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Assessing smallholder preferences for incentivised climate-smart agriculture using a discrete choice experiment

Marije Schaafsma,⁎ Silvia Ferrini, R. Kerry Turner

A R T I C L E  I N F O

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pro-poor
sustainable development
Malawi

A B S T R A C T

The promotion of climate smart agriculture (CSA) techniques to increase farmer resilience against climate change and improve their livelihoods is high on the international development agenda and aims to help achieve Sustainable Development Goals of food security (SDG 2), climate resilience and mitigation (SDG 13). We present the results of a discrete choice experiment (DCE) conducted in face-to-face interviews. In a study in Malawi, farmers responded to a series of questions about different cropping techniques and tree planting options to improve soil fertility and climate change resilience. A combination of financial and non-financial incentives was proposed to increase adoption and success rates. The results show that for different policy objectives, different climate smart packages are suitable. Our results demonstrate that farmers prefer options that secure the production of maize and include crops with both domestic use and local markets. The drought-resistant crop sorghum was unpopular among respondents; achieving SDG 13 through this CSA approach would therefore require high incentive payments. If CSA is to help achieve multiple goals e.g. poverty and inequality reduction (SDGs 1 and 10) as well as SDGs 2 and 13, a range of CSA packages, with different types of crops, rotation versus intercropping techniques and incentive levels, should be offered to smallholders.

1. Introduction - climate smart agriculture and adoption

Globally, there are an estimated 500 million smallholder farms, who produce 75% of all food (Lowder et al., 2016), yet many smallholders live below the international income poverty line. Widespread calls for radical changes in the current food and agriculture system (e.g. TEEB, 2018) towards sustainable agricultural intensification (Rockström et al., 2017) have been motivated by damage to biodiversity and ecosystems – with estimated costs of up to 18% of global economic output by 2050, up from around 3.1% (US$2 trillion) in 2008 (UNPRI, 2017). The food and agriculture system is therefore considered as one of the four biggest opportunities for SDG investment for business and governments (ibid.).

Several international development organisations, including the World Bank and the FAO, have adopted Climate Smart Agriculture (CSA), as the main strategy for sustainable agriculture driven development to support food security under climate change (Lipper et al., 2014). These organisations, who have set up networks with large private sector agents but also work with local stakeholders, try to promote CSA practices and its recognition in policy. CSA aims to improve farmer incomes and livelihoods, increase farmer resilience to climate change, and where possible reduce greenhouse gas emissions from farming. The set of CSA techniques include off- and on-farm techniques, covering multiple steps in the agricultural commodity chain.

There is an intense debate across stakeholder groups about the advantages and disadvantages of sustainable intensification and CSA. Proponents argue that poor and non-farming households benefit from agricultural development through higher food availability, lower prices and labour opportunities (Gomez et al., 2011). Arguably, CSA and intensification practices provide win-wins (Waldron et al., 2017) and help to reduce emissions globally by reducing forest and woodland conversion (Burney et al., 2010). The introduction of new crops and tree planting may help to increase farm revenue, climate resilience, soil fertility (Akinnifesi et al., 2011) and reduce deforestation (Kaczan et al., 2013).

Critics question the socio-political dimension of CSA, the emphasis on technology rather than political reform, and on win-wins rather than trade-offs in complex systems (Taylor, 2018; Whitfield et al., 2018). Civil society organisations have published their concerns about CSA leading up to the COP21 and reject the Global Alliance for Climate-Smart Agriculture (GACSA). They argue that CSA is a re-branding of...
industrial practices, some of which may help to adapt to climate change, but which increase dependencies on corporations without respecting ecological boundaries and local culture, knowledge and skills. They claim that private sector projects often fail to engage the poorest farmers or take their land (Rosset, 2011).

Others warn against win-win thinking. Evaluations of existing projects have found that projects fail to deliver on social and ecological goals simultaneously (Zeng et al., 2014; Rasmussen et al., 2018). Successful implementation require agricultural extension services and appropriate institutions (Coulilbaly et al., 2015). Rosenstock et al. (2015) find that win-wins (synergies) between resilience and yield improvements are found in just over half the CSA studies.

Moreover, sustainable agricultural practices, including agroforestry and conservation agriculture (Pittelkow et al., 2015), have seen little to no sustained adoption among smallholder farmers (Nebraska Declaration 2013, Corbeels et al., 2014) and have very mixed effects on the wellbeing conservation agriculture (Pittelkow et al., 2015), have seen little to no

ments are found in just over half the CSA studies.

find that win-wins (synergies) between resilience and yield improve-

ments are found in just over half the CSA studies.

