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**Corresponding author:**
Marije Schaafsma; Email: M.Schaafsma@vu.nl



# Assessing multidimensional well-being impacts of sustainable agriculture options in rural Malawi using multi-criteria analysis

Marije Schaafsma[1,2], Kate Schreckenberg[3] and R Kerry Turner[4]

[1]School of Geography and Environmental Science, University of Southampton, Southampton, UK; [2]Department of Environmental Economics, Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; [3]Department of Geography, King's College London, London, UK and [4]Centre for Social and Economic Research on the Global Environment, School of Environmental Sciences, University of East Anglia, Norwich, UK

**Summary**

Climate-smart agriculture that promotes climate change adaptation and mitigation while improving livelihoods is being advocated to smallholder farmers. Most studies in this area focus on the yield and income impacts of practices, but we explore farmer well-being impacts. Using a multi-criteria analysis embedded in an in-person questionnaire, our findings suggest that smallholder farmers in Southern Malawi have diverse preferences for climate-smart practices based on location, access to markets and resources and importance placed on climate adaptation. The use of multidimensional well-being criteria provides deeper insights into the motivations and priorities of farmers, revealing trade-offs between immediate food needs and climate adaptation concerns, as well as between the need for incentives versus the risk of conditional credits. Our study calls for tailored climate-smart agriculture projects that allow farmers to adopt practices that meet their needs.

## Introduction

Climate change is expected to negatively affect attainable yields of crop production and food security (Pugh et al. 2016). Climate change and global consumption patterns will impose threats to achieving United Nations Sustainable Development Goal (SDG) 2 of zero hunger (Mason-D'Croz et al. 2019). Irrespective of climate change, yield gaps remain high, especially in sub-Saharan Africa, keeping realized yields well below attainable yields (Van Zeist et al. 2020). In response, for agriculture to be sustainable, several solutions have been put forward, some of which directly address adaptation, others helping to reduce yield gaps (Minoli et al. 2019) and thereby reduce rural poverty and food insecurity (Erbaugh et al. 2019). Efforts such as sustainable intensification balance conservation with food production (Rasmussen et al. 2018), while climate-smart agriculture (CSA) emphasizes adaptation to and, where possible, mitigation of climate change, as well as farmers' livelihoods (Lipper et al. 2014). CSA includes diverse off- and on-farm practices: some CSA options are information and communications technology based for closing yield gaps (Walter et al. 2017), but these are often inaccessible to farmers in low-income settings (Nasser et al. 2020); others focus on livelihoods (Karlsson et al. 2018). Farm-level CSA practices such as conservation agriculture, crop diversification and agroforestry help farmers manage the risks of production variability, recover from climate shocks or reduce negative coping strategies, but the results depend on agroecological conditions and farmer characteristics (Hansen et al. 2019).

CSA project evaluations typically focus on yield, profitability and physical metrics for mitigation and adaptation (Thierfelder et al. 2017). However, these fail to capture all of the dimensions of food security and farmer income (Chandra et al. 2017). The evidence remains insufficient to assess the effects of CSA on income poverty reduction (Hansen et al. 2019) – and even more so on multidimensional poverty, our focus in this paper. Expanding metrics and evaluation domains reveals trade-offs between the three CSA objectives (Antwi-Agyei et al. 2023) and the overarching goals of SDG 1 (zero poverty) and SDG 10 (reducing inequalities) (Hellin & Fisher 2019).

In Malawi, high poverty combined with high reliance on agriculture have attracted CSA projects on conservation agriculture, soil fertility management and agroforestry, with mixed success (Dougill et al. 2017, Amadu et al. 2020b). CSA adoption remains low, with often considerable post-project disadoption (Khoza et al. 2022), due to large upfront investments vis-à-vis smaller benefits over time (Branca et al. 2021, Ignaciuk et al. 2021). However, sustained promotion, demonstration plots and dedicated extension services may improve the chances of continued adoption (Pangapanga-Phiri et al. 2024). Inclusive and equitable CSA initiatives must also address barriers for poorer farmers, including access to tools, transport, credit and energy

(Murray et al. 2016). Cash transfers may complement CSA (Hellin & Fisher 2019). Evidence from a study on the public works programme Malawi Social Action Fund (MASAF) suggests that participation increased CSA adoption (Scognamillo & Sitko 2021).

This paper examines whether CSA contributes to multidimensional well-being, aligning with SDG 1 target 1.4: poverty reduction in all its dimensions. We explore farmers' perceptions of the contribution to multiple monetary and non-monetary well-being dimensions of a hypothetical incentivized CSA project using multi-criteria decision analysis (MCDA) in Southern Malawi. MCDA evaluates options based on decision criteria, importance weights and criterion performance scores (Cinelli et al. 2014), and it is widely applied in agricultural sustainability (Cicciù et al. 2022). Unlike cost–benefit analyses, MCDA methods can accommodate non-monetary values and economic, equity and ecological sustainability criteria (Barbosa Junior et al. 2022). MCDA has been used to analyse soil and water conservation practices in Ethiopia (Teshome et al. 2014), to evaluate food system sustainability (Alrøe et al. 2016) and to create land suitability maps (e.g., Mugiyo et al. 2021). For CSA, MCDA has been used to identify target areas (Brandt et al. 2017) and upscaling potential (Wassmann et al. 2019). Early MCDA methods were designed for model- or expert-based judgement of criteria, weights and scores (Wassmann et al. 2019). More recent participatory and social MCDA studies combine expert and stakeholder input, but stakeholder input is usually limited to providing weights (Etxano & Villalba-Eguiluz 2021).

We contribute to the literature on CSA using MCDA by asking farmers not only to weigh the well-being dimensions, but also to score the CSA options on their well-being performance, thereby providing insights into farmers' perceptions, knowledge and values. This approach allowed us to identify which well-being dimensions are most important to farmers, as well as how different CSA options result in trade-offs between well-being dimensions, moving beyond expert-based yield or adaptation assessments.

