scognamillo and Sitko, 2021; Holden, Barrett and Hagos 2006). Given that investments in agroforestry and improved tillage methods also generate GHGs emission reduction benefits, there is the possibility of leveraging climate financing to support this initiative, similar to a payment for ecosystem services scheme. Alternatively, risk sharing mechanisms to support local lending and micro-credit institutions to extend lending periods (currently only one week to one month) while keeping them compatible with the other objectives of the institution, and to target climate-smart investments is another potential option.

Yet these inventions require simultaneous support to develop complimentary markets and support institutions. Farmers need adequate price incentives and access to necessary inputs and information to pursue alternative climate-smart, farm investments. Field interviews suggest that a multi-dimensional approach to promoting climate-smart agriculture is necessary. This can entail bundling the financial support described above with training on market integration, such as commodity aggregation or use of existing warehouse receipts, development of community based agro-forestry nurseries and farmer field schools to develop and share farming information. Through a multi-dimensional approach that reduces the liquidity and risk barriers to adopting new practices and supports farmers to access better market prices and enabling institutions, Malawian farmers will be in a better position to integrate climate-smart agricultural practices into their systems and derive the benefits of this over time.

References

Anker, R. & Anker, M. 2014. *Living wage for rural Malawi with focus on tea growing area of southern Malawi.* Report prepared for Fairtrade International (Bonn), Sustainable Agriculture Network/Rainforest Alliance and UTZ Certified.

Arslan, A., Belotti, F. & Lipper, L., 2017. Smallholder productivity and weather shocks: Adoption and impact of widely promoted agricultural practices in Tanzania. *Food policy*, 69: 68–81.

Asfaw, S. & Maggio, G. 2018. Gender, weather shocks and welfare: Evidence from Malawi. *The Journal of Development Studies*, 54: 271–291.

Blantyre District Council. 2017. District Socio-economic profile.

Coulibaly, J.Y., Chiputwa, B., Nakelse, T. & Kundhlande, G. 2017. Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agricultural systems*, 155: 52–69.

Dougill, A.J., Whitfield, S., Stringer, L.C., Vincent, K., Wood, B.T., Chinseu, E.L., Steward, P. & Mkwambisi, D.D. 2017. Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional barriers. *Journal of Environmental Management*, 195: 25–34.

Global Facility for Disaster Reduction and Recovery. 2011. *Climate Risk and Adaptation Country Profile: Malawi. Vulnerability, Risk Reduction, and Adaptation to Climate Change*.

International Food Policy Research Institute (IFPRI). 2019. Sourcing farm gate prices for pigeon peas and chickpeas – a pilot study in 13 districts in Southern Malawi. In: *IFPRI Malawi* [online]. [Cited 7 June 2021]. https://massp.ifpri.info/2019/09/13/sourcing-farm-gate-prices-for-pigeon-and-chickpeas-a-pilot-study-in-13-districts-in-southern-malawi

International Center for Tropical Agriculture (CIAT) & World Bank. 2018. *Climate-smart agriculture in Malawi.* CSA Country Profiles for Africa Series. Washington, DC.

Maggio, G., & Asfaw, S. 2020. Heterogeneous Effects of Sustainable Agriculture Practices: Micro-evidence from Malawi. *Journal of African Economies*, 29(4): 333–374.

Murray, U., Gebremedhin, Z., Brychkova, G. & Spillane, C. 2016. Smallholder farmers and climate-smart agriculture: Technology and labor-productivity constraints amongst women smallholders in Malawi. Gender, Technology and Development, 20(2): 117–148.

Mng'omba, S.A. and Akinnifesi, F.K., 2019. Effect of soil amendment with *Gliricidia sepium* and *Tephrosia vogelii* biomass on maize yield at Makoka in Malawi. *Agroforestry Systems*, 94: 441–449.

Neno District Council 2017. *District Socio-economic profile*. Lilongwe, Malawi, Government of the Republic of Malawi Press.

Phalombe District Council 2017. *District Socio-economic profile*. Lilongwe, Malawi, Government of the Republic of Malawi Press.

Priyanka, B., Sekhar, K., Sunita, T., Reddy, V.D. & Rao, K.V., 2010. Characterization of expressed sequence tags (ESTs) of pigeonpea (Cajanus cajan L.) and functional validation of selected genes for abiotic stress tolerance in Arabidopsis thaliana. *Molecular Genetics and Genomics*, 283(3): 273–287.

Raseduzzaman, M.D. & Jensen, E.S. 2017. Does intercropping enhance yield stability in arable crop production? A meta-analysis. *European Journal of Agronomy*, 91: 25–33.

Rusinamhodzi, L., Corbeels, M., Nyamangara, J. & Giller, K.E. 2012. Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field crops research*, 136: 12–22.

Thierfelder, C., Chisui, J.L., Gama, M., Cheesman, S., Jere, Z.D., Bunderson, W.T., Eash, N.S. & Rusinamhodzi, L. 2013. Maize-based conservation agriculture systems in Malawi: long-term trends in productivity. *Field Crops Research*, 142: 47–57.