Furthermore, the steady decline (<40% between 2000 and 2015)2, evidence from context-

erns through tree product sales (Akinnifesi et al., 2008), improved

unfertilised mono-cropping (Ajayi et al., 2011), and higher farm rev-

in the country (Stevens and Madani, 2016). Climate change may increase

alternative cereals such as millet and sorghum which are seen as inferior,

in agricultural diversification and technological development (Dorward

et al., 2009; Chinsinga and Cabral, 2010; Chinsinga, 2014). Moreover,

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maize production in some areas in the short-term, but this will increase

hunger among a large proportion of people. Despite subsidies, fertilisers

increased price spikes on the black maize market that have caused

bans. Ellis and Manda (2012) argue that these interventions may have

increased price spikes on the black maize market that have caused

hunger among a large proportion of people. Despite subsidies, fertilisers

are still expensive, farmers do not have access to loans and other fi-

nancial services (Lea and Hanmer, 2009), and market infrastructure is

underdeveloped (Dorward et al., 2009; Tchale and Keyser, 2010).

The farmer input subsidies have been criticised for failing to increase maize yields and to alleviate poverty as they were not distributed at the right time and to the right people (Lunduka et al., 2013; Pauw et al., 2016); and for causing fraud, corruption and distortion of the market for agri-

cultural inputs (World Bank, 2013). The fertilizer coupons are in-

sufficient and fail to reach the poorest (Denning et al., 2009; Lunduka et al., 2013). The emphasis on maize and subsidies has taken up so much of the government budget for agriculture that it causes underinvestment in agricultural diversification and technological development (Dorward et al., 2009; Chinsinga and Cabral, 2010; Chinsinga, 2014). Moreover, maize promotion may have negatively affected public perception of al-

ternative cereals such as millet and sorghum which are seen as inferior,

crops for the desperate (Chinsinga et al., 2011). In addition, besides soil

loss, climate change is putting increasing pressure on farmers in Malawi.

Both droughts and floods have had devastating impacts on food security in the country (Stevens and Madani, 2016). Climate change may increase maize production in some areas in the short-term, but this will increase the rate of soil loss (Stevens and Madani, 2016).

In response, several organisations in Malawi have trialled climate-

smart, agroforestry and conservation agriculture practices (Gilbert, 2012; Carsan et al., 2014), but with mixed levels of success. Agrofor-

estry studies in Malawi have reported increased yields compared to unfertilised mono-cropping (Ajayi et al., 2011), and higher farm rev-

enues through tree product sales (Akinnifesi et al., 2008), improved

resilience to climate change (Verchot et al., 2007) and food security

(Snapp et al., 2010). However, lack of land and knowledge about

\[1 \text{ Available from: https://ispc.cgiar.org/publication/nebraska-declaration-conservation-agriculture}\]

\[2 \text{ Available at: http://www.fao.org/sustainable-development-goals/indicators/2a1/en/}\]
agroforestry practices mean that farmers do not prioritise agroforestry (Cromwell et al., 2001). Poverty can also limit the adoption of trees on farmland, when farmers are not willing to invest scarce resources in trees which have delayed benefits and involve risks of food insecurity and technological failure (Walker, 2004; Kamanga et al., 2010; Jerneck and Olsson, 2014; Meijer et al., 2015). Land scarcity, lack of tree seeds and seedlings, tree theft and low tree survival rates were reported in focus groups discussing agroforestry (Meijer et al., 2015). Support to invest in agroforestry through microfinance has therefore been put forward as a possible way to increase adoption and success rates (ibid.).

Short-term benefits are hence important for adoption of on-farm trees and other sustainable farming options, especially in the context of Malawi with high subsistence farming rates. Farmers are most likely to adopt legume intercropping systems with crops that fulfil immediate food needs or have easy market access, such as pigeon peas (Sirrine et al., 2010; Waldman et al., 2017), and more likely to adopt improved grains than non-grain legumes (Pircher et al., 2013). Intercropping maize with legumes may be more beneficial and less risky than rotation of these crops (Kamanga et al., 2010).