## Data and methods

### Study area

Malawi has a high income-poverty rate, with 70% of its population living below the USD 2.15/day poverty line (UNCTAD 2023); the country is ranked 174th out of 189 on the Human Development Index 2020. The economy of Malawi is heavily reliant on agriculture, with half of rural households being pure subsistence farms.

Zomba Rural District (i.e., excluding Zomba City), part of the Southern Region, has a tropical climate and faces extreme weather events. There has been an increasing concentration of heavy rains, with longer and more frequent dry spells (Wood & Moriniere 2013), as well as increasing temperature (Warnatzsch & Reay 2020) and temperature variation (World Bank 2019). Eighty-eight per cent of households experience very low food security (NSO 2020). As 84% of households mainly use firewood and a further 15% use charcoal (NSO 2020), the country's trees are under constant threat. Maize is the main crop produced for subsistence and sale. Of all cultivated plots, 70% are mixed cultivated (where crops are grown simultaneously on the same land without a row pattern and crops may compete), while only 14% are intercropped (where crops are planted in a strict row pattern and crops do not compete) and 13% are monocropped.

### Multi-criteria decision analysis

The objective of our MCDA exercise was to assess how different on-farm CSA projects contribute to the multidimensional well-being of smallholders using an ex ante assessment of the hypothetical CSA options (Cicciù et al. 2022). We elicited the perception and knowledge of smallholders to determine both the weights and the scores of options at the individual farmer level so as to provide local grounding through a questionnaire (Appendix S1).

Using existing studies on CSA projects in Malawi, we developed four CSA options with six characteristics for this MCDA (Fig. 1). As an independent research project, these options were not tied to existing CSA programmes, and no prior data existed on their context-specific contributions to the three CSA goals or to farmer well-being. The levels of delay in receiving benefits and the increase in maize harvests were hence based on existing literature for Malawi. The options were defined so that none was expected to be strictly dominant in net well-being terms. Annual credit levels were designed to compensate for lower maize gains or longer benefit delays. Pre-tests indicated that participants found the options realistic and applicable to their area.

The first two elements – crop diversification and additional trees – characterize the CSA options as woody and non-woody plant additions (Amadu et al. 2020a), aiming to enhance soil fertility, diversify income and increase climate resilience. This combination, known as 'double-up adoption' (Tikita & Lee 2024), varies in terms of labour and land requirements: agroforestry fruit trees typically require more land, while intercropping requires little to none; both require only low to medium extra labour. Crop diversification included soy–maize rotation or intercropping maize with pigeon pea, groundnut or sorghum. Soy is a cash crop, pigeon pea and groundnuts are locally traded food crops and sorghum is drought-resistant (Stevens & Madani 2016). Soy, groundnuts and pigeon peas (in options A, B and C in Fig. 1) are nitrogen-fixing legumes that enhance soil fertility and thereby increase maize yield while providing income or food (Mhango et al. 2017). The additional trees planted on *mundas* (main type of plot, not riverine) varied from 3 to 20 trees per plot in consideration of the small land parcels in the area (on average 0.6 ha; NSO 2021) and agroforestry research (Amadu et al. 2020b). Planting trees can improve soil fertility, help protect farmers against floods and storms, regulate water flow, prevent soil erosion and sequester carbon (Branca et al. 2021), for which farmers could potentially be rewarded.

The third element was the time that farmers would have to wait until they would obtain higher maize yields and tree products, ranging from 1 to 10 years based on Garrity et al. (2010).

The fourth element was the increase in maize yields due to planting trees and crop diversification based on Kamanga et al. (2010) and Sauer and Tchale (2009), and consistent with studies published after our data collection period, such as van Vugt et al. (2018) and Nyagumbo et al. (2022). While intercropping sorghum and maize is practised in Southern Malawi (Li et al. 2022), global yield improvement evidence is mixed (Mahmood et al. 2013, Zhang et al. 2023), justifying option A's modest yield increase.

The fifth element represented tree products, including fruits, poles and firewood (Coulibaly et al. 2017). We excluded fertilizer trees because fertilizer is such a contested topic in the study area that it could draw attention away from the other programme elements.

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| | Current situation | Option A | Option B | Option C | Option D |
|---|---|---|---|---|---|
| *Crop diversification* | Current crops and cropping system | Maize and sorghum intercrop | Maize and soy rotation | Maize and groundnut intercrop | Maize and pigeon pea intercrop |
| *Number of additional large trees on munda* | 0 | 5 extra trees | 3 extra trees | 10 extra trees | 3 extra trees |
| *Number of years after which you get tree products and maize harvest increase* | 0 | After 5 years | After 1 year | After 10 years | After 2 years |
| *Increase in maize harvest per year* | 0 bags of 50kg | 1 bag of 50kg | 4 bags of 50kg | 4 bags of 50kg | 2 bags of 50kg |
| *Tree product* | - | Fruit | Fruit | Poles | Fuelwood |
| *Credit per year for 5 years* | MK 0 | MK 40000 | MK 15000 | MK 25000 | MK 5000 |

**Figure 1.** Characteristics of the current situation and the four hypothetical options in our multi-criteria decision analysis. MK = Malawian Kwacha.

The final element was the financial incentive in the form of an annual conditional credit that farmers would receive for 5 years, being waived if trees would remain on their land after 5 years, which was included to offset initial costs for farmers. Amounts ranged from 5000 to 40 000 Malawian Kwacha (MKW) per year (€9–70) based on the additional labour costs required and initial maize losses. A visual aid illustrated the payment structure (Appendix S1 & Fig. S1).

We explained to respondents that additional extension services would support introducing the new cropping techniques and tree management, with tree seedlings and seeds being provided at the start. The programme would be implemented by a non-governmental organization, which would monitor and check the presence of the trees, in collaboration with the village development committee, which would oversee the conditional credit scheme. Pre-tests confirmed this as the most suitable approach.