Thorlakson, T. & Neufeldt, H. 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture & Food Security*, 1(15).

Waddington, S.R., Mekuria, M., Siziba, S. & Karigwindi, J. 2007. Long-term yield sustainability and financial returns from grain legume–maize intercrops on a sandy soil in subhumid north central Zimbabwe. *Experimental agriculture*, 43(4): 489–503.

Waldman, K.B., Ortega, D.L., Richardson, R.B. & Snapp, S.S. 2017. Estimating demand for perennial pigeon pea in Malawi using choice experiments. *Ecological Economics*, 131: 222–230.

World Bank. 2019. Malawi – Integrated household panel survey. In: *World Bank* [online]. Washington, DC. [Cited 6 March 2020]. https://microdata.worldbank.org/index.php/catalog/2939

World Bank. 2020. DataBank | World Development Indicators. In: *World Bank* [online]. Washington, DC. [Cited 6 March 2020]. https://databank.worldbank.org/source/world-development-indicators

Zomba District Council. 2017. *District Socio-economic profile*. Lilongwe, Malawi, Government of the Republic of Malawi Press.

Annex 1

Table A1. Average observed costs in Malawian Kwacha observed during the first year of investment by agricultural system

		Average observed cost during the first year (MWK)	
		BAU1 and CSA1	BAU2 and CSA2
Land preparation and labour variables	Land clearing and preparation	46 875	25 000
	Fertilizer and manure application	9 375	5 000
	Planting	9 375	10 000
	Weeding	46 875	20 000
	Harvesting and transporting	18 750	20 000
	Shelling and packing	37 500	20 000
	Soil erosion control bund	35 000	35 000
	Marker ridges	3 817	3 817
Overhead costs	Land lease	18 750	10 000
Input	Maize seeds	5 592	2 238
	Pigeon pea seeds	-	3 584
	Basal fertilizer	63 447	25 378
	Top dress fertilizer	57 635	23 052
	Organic fertilizer	21 630	8 652
Tools	Hoes	9 713	9 713
	Panga knife	1 600	1 600
	Sickle	845	845
	Axe	1 967	1 967
	Watering Cane	2 291	2 291
	Sholve	2 833	2 833
Agro-forestry	Tree seeds	47	47
	Transportation	1 000	1 000
	Starting up and operation costs per tree	29 602	29 602
	Tree maintenance	15 456	15 456
Goat raising	Goats x 3	45 750	-
	Vaccination	1 010	-
	Feeding	15 000	-
	Labour for ridging the goat	48 000	-

Notes: The cost reported in the table derives from the observational work during the field work. Differences between the two systems depends on the quantity of input applied and on the land size treated.

Source: Authors' own calculation.

Table A2. Average observed returns in Malawian Kwacha observed during the first year of investment by agricultural system

System		Assumptions/field observation	Value of production
BAU1	Maize production	Production of maize in a deterministic scenario is 1 712.5 kg/ha.	291 125
	Compost production	About 1 ox-cart of potential material for compost, price is 5 000 MWK/ox-cart. Compost price does not vary so much for small quantities as observed in the field.	5 000
CSA1	Maize production	Maize production Effect of agro-forestry is about 337.5 kg/ha, maize production is 2050 kg/ha in a deterministic scenario.	365 500
	Compost production	About 1 ox-cart of potential material for compost, price is 5 000 MWK/ox-cart. Compost price does not vary so much for small quantities.	10 000
	Goat production	Goat planning and selling follows an algorithm such as: each female goat give birth to an average of one goats twice a year after the first 1.5 years. Male and female have equal probability of birth (0.5), but in case of odd newborns, the majority is female. We sell the male goat after 1 year. Female goats are sold after two years and two litters. The average sold price per goat is 25 000. The revenue figure refers to the first revenue after four years.	100 000
BAU2	Maize production	Maize-legume intercropping is assumed to deliver 1 919.25 kg/ha in a deterministic scenario.	117 458
	Pigeon pea production	Pigeon pea production is assumed to deliver 246.6 kg/ha in a deterministic scenario.	67 815
	Compost production	About 1/2 ox-cart of potential material for compost, price is 5 000 MWK/ox-cart. Compost price does not vary so much for small quantities.	2 500
CSA2	Maize production	Maize-legume intercropping is assumed to deliver 1 919.25 kg/ha in a deterministic scenario. We add the benefits from *gliricidia* (135 kg/ha) as observed in the field.	153 459
	Pigeon pea production	Pigeon pea production is assumed to deliver 246.6 kg/ha in a deterministic scenario.	67 815
	Compost production	About 1/2 ox-cart of potential material for compost, price is 5 000 MWK/ox-cart. Compost price does not vary so much for small quantities.	2 500

Notes: the crop value is multiplied to the random weather coefficient of fluctuations assuming values between 0.95/1.00 every two years.

Source: Authors' own calculation.

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