If sustainable techniques do not generate short-term net-benefits, external incentives may be necessary for adoption. In dry low-elevation areas, yields under conservation agriculture have been found to increase compared to high-elevation areas and control settings, suggesting that farmers in high-elevation areas may need considerably higher incentives for some of the conservation agriculture techniques (Ngwira et al., 2013). Agroforestry may also need short-term subsidies, because the number of trees necessary to improve maize yields takes up land while the improvement of soil properties takes multiple years, which therefore may mean that farmers have to forego yields in the initial years (Sirrine et al., 2010). Other labour and capital costs of agroforestry also tend to be higher in the short-term: maize agroforestry is more labour-intensive than conventional maize cropping during the first two years, when the management of the saplings and tree growth requires considerable attention (Garrity et al., 2010). However, there are few studies that have investigated whether and what level of subsidies farmers perceive to be necessary to offset their opportunity costs.

3. Methods

3.1. Discrete choice experiments

This study uses a discrete choice experiment (DCE) to elicit farmers’ preferences for a climate-smart agricultural program to understand whether preference for on-farm agricultural projects would vary with individual wealth and wellbeing levels. DCEs are useful for eliciting values when no functioning markets exist in which farmers reveal their preferences for CSA. Instead, DCE rely on hypothetical markets to analyse the welfare effects of policies. This can inform decisions on investment in CSA, especially if the flow of benefits of different CSA options can be compared against their costs (Thornton et al., 2018).

In the standard economic model of rational choice in decision making, individuals are assumed to maximise their utility by determining what options are available and then choosing the most preferred one. The DCE is a method in which respondents are asked to indicate their preference among two or more multi-attribute alternatives; the value of these alternatives can be associated with changes beyond existing markets or conditions (Johnston et al., 2017). In a DCE, respondents are usually asked to complete a sequence of choice sets, which each consists of two or more options, together with an opt-out option.

The DCE data can be used to estimate discrete choice models. In the random utility framework which underlies the DCE technique, utility is comprised of a systematic component $V_{ijt}$ and an error term $\varepsilon_{ijt}$ formalized in the following basic relationship:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt}$$

$V_{ijt}$ is the deterministic component of the utility and can be specified as linear function of parameters where a respondent $n$ chooses option $i$ out of a set of options $J$ in choice situation $t$ so that the utility function $U$ for respondent $n$ is defined as:

$$U_{ijt} = \beta_0 X_{nte} + \varepsilon_{ijt} = \sum_{r=1,2} (\beta_0 + \epsilon_{0r}) A_{nte} + \sum_{k=1} k (\beta_k + \epsilon_{kr}) X_{kte} + \sum_{k=n+1} k (\beta_k + \epsilon_{kr}) X_{nte} + \epsilon_{ijt}$$

$\epsilon$ is the vector of parameters to estimate and the matrix $X$ summarizes observable variables. $A_1$ is a dummy variable that takes the value 1 for the two alternative policies, and 0 for the opt-out, and $\alpha$ is the mean parameter of these alternative specific constants. The attributes $X_{nte}$ of matrix $X$ are portioned in $k$ random coefficients $\beta$ across respondents ($n$) and in the remaining fixed $\gamma$ coefficients. Both alternative specific constants and random parameters are normally distributed with standard deviation parameters $\sigma_{\alpha,\beta}$. The component of respondent $n$’s utility that cannot be observed is denoted by $\epsilon_{ijt}$ and distributed as extreme value type I. The parameter $\alpha$, and its normal random distribution, characterise a error-component model that can accommodate correlation among alternatives to reflect that less familiar hypothetical alternatives are compared with the current situation (Brownstone and Train, 1998; Scarpa et al., 2005). The random component model is defined by the parameters $\beta$ and $\sigma^2$ and allows for heterogeneous preferences within the sampled population, unrestricted substitution patterns and correlation between the different aspects of utility (Train, 2009).

Choices are a function of the probability that the utility of option $i$ is higher than for the other alternatives. In the mixed logit model, the choice probability function is described as the integral of the conditional individual probabilities over all possible choice variables and their marginal effects, where $f(\theta | \Phi)$ is the density function of $\theta$ with distribution $\Phi$:

$$P_{ijt} = \int \frac{e^{\theta' X_{nte}}}{\sum_{j=1} J e^{\theta' X_{nte}}} f(\Phi) \, d\Phi \text{ for all } i \neq j$$

Because the unconditional probability of the sequence of observed choices (i.e. $t = 1; 2; \ldots 6$) has no closed form, the probability needs to be approximated through simulation by factoring out the random and error component coefficients over the standard normal distributions. This model specification can also account for the panel structure of the data.