To assess the contribution of the CSA options to well-being, we used different well-being dimensions as impact criteria. We pre-selected relevant well-being criteria (Appendix S1 & Fig. S2) based on (1) CSA goals in low-income settings – food security and climate adaptation; (2) multidimensional poverty and well-being studies (Alkire & Santos 2014); and (3) smallholder input. During pre-tests, we asked an open question (how the presented options would affect well-being), followed by a ranking exercise, resulting in seven frequently selected criteria. These criteria were presented first in the final MCDA exercise, and then respondents could choose one or two additional criteria from the remaining nine (and one blank card for customization), to a maximum of eight criteria. Choosing two additional criteria required removing another. The primary criteria set covered material well-being and health, while the secondary set included, for instance, intimacy, privacy, community and emotional well-being (Maduekwe et al. 2020). This approach meant that not all respondents used the same well-being evaluation criteria, but it fulfils the methodological requirement of criteria completeness and relevance at the individual level (Geneletti 2019). The criteria were deemed to be non-redundant, functional and independently scorable (Geneletti 2019).

Our pre-tests showed that a rank-based method whereby no equal ranks were allowed worked best. Each respondent was asked to rank their eight well-being criteria from most to least important to their household's well-being. These ranks were converted into a score from 1 to 8.

Pre-test respondents understood the exercise best when they were asked to score the four options relative to the current situation, using a fixed scale from 1 to 5, with 1 meaning much worse, 3 meaning the same as and 5 meaning much better than the current situation, and with 2 and 4 being scores in between.

After establishing the criteria, weights and scores, the interviewer calculated the overall score for each option. We used a linear additive decision rule, which is simple for paper-and-pencil surveys, widely applied and was easier for our sample to understand than other MCDA methods (Hajkowicz & Collins 2007). The interviewers then ranked the options based on total scores and asked respondents to confirm whether the ranking aligned with their preferences. If not, the interviewers probed why and which option(s) respondents would prefer most or least. These

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qualitative answers informed our interpretation. A sensitivity analysis was performed using Monte Carlo simulation (results are given in Appendix S2).

The final questionnaire with the embedded MCDA consisted of seven sections: (1) agricultural yields; (2) forest use and revenues; (3) the MCDA exercise; (4) perceptions of barriers, financial credit and institutions; (5) benefits of tree planting, crop diversification and forest conservation; (6) household characteristics; and (7) an interviewer evaluation. All texts were translated into Chichewa.

Due to low literacy levels and the benefits of visual aids, we used figures and pictograms to explain the options (Fig. 1), scheme conditions (Appendix S1 & Fig. S1) and criteria (Appendix S1 & Fig. S2). For scoring, respondents used beans and a hard paper board with a scoring matrix: the chosen criteria were placed at the top, and scores for each option were assigned in the rows.

We pre-tested the methods in four villages in April 2015 with three experienced Malawian enumerators before final data collection took place from mid-June to mid-August in 2015. Four trained Malawian enumerators conducted the interviews in four group-villages, covering 10 sub-villages selected based on population size (data from the 2010 census) and distance to Zomba City and the Zomba-Malosa forest.

After household mapping, most villages had all households selected and assigned either to this MCDA exercise or to another research activity. The sampling selection mainly aimed for gender balance, as observable well-being differences were relatively small. Only respondents aged between 18 and 65 were eligible. We carefully explained that the scenarios were hypothetical and for research purposes only, without any future project implementation plans. The participants of the pre-tests and final data collection received monetary remuneration to compensate them for their time.

In March 2016, we organized feedback meetings in each group-village to share the preliminary results. We noted down some farmers' quotes to contextualize the findings and explain the heterogeneity, but we did not make audio recordings or systematically collect additional data due to practical constraints.

## Results

### *Descriptive statistics*

In total, 98 respondents participated in the MCDA study (descriptive statistics of the sample are given in Table 1). The interviews took on average 77 min.

The numbers of male and female respondents were almost equal. Households produced 519 kg of maize (c. 108 kg of maize per person), leading to perceived food insufficiency. On average, households produced enough food to meet domestic needs for 9 months of the year. Other important crops were groundnuts (80 kg/ha), pigeon peas (30 kg/ha) and cotton (57 kg/ha); sorghum and soy production was low, at less than 10 kg/ha. Ninety-seven per cent of respondents used chemical fertilizer, but the mean amount used was low (72 kg/ha) in comparison with industrialized countries (e.g., 200 kg/ha in Germany).

Most crop production was for domestic consumption, and farm revenues were relatively low. Few households owned woodlots, and mean woodlot revenues were negligible, but forest revenues (mainly from selling charcoal, bamboo, firewood and grasses) were relevant. Seventy-three per cent of households owned livestock (primarily goats and chickens), with average earnings of MKW 2400 (~€4). Relative to these figures, the credit levels in the MCDA options seemed to be appropriately scaled, particularly since the options would imply a considerable change in the primary food production source.

**Table 1.** Descriptive statistics of the sample (n = 98).

| Variable | Mean (unless indicated otherwise) |
|---|---|
| Respondent gender (% male) | 49% |
| Respondent age (in years) | 39 |
| Respondent education – median | Up to 5 years (standard 5) |
| Respondent head of household (dummy variable, 1 = yes, % of sample) | 63% |
| Household size (number of family members) | 4.8 |
| Number of plots | 1.9 |
| Total plot area (in ha) | 0.84 |
| Quantity of maize produced (in kg) | 519 |
| Total number of trees on farm | 12.5 |
| Woodlot ownership (dummy variable, 1 = yes, % of sample) | 9.1% |
| Amount of fertilizer used (in kg) | 72.4 |
| Previously received extension services in intercropping/rotation projects (dummy variable, 1 = yes, % of sample) | 21% |
| Previously received extension services in tree planting projects (dummy variable, 1 = yes, % of sample) | 55% |
| Number of months that food was sufficient for family | 8.9 |
| Other cash income (dummy variable, 1 = yes, % of sample) | 64% |
| Agricultural revenue (in Malawian Kwacha) | 20 075 |

**Table 2.** Weights of the eight most often selected well-being criteria. Respondents were asked to choose eight criteria: to the primary set (Appendix S1 & Fig. S2) they could add one criterion and optionally use one criterion to replace a primary criterion. Therefore, the number of times that each criterion was chosen varies. Weights for criteria excluded by the respondent were set to zero. Averages and medians included the zero weights for non-chosen criteria.

| Well-being criterion | Average weight | Standard deviation | Median | Times included (n) |
|---|---|---|---|---|
| Food | 7.31 | 1.62 | 8 | 97 |
| Income for food | 4.68 | 2.21 | 5 | 92 |
| Income for education | 3.99 | 1.58 | 4 | 95 |
| Income for health | 3.91 | 1.90 | 4 | 97 |
| Dealing with floods/droughts | 3.65 | 2.25 | 3 | 97 |
| Fuelwood | 2.99 | 2.22 | 2 | 91 |
| Income for assets | 2.44 | 2.99 | 0 | 45 |
| Good social relationships | 2.38 | 1.87 | 2 | 83 |

### *Criteria selection and weights*

Respondents ranked food and income for food as the most important well-being criteria (Table 2); there was statistically significant heterogeneity in the sample (non-parametric Wilcoxon rank-sum tests, $\alpha = 0.05$). Respondents <30 years of age ranked the ability to deal with floods and droughts higher than older respondents ($Z = -2.166$, $p = 0.03$). Male respondents ranked the ability to deal with floods and droughts less highly than did women ($Z = 2.716$, $p = 0.01$), while they ranked fuelwood availability

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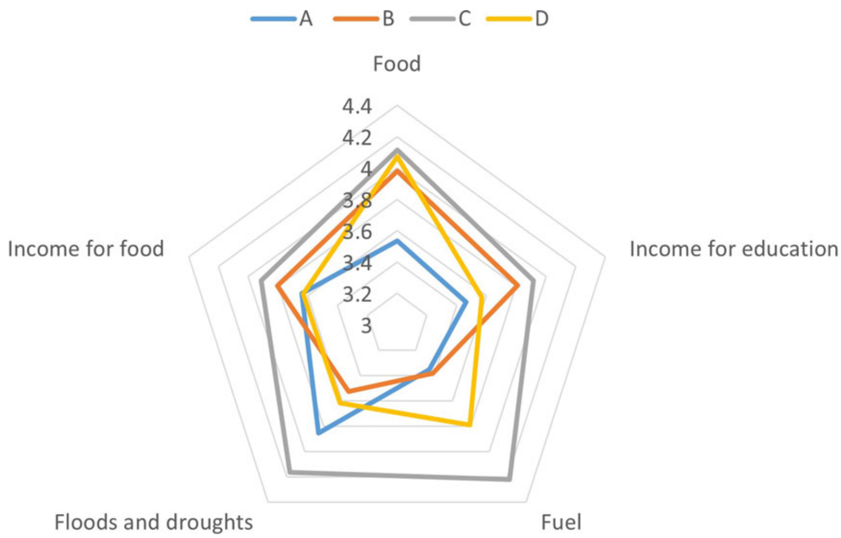


**Figure 2.** Unweighted scores of our multi-criteria decision analysis options on five main criteria.

higher (Z = –2.187, p = 0.03). Differences between villages were only found for the criterion income for assets (Kruskal–Wallis rank tests: $\chi^2(3) = 10.29$, $p = 0.02$).

### *Option scores and ranks*

The scoring of the options against the well-being criteria provided insights into the perceived performance of the CSA options in terms of their well-being contribution. Five of the eight criteria for options A–D contributed most to the observed overall score and option ranking (Fig. 2); these five criteria differed across options and respondents (Wilcoxon signed-rank tests).

Option C scored highest on all criteria, while option A scored lowest on all criteria except on dealing with floods and droughts. Option A includes sorghum and only one extra bag of maize after 5 years; respondents believed that sorghum would grow well in drought years but would negatively affect maize yields in normal years. Therefore, they scored option A significantly lower on food than the other options.

Based on the weights and scores, respondents ranked and scored option C highest, followed by options B and D (in joint second place), and then option A (Table 3). The current situation was ranked lowest. Option C has the most trees and the longest delay before receiving benefits but provides immediate food (from groundnuts), greater extra maize yields and more money than options B and D. Option A, with the highest credit, was ranked lowest. The differences in the ranks and scores of options B and D were not significant. Option B, with a higher payment and the cash crop soy, performed slightly better on the criteria associated with money. Option D scored higher on fuelwood and flood and drought resistance, which may be because pigeon peas are drought resistant and its branches are used for firewood.

### *Score and ranking differences across villages and individuals*

There were prominent differences in the ranking and scoring of options across group-villages (Table 3). The total scores and ranks of options C and D differed from each other (Kruskal–Wallis test: option C, rank $\chi^2(3) = 11.04$, $p = 0.02$, score $\chi^2(3) = 16.23$, $p = 0.01$; option D rank $\chi^2(3) = 8.87$, $p = 0.03$, score $\chi^2(3) = 14.62$, $p = 0.01$). The ranks and total scores differed because option scores on food, income for health and income for food differed. Group-village W scored option D lowest on food and income for food as the respondents did not believe it would provide a high contribution to their food security, in contrast to group-village X, which ranked option D highest (Table 3).

For income for health, group-villages W and X gave options A and C lower scores than other group-villages, as well as significantly lower-weighted scores. Group-village W placed much less importance on the assets criterion than the other group-villages, leading to different-weighted scores for the options. Significant differences were also found between group-villages in their scores for fuelwood, income for education, social relationships and dealing with floods and droughts for some options (Fig. 3), but these did not result in significantly differently weighted scores.

Significant heterogeneity across individuals was found based on observed characteristics. The weighted score on food in option B and the weighted scores for options B and C were higher among respondents aged 30 or younger than among older respondents. This led to a ranking of C > A > B > D among the younger respondents versus C > D > B > A among those aged >30 years.

Respondents with intercropping training scored option B lower on food provision and ranked it lower than option A, contrary to those without intercropping training. Respondents who had received training on tree planting gave option D, with only three trees, a lower overall score than others, but no similar effect was found for option B, also with three trees, and the option ranking did not significantly change.