The estimates of the coefficient vector indicate the average utility weights of the attributes included in the choice tasks. The willingness to pay (WTP) value or the implicit price for each non-price attribute $z$ can be calculated as $WTP = -\beta_z / \beta_p$ where $\beta_z$ and $\beta_p$ represent the (mean of the distribution of the) coefficients of the $z$-th attribute and of the price attribute respectively. With the estimates of the coefficient vector it is also possible to derive individual-specific (conditional) WTP measures (Train, 2009). These post-estimation measures provide a marginal WTP (i.e. compared to a baseline) for the adoption of the attribute considered in the DCE for each individual. Individual characteristic and socio-economic conditions can play a role in explaining these WTP measures and alternative approaches are available to disentangle heterogeneity in preferences (e.g. Ward et al., 2016). Seemingly unrelated regression (SUR) models the $n$ individual WTP by considering a set of $z=(1, Z)$ marginal WTP equations that are explained by the matrix of characteristics ($Y_{nct}$) and their error terms are correlated:

$$MWTPE_c = f(Y_{nct}, \theta_c) + \varepsilon_{nct}$$

$$E(\varepsilon_{nct} | Y_{nct}) = 0$$

$$E(\varepsilon_{nct} \varepsilon_{nct}^T | Y_{nct}) \neq 0$$

Different individual and social characteristics can influence the matrix $Y_{nct}$. The SUR model efficiently accommodates the correlation across equations but not across individuals (Cameron and Trivedi,
2005). The SUR model provides a broad understanding of factors influencing the adoption of CSA techniques and results can support decision makers in tailoring interventions to different subpopulations.

DCEs have not been applied extensively to understand agricultural choices in Malawi. Waldman et al. (2017) assess the choices farmers make between annual and perennial maize-pigeon pea intercropping systems, and how farmer characteristics affect opt-out choices. Ward et al. (2016) investigate the impact of subsidies on adoption of conservation agriculture and reveal preference heterogeneity among farmers in Malawi by assessing individual WTP estimates for different attributes. Marenya et al. (2014) used framed choice experiments to investigate whether farmers were interested in crop insurance to cope with drought risks, and risk aversion affected insurance uptake. Our study provides further insight into the preferred CSA techniques of different subgroups among rural farmers to provide recommendations for CSA package design.

3.2. Discrete choice experiment design

For the DCE we defined two attributes reflecting on-farm CSA techniques, two attributes that explained the additional yields of these techniques, an attribute indicating the temporal distribution of these additional yields, and one attribute reflecting a conditional payment to cover the adoption costs (see Table 1). Farmers were assumed to be able to assess and trade-off the costs and benefits of these techniques over time, and thereby indicate the minimum compensation level they would require.

The first attribute was the crop diversification attribute, with four levels: soy-maize rotation, pigeon pea-maize intercropping, groundnut-maize intercropping and sorghum-maize intercropping. Soy is mostly a cash crop (Tinsley, 2009), pigeon pea and groundnuts are food crops traded in local markets, and sorghum is a climate resistant wheat crop (Cooper et al., 2008). The second attribute was the additional number of trees planted on the “mundas” (main type of plot, not riverine), varying from three to twenty trees in total. The levels of this attribute were based on the required 25–30 trees per hectare for achieving improved maize yields, and the relatively small land parcels in the area (NSO, 2017a). The third attribute was the number of years that it would take to improve maize yields and harvest tree products, varying from one to ten years as reported in Garrity et al. (2010). The fourth attribute was the increase in maize yields, varying from zero to three bags of 50 kg per year, based on studies such as Kamanga et al. (2010) and Kaczan et al. (2013). The tree products included fruits, poles and firewood, as represented by the fifth attribute.

The sixth attribute was the financial incentive, which was presented as a conditional annual credit that farmers would receive for five years, and that they would not have to pay back if the trees were still present on their land after five years. However, should they fail to manage the trees then the payments would be turned into a loan. The amounts, varying from five to forty thousand Malawian Kwacha (MKW) per year (EUR 7–40), were based on a calculation of the costs of additional labour required for the systems, and the loss of maize in initial years. The choice for a WTA question was not only motivated by the fact that implementation of the programs would impose costs on farmers in the first few years, but also that part of the benefits of such projects would accrue to the more distant communities that could potentially benefit from regulation of water flow, carbon sequestration and lower pressure on forests. A subsidy is coherent with the current fertiliser subsidy programme even if the subsidy is provided in the form of coupons. Moreover, in low-income countries, household budget constraints can prohibit WTP questions (Rai and Scarborough, 2015).