## Discussion

Using well-being criteria to evaluate CSA provided a nuanced understanding of its perceived contribution to smallholders' well-being. The ranking of criteria and options demonstrated that food security was the most important well-being dimension for the respondents. As families were self-sufficient in food for only 9 months a year, the soy–maize rotation option was seen as a threat to food self-sufficiency because respondents preferred planting maize every year and because markets are distant (Yohane et al. 2021).

Food needs took precedence over financial needs, influencing crop preferences and option rankings. Option C provided less

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**Table 3.** Mean observed score (based on the individually chosen criteria set of each respondent) and rank (1 = highest, 5 = lowest) of the options for the full sample and scores of the four group-villages. Mean scores in bold indicate the highest scores among the four options.

| | Full sample | | Group-village W | Group-village X | Group-village Y | Group-village Z |
|---|---|---|---|---|---|---|
| Option | Mean rank (SD) | Mean score (SD) | Mean score (SD) | Mean score (SD) | Mean score (SD) | Mean score (SD) |
| Option A | 3.2 (1.3) | 129 (28) | 124 (31) | 122 (29) | 129 (29) | 138 (21) |
| Option B | 2.9 (1.3) | 135 (28) | **131** (32) | 121 (32) | 140 (24) | 144 (21) |
| Option C | 2.1 (1.1) | **145** (27) | **131** (32) | 132 (34) | **156** (15) | **157** (14) |
| Option D | 2.8 (1.3) | 136 (24) | 119 (31) | **136** (18) | 148 (20) | 140 (14) |
| Current situation | 4.4 (1.0) | 108 (default) | 108 | 108 | 108 | 108 |
| N | 98 | 98 | 26 | 18 | 26 | 28 |

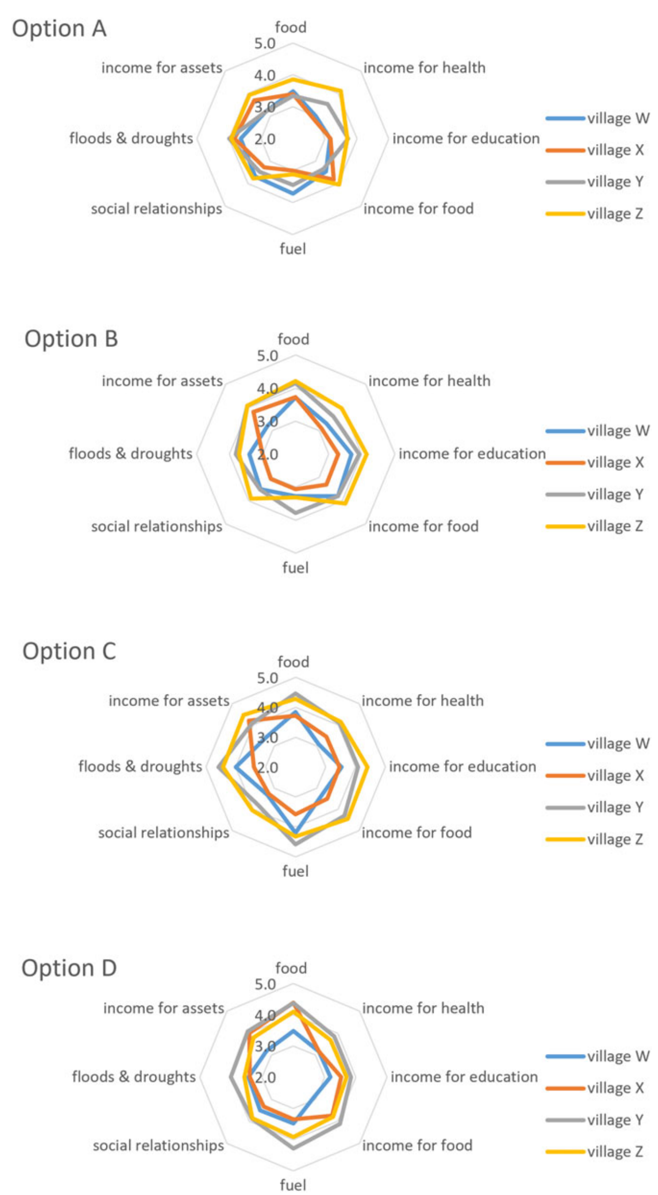


**Figure 3.** Unweighted scores per option disaggregated by village for the eight criteria that were most often chosen across the sample. Scores were set to zero for criteria that the respondent excluded.

financial compensation than option A, which included sorghum, a crop used for porridge and *nsima* (a different type of thick, starchy porridge) but that is perceived as inferior to maize. Although some organizations promote sorghum to address droughts (Stevens & Madani 2016) and farmers in other regions of Malawi grow sorghum as a drought-coping strategy (Kerr et al. 2019), both farmers and experts argued that sorghum is unsuitable for the agroecological zone of our study area under current climatic conditions.

High food insecurity may lead to farmers using payments to supplement farm yields, with respondents mentioning using these payments to obtain fertilizer, *ganyu* (casual labour) and food most often. The incentive would cover the higher labour requirements and initial yield reductions when adopting the options, but in years of poor crop yields farmers may need to spend more on food, leading to disadoption. Disadoption would, in our hypothetical study, mean returning the funds, which could further hinder their well-being. While conditional schemes are promoted (Adjognon et al. 2022), this compound risk is not well recognized.

Our results support the use of multidimensional poverty indices and highlight the importance of non-material dimensions and vulnerability. Notably, climate adaptation is perceived as very important for well-being, for which women and younger respondents expressed stronger preferences than men and older people. Female smallholders often have a lower ability to adopt CSA practices because they lack decision-making power and access to resources such as land, fertilizer coupons and knowledge (Duffy et al. 2020). In the village meetings discussing our preliminary results, a male farmer said: ‘Women cannot decide what happens on the farm .... We need agricultural extension officers to train both men and women.’ Women explained that they prioritized the ability to deal with floods and droughts over firewood because firewood could always be obtained somewhere, whereas ensuring a farm was flood and drought resistant was their primary responsibility at the start of the season. These perceptions and preferences agree with results from earlier studies (e.g., Huyer et al. 2024), but further research on such motivations may help with the promotion of CSA practices (Khoza et al. 2021). Behavioural change activities should address power imbalances within household, village and national decision-making processes. Our findings also urge CSA practitioners to reduce women’s workloads, increase their access to resources and organize communities for women’s collective action (Mutenje et al. 2019, Perelli et al. 2024).