In the hypothetical scenario, the options would be supported by additional extension services to train farmers in the methods and tree caring, and seedlings as well as seeds for the new crop would be provided in year 1. The program would be implemented by an NGO in collaboration with the village development committee. The NGO would monitor and check the presence of the trees; the village development committee would manage the conditional credit scheme.

Fig. 1 presents an example of a choice card. The design for the DCE was generated using SAS software following procedures for a D-efficient design with non-informative priors as outlined in Kuhfeld (2010). The design consisted of 36 choice cards split into six versions (blocks). The experimental design was optimised for main effects but does not allow for the analysis of interaction effects (synergies) between the attributes.

3.3. Pre-tests and data collection

The methods were pre-tested in comparable villages during April 2015 with the help of experienced Malawian enumerators. Low levels of literacy necessitated the use of figures and pictograms to explain the attributes, levels, and hypothetical market. The main change made during the pre-tests was an increase in the level of credit, as pre-test respondents deemed the initial levels too low to overcome the adoption costs.

Data were collected from mid-June until mid-August 2015. Four trained Malawi interviewers conducted the interviews. The household questionnaire consisted of seven parts, including questions on (a) current agricultural yields, (b) forest use and revenues, (c) the choice experiment, (d) perceptions on the barriers, financial credit, and institutions involved in the hypothetical market, (e) perception on benefits of tree planting, crop diversification and forest conservation, (f) household characteristics, and (g) an interview assessment completed by the interviewer.

Respondents were selected after a household mapping exercise in the villages. Four group-villages were selected, with ten sub-villages in total. One group-village is located in Zomba District, the other three in Machinga District. The locations were chosen based on the distance to the town of Zomba and to the most intact part of the Zomba-Malosa forest. One of the group-villages was involved in the community-based forest management of this forest. In each group-village, fifty individual choice experiments were conducted. Participants had to be aged between 18 and 65 years and were selected to achieve proportional representation of gender and age groups, representative of the village population.

4. Results

4.1. Descriptive statistics

In total, 198 respondents participated in the DCE, and 196

<table>
<thead>
<tr>
<th>Attribute Level</th>
<th>Soy - maize rotation</th>
<th>Groundnut - maize intercropping</th>
<th>Pigeon pea - maize intercropping</th>
<th>Sorghum - maize intercropping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of extra trees</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Time until improvement</td>
<td>1 year</td>
<td>2 years</td>
<td>5 years</td>
<td>10 years</td>
</tr>
<tr>
<td>Increase in maize yield</td>
<td>0 bags of 50 kg</td>
<td>1 bag of 50 kg</td>
<td>2 bags of 50 kg</td>
<td>4 bags of 50 kg</td>
</tr>
<tr>
<td>Tree product</td>
<td>fuelwood</td>
<td>fruits</td>
<td>poles</td>
<td></td>
</tr>
<tr>
<td>Credit (MKW/year)</td>
<td>5000</td>
<td>15000</td>
<td>25000</td>
<td>40000</td>
</tr>
</tbody>
</table>
observations remained for analysis after data cleaning; descriptive statistics are presented in Table 2. The number of female respondents was higher than male respondents. Education levels were low, with only 34% of the sample having completed primary schooling or above. The mean household size was 4.5. The average land holdings were just under 1 ha per household and 35% of the respondents had only one plot.

Households produced on average 681 kg of maize, but the skewed maize yield distribution implies that for a considerable proportion of the sample the farm does not produce sufficient food to last the whole year – on average, respondents reported that their farm produced enough food for 9 months of the year. Other important crops are groundnuts (with a yield of 237 kg/ha), pigeon peas (32 kg/ha) and cotton (57 kg/ha); sorghum and soy production were low.

Almost all respondents (96%) use chemical fertiliser, but the amount of fertiliser that households can get or afford is low (median = 87 kg/ha) in comparison to industrialised countries (e.g. 200 kg/ha for maize in Germany) (Roser and Ritchie, 2017). The mean number of fertiliser coupons that households get is 0.95; village politics dictate that coupons are shared among families and friends irrespective of need.