A limitation of the study is that respondents struggled with the scoring exercise, often requiring interviewers to repeat the explanation. Several factors may explain this. Firstly, the conceptual design of this MCDA, despite thorough pre-testing, may have been too complicated. Unlike many MCDA applications, this study asked respondents to define the scores for the impact matrix. Respondents may not have been sufficiently familiar with the crops and techniques to judge the performance and well-being impacts of the options. Nonetheless, the results are coherent, being validated in the village meetings, and the ranking of options remained stable in

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the sensitivity analysis (Appendix S2). Secondly, the options were designed to be balanced, which may have made it difficult to differentiate the overall well-being impacts. Each option involved trade-offs between food production, labour, money and tree products. This complexity creates risks for farmers, who may prefer to experiment on part of their land or with safeguards in place (Hockett & Richardson 2018). Furthermore, the hypothetical nature of the options may have reduced incentive compatibility (Bartolini & Viaggi 2010).

The differences in the ranking of the options across villages signal that blanket solutions are ineffective, even within the same agroecological zone, as the costs and benefits of CSA are contextual (Hermans et al. 2021). Group-village W near Zomba City and its trading centres, being the most food-secure group-village (measured by the number of months during which households have sufficient food), ranked option D lowest, rating its food improvement lower than other group-villages and giving this criterion a slightly lower weight. Group-villages Y and Z, located on the other side of Zomba Mountain near localized trading centres, preferred option C, as it scored slightly better on all criteria, with edible and locally marketable crops offering more income and better flood and drought resilience. Group-village X, located farthest from any trading centre, ranked option D highest, perceiving its contribution to food provision as greater than the other options. We speculate that the proximity to markets offers access to trading opportunities, thereby influencing these rankings, with villages closer to markets preferring tradeable crops for cash income and remote villages prioritizing food self-sufficiency. This heterogeneity in preferences and trade-off priorities suggests that, to increase CSA adoption rates, projects should be tailored to local needs and conditions.

## Conclusion

We show that CSA projects can contribute to multiple dimensions of well-being; our MCDA design allowed farmers to rank different hypothetical CSA options across criteria such as food security, climate adaptation, health, education and energy. This shifts CSA evaluations from focusing solely on yield or income to a more holistic assessment of well-being. These results are based on the perceptions of intended CSA users regarding CSA performance on well-being needs, offering crucial insights for tailoring CSA programme designs and communication approaches. Our multi-dimensional well-being MCDA may help investors and implementers design CSA projects that contribute to multidimensional poverty reduction, and it may be applicable across a wider set of interventions aimed at achieving the SDGs in all their dimensions.

The results justify an emphasis of CSA projects on food production in our context, but they also show that preferences differ within and across communities, influenced by market opportunities and respondent age and gender. Each option in the study involved trade-offs. Smallholders were willing to forego the adaptation benefits of sorghum for more food, education and energy benefits. Nonetheless, adaptation to floods and droughts was a relevant well-being criterion for all CSA options. The transferability of these perceived links between CSA options and well-being dimensions to other areas in Malawi or other countries remains open to further investigation, but we expect the results to be context-specific, varying with agroecological conditions, farmer capabilities and sociocultural differences in well-being concepts.

This preference heterogeneity calls for continued attention to the context-specificity of CSA projects, supported by innovative financing. Rather than offering a single crop or technique, our results show that providing farmers with a portfolio of options and clear incentives may help with CSA upscaling. This would benefit smallholders, biodiversity and ecosystems. More research is needed to identify the context-specific barriers and opportunities that smallholders face and to assess whether payback conditions impose acceptable risks.

**Supplementary material.** To view supplementary material for this article, please visit https://doi.org/10.1017/S0376892925000104.

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**Competing interests.** The authors declare none.

**Ethical standards.** The authors assert that all procedures contributing to this work comply with the applicable ethical standards of the relevant national and institutional committees on human experimentation. Ethical approval was obtained prior to the pre-tests, and the study complies with GDPR and FPIC requirements (University of Southampton Ethics Reference 13003).

## References

Adjognon GS, Huy TN, Guthoff J, van Soest D (2022) *Incentivizing Social Learning for the Diffusion of Climate-Smart Agricultural Techniques*. Policy Research Working Paper 10041. Washington, DC, USA: World Bank.

Alkire S, Santos ME (2014) Measuring acute poverty in the developing world: robustness and scope of the multidimensional poverty index. *World Development* 59: 251–274.

Alrøe HF, Moller H, Læssøe J, Noe E (2016) Opportunities and challenges for multicriteria assessment of food system sustainability. *Ecology and Society* 21: 38.

Amadu FO, McNamara PE, Miller DC (2020a) Understanding the adoption of climate-smart agriculture: a farm-level typology with empirical evidence from Southern Malawi. *World Development* 126: 104692.

Amadu FO, Miller DC, McNamara PE (2020b) Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: evidence from Southern Malawi. *Ecological Economics* 167: 106443.

Antwi-Agyei P, Atta-Aidoo J, Asare-Nuamah P, Stringer LC, Antwi K (2023) Trade-offs, synergies and acceptability of climate smart agricultural practices by smallholder farmers in rural Ghana. *International Journal of Agricultural Sustainability* 21: 2193439.

Barbosa Junior M, Pinheiro E, Sokulski CC, Ramos Huarachi DA, de Francisco AC (2022) How to identify barriers to the adoption of sustainable agriculture? A study based on a multi-criteria model. *Sustainability* 14: 13277.

Bartolini F, Viaggi D (2010) Recent developments in multi-criteria evaluation of regulations. *Quality Assurance and Safety of Crops & Foods* 2: 182–196.

Branca G, Arslan A, Paolantonio A, Grewer U, Cattaneo A, Cavatassi R, et al. (2021) Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: a case study in Southern Africa. *Journal of Cleaner Production* 285: 125161.

Brandt P, Kvakić M, Butterbach-Bahl K, Rufino MC (2017) How to target climate-smart agriculture? Concept and application of the consensus-driven decision support framework 'targetCSA'. *Agricultural Systems* 151: 234–245.

Chandra A, McNamara KE, Dargusch P (2017) Climate-smart agriculture: perspectives and framings. *Climate Policy* 18: 526–541.

Cicciù B, Schramm F, Schramm VB (2022) Multi-criteria decision making/aid methods for assessing agricultural sustainability: a literature review. *Environmental Science & Policy* 138: 85–96.

Cinelli M, Coles SR, Kirwan K (2014) Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. *Ecological Indicators* 46: 138–148.

Coulibaly JY, 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 AJ, Whitfield S, Stringer LC, Vincent K, Wood BT, Chinseu EL, et al. (2017) Mainstreaming conservation agriculture in Malawi: knowledge gaps and institutional barriers. *Journal of Environmental Management* 195: 25–34.

Duffy C, Toth G, Cullinan J, Murray U, Spillane C (2021) Climate smart agriculture extension: gender disparities in agroforestry knowledge acquisition. *Climate and Development* 13: 21–33.

Erbaugh J, Bierbaum R, Castilleja G, da Fonseca GA, Hansen SCB (2019) Toward sustainable agriculture in the tropics. *World Development* 121: 158–162.

Etxano I, Villalba-Eguiluz U (2021) Twenty-five years of social multi-criteria evaluation (SMCE) in the search for sustainability: analysis of case studies. *Ecological Economics* 188: 107131.

Garrity DP, Akinnifesi FK, Ajayi OC, Weldesemayat SG, Mowo JG, Kalinganire A, et al. (2010) Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* 2: 197–214.

Geneletti D (2019) *Multicriteria Analysis for Environmental Decision-Making*. New York, NY, USA: Anthem Press.

Hajkowicz S, Collins K (2007) A review of multiple criteria analysis for water resource planning and management. *Water Resources Management* 21: 1553–1566.

Hansen J, Hellin J, Rosenstock T, Fisher E, Cairns J, Stirling C, et al. (2019) Climate risk management and rural poverty reduction. *Agricultural Systems* 172: 28–46.

Hellin J, Fisher E (2019) The Achilles heel of climate-smart agriculture. *Nature Climate Change* 9: 493–494.

Hermans TD, Whitfield S, Dougill AJ, Thierfelder C (2021) Why we should rethink 'adoption' in agricultural innovation: empirical insights from Malawi. *Land Degradation & Development* 32: 1809–1820.

Hockett M, Richardson RB (2018) Examining the drivers of agricultural experimentation among smallholder farmers in Malawi. *Experimental Agriculture* 54: 45–65.

Huyer S, Loboguerrero AM, Chanana N, Spellman O (2024) From gender gaps to gender-transformative climate-smart agriculture. *Current Opinion in Environmental Sustainability* 67: 101415.

Ignaciuk A, Maggio G, Sitko NJ (2021) *Assessing the Profitability and Feasibility of Climate-Smart Agriculture Investment in Southern Malawi: Understanding the Costs and Benefits in a Volatile and Changing Climate*. FAO Agricultural Development Economics Working Paper 21-07. Rome, Italy: FAO.

Kamanga BCG, Waddington SR, Robertson MJ, Giller KE (2010) Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in central Malawi. *Experimental Agriculture* 46: 1.

Karlsson L, Naess LO, Nightingale A, Thompson J (2018) 'Triple wins' or 'triple faults'? Analysing the equity implications of policy discourses on climate-smart agriculture (CSA). *Journal of Peasant Studies* 45: 150–174.

Kerr RB, Kangmennaang J, Dakishoni L, Nyantakyi-Frimpong H, Lupafya E, Shumba L, et al. (2019) Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. *Agriculture, Ecosystems & Environment* 279: 109–121.

Khoza S, de Beer LT, van Niekerk D, Nemakonde L (2021) A gender-differentiated analysis of climate-smart agriculture adoption by smallholder farmers: application of the extended technology acceptance model. *Gender, Technology and Development* 25: 1–21.

Khoza S, van Niekerk D, Nemakonde LD (2022) Gendered vulnerability and inequality: understanding drivers of climate-smart agriculture dis- and nonadoption among smallholder farmers in Malawi and Zambia. *Ecology and Society* 27: 19.

Li C, Chimimba EG, Kambombe O, Brown LA, Chibarabada TP, Lu Y, et al. (2022) Maize yield estimation in intercropped smallholder fields using satellite data in Southern Malawi. *Remote Sensing* 14: 2458.

Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M, et al. (2014) Climate-smart agriculture for food security. *Nature Climate Change* 4: 1068–1072.

Maduekwe E, de Vries WT, Buchenrieder G (2020) Measuring human recognition for women in Malawi using the Alkire Foster method of multidimensional poverty counting. *Social Indicators Research* 147: 805–824.

Mahmood A, Cheema ZA, Mushtaq MN, Farooq M (2013) Maize–sorghum intercropping systems for purple nutsedge management. *Archives of Agronomy and Soil Science* 59: 1279–1288.

Mason-D'Croz D, Sulser TB, Wiebe K, Rosegrant MW, Lowder SK, Nin-Pratt A, et al. (2019) Agricultural investments and hunger in Africa modeling potential contributions to SDG2 – Zero Hunger. *World Development* 116: 38–53.

Mhango WG, Snapp S, Kanyama-Phiri GY (2017) Biological nitrogen fixation and yield of pigeonpea and groundnut: quantifying response on smallholder farms in northern Malawi. *African Journal of Agricultural Research* 12: 1385–1394.

Minoli S, Müller C, Elliott J, Ruane AC, Jägermeyr J, Zabel F, et al. (2019) Global response patterns of major rainfed crops to adaptation by maintaining current growing periods and irrigation. *Earth's Future* 7: 1464–1480.