As most of the farm produce is used for domestic consumption, cash revenues from respondents’ farms are relatively low. Few households own a private woodlot, and mean woodlot revenues are negligible, but public or communal forest revenues (mainly from selling charcoal, bamboo, firewood and grasses) are relevant. More than half of the households (58%) own livestock. Within the ‘other income’ pool, the largest source is formal employment, with smaller contributions from charcoal trade, non-agricultural activities, remittances, social cash transfers and agricultural wage labour. Compared to the sample

<table>
<thead>
<tr>
<th><strong>Mbeu zosiyanasiya mkalimiwe</strong></th>
<th><strong>Kusinthasintha chimanga ndi soya</strong></th>
<th><strong>Kupachiza chimanga ndi mtetza</strong></th>
<th><strong>Kungodala ulimi wanu (mwanthawi zonse)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nambola ya mitengo yowonjezer a m'munda</strong></td>
<td><strong>Mitengo 3 younjedzera</strong></td>
<td><strong>Mitengo 10 younjedzera</strong></td>
<td><strong>Osawoyenjedzera mitengo</strong></td>
</tr>
<tr>
<td><strong>Zaka zomwe zingadutse kuti muthu ayambe kuko lolo kuchokera ku mitengo ndiponso chimanga</strong></td>
<td><strong>Chaka chimodzi</strong></td>
<td><strong>Chaka makumi</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Zokolola zowonjedzera pachaka</strong></td>
<td><strong>4 nthumbala 50kg</strong></td>
<td><strong>4 nthumbala 50kg</strong></td>
<td><strong>Popanda mitengo woonjezer a nthaka osasitha</strong></td>
</tr>
<tr>
<td><strong>Zokolola ku mitengo</strong></td>
<td><strong>Zipatso</strong></td>
<td><strong>Mapolo</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Khubili kwa dzaka zitsano</strong></td>
<td><strong>MK 25000</strong></td>
<td><strong>MK 15000</strong></td>
<td><strong>MK 0</strong></td>
</tr>
</tbody>
</table>

Fig. 1. Example choice card.
The opt-out rate was very low, with only 7% of choices for the current situation. The main motivations for choosing the opt-out were that respondents thought the options would not be more beneficial than their current farming practices, they would not be able to afford the additional labour required for the new practices, or number of trees in their current farming practices, they would not be able to afford the

4.3. Observed preference heterogeneity

The results of the mixed logit model show considerable heterogeneity, with some respondents assigning positive utility changes to some of the attributes, while others express negative utility changes. Explaining this heterogeneity would help to understand which segments of the population are likely to adopt certain CSA packages. Therefore, we estimate how the heterogeneity in the conditional means of the random parameters of the DCE attributes are associated with indicators for different types of capitals (human, financial, natural, social and physical). We estimated a SUR model using STATA software and procedures and present the results in Table 4.
preferences towards extra trees. Preferences for poles was positively associated with the number of trees that respondents already owned on their plots, which may reflect a knowledge effect. Finally, the preferred credit amount was negatively associated with having more supporting relatives and with living in village 1. There are differences between the four villages in various characteristics, but none of these had a direct effect on the conditional parameter of the credit amount. Several variables found to be significant in previous studies (e.g. Giller et al., 2011; Kassie et al., 2015), such as the access to fertiliser inputs, to financial and agricultural markets, were not significant in our dataset.

The χ² tests of the individual regressions demonstrate that the models are significantly better than their constant-only counterparts; the Breusch-Pagan test of independence is a Lagrange multiple statistic, of which the results here show that the errors of the five equations are significantly correlated. For 10 respondents, data on the relevant characteristics were missing, so they were excluded from this analysis.

4.4. Implications for CSA policies: estimating conditional adoption rates of CSA packages

To demonstrate the implications of our findings on the incentive payments required for different packages, Table 5 provides estimates of WTA and proportion of market shares for four different potential

---

Table 3
Choice model results.

<table>
<thead>
<tr>
<th>Random parameters</th>
<th>Mean (s.d.)</th>
<th>Standard deviation (s.d.)</th>
<th>% β &gt; 0</th>
<th>WTA⁻¹ (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra bags of maize</td>
<td>0.382*** (0.065)</td>
<td>0.446*** (0.086)</td>
<td>93</td>
<td>−7.16 (−14.44; −4.29)</td>
</tr>
<tr>
<td>Extra trees</td>
<td>−0.091*** (0.018)</td>
<td>−0.146*** (0.022)</td>
<td>18</td>
<td>1.70 (0.77; 3.38)</td>
</tr>
<tr>
<td>Soy rotation (mean)</td>
<td>−1.223*** (0.220)</td>
<td>−1.375*** (0.294)</td>
<td>7</td>
<td>23.17 (10.44; 46.46)</td>
</tr>
<tr>
<td>Poles (mean)</td>
<td>0.216 (0.186)</td>
<td>1.113*** (0.311)</td>
<td>n.s.</td>
<td>−4.29 (−14.12; 2.95)</td>
</tr>
<tr>
<td>Credit level (in MKW 1000)</td>
<td>0.064*** (0.018)</td>
<td>−0.114*** (0.003)</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

Fixed parameters

| Alternative specific constant           | 4.915*** (0.681)     |                      | −93.54 (−193.39; −45.73) |
| Sorghum intercrop                       | −0.741*** (−3.503)   | 14.34 (4.96; 30.67)   |
| Pigeon pea intercrop (mean)             | 0.080 (0.189)        | −0.023 (0.018)        | 4.02 (−0.26; 1.25)       |
| Time (in years)                         | 0.402* (0.158)       | −2.696*** (0.502)     | −7.23 (−16.23; −1.47)    |

Error component

| Loglikelihood                           | −886.6               |                      |                    |
| No. Obs.                                | 1176                 |                      |                    |

Notes: *** p < 0.01, ** p < 0.05, *p < 0.10. N.s. = not significant. ¹ Note that WTA is calculated as: −(β/αₘₛₜ), so that positive WTA estimates imply that farmers require compensation, while negative WTA estimates imply that farmers would be willing to pay to achieve increases in the attribute.

Table 4
Results of seemingly unrelated regression model.

<table>
<thead>
<tr>
<th>Conditional mean</th>
<th>R² (χ²)</th>
<th>Explanatory variable</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy rotation</td>
<td>0.03**  (7.50)</td>
<td>Gender respondent (1=male)</td>
<td>−0.229**</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only 1 plot owned</td>
<td>−0.251**</td>
<td>0.121</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>−1.062***</td>
<td>0.090</td>
</tr>
<tr>
<td>Number of extra maize bags</td>
<td>0.08*** (18.13)</td>
<td>Number of relatives in village for support</td>
<td>−0.014**</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education level of 5 years or more</td>
<td>0.099**</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only 1 plot owned</td>
<td>−0.084**</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.414***</td>
<td>0.030</td>
</tr>
<tr>
<td>Number of extra trees</td>
<td>0.15*** (33.65)</td>
<td>Expecting government assistance</td>
<td>0.025**</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Involved in intercropping projects</td>
<td>0.035**</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Revenues (log)</td>
<td>0.004***</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of plots</td>
<td>0.024***</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>−0.018***</td>
<td>0.018</td>
</tr>
<tr>
<td>Poles</td>
<td>0.04*** (3.94)</td>
<td>Total number of trees on farm (log)</td>
<td>0.072***</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.101***</td>
<td>0.062</td>
</tr>
<tr>
<td>Credit</td>
<td>0.07*** (15.35)</td>
<td>Living in village 1</td>
<td>−0.006**</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of relatives in village for support</td>
<td>−0.001***</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constant</td>
<td>0.011***</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Number of observations: 1176
Breusch-Pagan test of independence (χ²(10)) 25.15; P = 0.0051

Notes: *** p < 0.01, ** p < 0.05, *p < 0.10.
packages, informed by existing research on CSA in East and Southern Africa (Snapp et al., 2002; Kamanga et al., 2010; Sani et al., 2011; Sirrine et al., 2010, Kacan et al., 2013, Carsan et al., 2014; Smith et al., 2016; Franke et al., 2018; Snapp et al., 2018). Package 1 is a soy rotation package, that is expected to provide fuelwood from the 5 trees, and improve soil fertility and therefore maize production by about 4 bags a year after 5 years. Package 2 is a pigeon pea package intercropped with maize, where 5 additional trees provide fruits and maize yields increase by 2 bags a year due to the soil improvements of nitrogen fixation of the pigeon peas after 5 years. Package 3 is the drought-resistant sorghum package, where 10 extra trees for poles are planted, and one extra maize is earned from 3 years onwards. Package 4 is a basic package, which provides fuelwood from three extra trees and 1 extra bags of maize after 5 years thanks to trees improving soils.