Moraine M, Grimaldi J, Murgue C, Duru M, Therond O (2016) Co-design and assessment of cropping systems for developing crop–livestock integration at the territory level. *Agricultural Systems* 147: 87–97.

Mugiyo H, Chimonyo VG, Sibanda M, Kunz R, Nhamo L, Masemola CR, et al. (2021) Multi-criteria suitability analysis for neglected and underutilised crop species in South Africa. *PLoS ONE* 16: e0244734.

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: 117–148.

Mutenje MJ, Farnworth CR, Stirling C, Thierfelder C, Mupangwa W, Nyagumbo I (2019) A cost–benefit analysis of climate-smart agriculture options in Southern Africa: balancing gender and technology. *Ecological Economics* 163: 126–137.

Nasser F, Maguire-Rajpaul VA, Dumenu WK, Wong GY (2020) Climate-smart cocoa in Ghana: how ecological modernisation discourse risks side-lining cocoa smallholders. *Frontiers in Sustainable Food Systems* 4: 73.

Newell P, Taylor O, Naess LO, Thompson J, Mahmoud H, Ndaki P, et al. (2019) Climate smart agriculture? Governing the sustainable development goals in sub-Saharan Africa. *Frontiers in Sustainable Food Systems* 3: 55.

NSO (2020) *The Fifth Integrated Household Survey (IHS5) 2020 Report*. Zomba, Malawi: National Statistics Office.

NSO (2021) *Malawi Poverty Report 2020*. Zomba, Malawi: National Statistics Office.

Nyagumbo I, Mutenje M, Setimela P, Chipindu L, Chisaka A, Simwaka P, et al. (2022) Evaluating the merits of climate smart technologies under smallholder agriculture in Malawi. *Soil Use and Management* 38: 890–906.

Pangapanga-Phiri I, Ngoma H, Thierfelder C (2024) Understanding sustained adoption of conservation agriculture among smallholder farmers: insights from a sentinel site in Malawi. *Renewable Agriculture and Food Systems* 39: e10.

Perelli C, Cacchiarelli L, Peveri V, Branca G (2024) Gender equality and sustainable development: a cross-country study on women's contribution to the adoption of the climate-smart agriculture in sub-Saharan Africa. *Ecological Economics* 219: 108145.

Pugh TAM, Müller C, Elliott J, Deryng D, Folberth C, et al. (2016) Climate analogues suggest limited potential for intensification of production on current croplands under climate change. *Nature Communications* 7: 1–8.

Rasmussen LV, Coolsaet B, Martin A, Mertz O, Pascual U, Corbera E, et al. (2018) Social-ecological outcomes of agricultural intensification. *Nature Sustainability* 1: 275–282.

Sauer J, Tchale H (2009) The economics of soil fertility management in Malawi. *Review of Agricultural Economics* 31: 535–560.

Scognamillo A, Sitko NJ (2021) Leveraging social protection to advance climate-smart agriculture: an empirical analysis of the impacts of Malawi's Social Action Fund (MASAF) on farmers' adoption decisions and welfare outcomes. *World Development* 146: 105618.

Stevens T, Madani K (2016) Future climate impacts on maize farming and food security in Malawi. *Scientific Reports* 6: 1–14.
Teshome A, de Graaff J, Stroosnijder L (2014) Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi-criteria analysis. *Frontiers in Environmental Science* 2: 60.
Thierfelder C, Chivenge P, Mupangwa W, Rosenstock TS, Lamanna C, Eyre JX (2017) How climate-smart is conservation agriculture (CA)? Its potential to deliver on adaptation, mitigation and productivity on smallholder farms in Southern Africa. *Food Security* 9: 537–560.
Tikita BY, Lee SH (2024). Factors influencing the double-up adoption of climate change adaptation strategies among smallholder maize farmers in Malawi. *Sustainability* 16: 602.
UNCTAD (2023) *Reducing Inequality and Poverty in Malawi: Policy Analyses and Options*. UNCTAD/ALDC/2023/4. Geneva, Switzerland: United Nations Conference on Trade and Development.
van Vugt D, Franke AC, Giller KE (2018) Understanding variability in the benefits of $N_2$-fixation in soybean–maize rotations on smallholder farmers' fields in Malawi. *Agriculture, Ecosystems & Environment* 261: 241–250.
Van Zeist WJ, Stehfest E, Doelman JC, Valin H, Calvin K, Fujimori S, et al. (2020) Are scenario projections overly optimistic about future yield progress? *Global Environmental Change* 64: 102120.
Walter A, Finger R, Huber R, Buchmann N (2017) Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences of the United States of America* 114: 6148–6150.
Warnatzsch EA, Reay DS (2020) Assessing climate change projections and impacts on Central Malawi's maize yield: the risk of maladaptation. *Science of the Total Environment* 711: 134845.
Wassmann R, Villanueva J, Khounthavong M, Okumu BO, Vo TBT, Sander BO (2019) Adaptation, mitigation and food security: multi-criteria ranking system for climate-smart agriculture technologies illustrated for rainfed rice in Laos. *Global Food Security* 23: 33–40.
Wood L, Moriniere L (2013) Malawi climate change vulnerability assessment. United States Agency for International Development (USAID) [www document]. URL https://www.climatelinks.org/sites/default/files/asset/document/Malawi%2520VAFinal%2520Report_12Sep13_FINAL.pdf
World Bank (2019) *Malawi Country Environmental Analysis*. Washington, DC, USA: World Bank.
Yohane EN, Shimelis H, Laing M, Shayanowako A, Mathew I, Chintu JM (2021) Pigeonpea production constraints and farmers' trait preferences in Malawi: implications for variety design. *South African Journal of Plant and Soil* 38: 326–337.
Zhang M, Gao X, Chen G, Afzal MR, Wei T, Zeng H, et al. (2023) Intercropping with BNI-sorghum benefits neighbouring maize productivity and mitigates soil nitrification and $N_2O$ emission. *Agriculture, Ecosystems & Environment* 352: 108510.