Firstly, the WTA estimates show that Package 2 has a negative WTA estimate (-8.86 thousand MKW), which suggests that respondents would not require a financial incentive to adopt this package. We exclude the alternative specific constant from the WTA estimation. If Package 2 was the only option on offer, the WTA results suggest that 71% of smallholders in our sample would not experience a utility loss and hence not require a financial incentive. The WTA estimates are higher for the other packages, ranging from approximately zero MKW for Package 4, to 21 thousand MKW for the unpopular Package 3. If the policy objective is to increase soy production (Package 1), 49% of the farmers in our sample would require no financial incentive. However, if the policy objective is to increase farmers’ resilience to droughts, then either a different crop than sorghum should be offered, or 80% of farmers would require a financial incentive to adopt sorghum (Package 3).

Second, if multiple packages were offered to farmers at the same time, the estimates show that Package 2 is ranked highest of the four packages by 61% of the respondents of our sample. Although intercropping pigeon peas is not valued higher than intercropping groundnuts, the higher number of additional bags of maize (as a result of higher expected soil improvements when intercropping with pigeon peas) lead to a higher ranking of Package 2 than the other packages.

Noticeable from the percentage of respondents that ranked Package 1 highest is the effect of heterogeneity towards soy rotation package. Package 1 has a higher mean WTA than Package 4, i.e. its adoption requires a higher financial incentive, yet more respondents rank it highest (26% compared to 11%).

A further exploration of these results, informed by the SUR analysis in Section 4.3, shows that Package 1 is ranked highest by 31% of respondents with multiple plots, compared to only 15% of respondents with a single plot. Respondents who own one plot rank Package 4 first almost as often as Package 1. Hence, if the policy objective is to include farmers with small land holdings, then Package 4 is important to include in a portfolio of CSA programmes.

Finally, if the policy is to achieve a yield target for individual crops when multiple packages are on offer, the results show that Package 4 would have to be accompanied by an incentive payment of MKW 40 thousand for this Package to be ranked highest by a majority of respondents (more often than package 2). This shows not only that Package 2 is most popular on average, but also that the heterogeneity towards the incentive payment creates a need for a higher compensation than would be expected from the difference in mean WTA estimates alone.

### 4.5. Limitations

There are some limitations to our study that affect the use of the results for further policy appraisal and implications for poverty and inequality reduction. Firstly, the sample size of our study (n = 196) is too small to aggregate the findings across the wider population of the two sampled districts of our study (over 1 million people), as the socioeconomic and agroecological conditions of two districts are more diverse than reflected in our sample. We therefore do not provide population level estimates of WTA. Our scenario analysis aimed to provide insight into the profiles of farmers that would be likely to adopt different packages, but not to estimate aggregate welfare estimates or adoption rates. We argue that such profiles provide valuable information to development practitioners who tend to operate in selected communities and would be able to target farmers depending on their profiles with the appropriate packages.

Secondly, we expect that the high effect size of the alternative specific constant should not be used to assess potential adoption rates of the climate smart agriculture packages evaluated in this study. We expect that these estimates are subject to hypothetical bias and suggest a propensity to change that is much higher than observed in ex-post evaluation studies on the adoption of conservation agriculture and agroforestry programmes (Andersson and D’Souza 2014, Chinseu et al., 2019).

Thirdly, the effect of land ownership on preferences for the proposed CSA options was important. Our study sample included farmers with at least one plot and excluded landless people who would not be able to adopt the practices. CSA projects focused on-farm practices (rather than off-farm activities further down the value chain) may fail to reach landless people, who represent an estimated 16.7% of Malawi’s rural households (NSO, 2017b). It was beyond the scope of our study to assess preferences of landless people, or for off-farm CSA activities. Also excluded from our sampling frame were households where the head of the household was younger than 18 years, such as orphaned children living alone, and respondents older than 65 years. These groups may be more vulnerable or poor, and whether CSA projects will be able to provide benefits to these groups remains an open question.
5. Conclusions

Different agricultural projects have been implemented in Sub-Saharan Africa with the aim to increase food production as well as smallholder wellbeing and resilience, including climate smart agriculture, sustainable intensification and conservation agriculture. Our ex-ante evaluation of different climate smart agriculture packages, using a discrete choice experiment among smallholders in Malawi, shows that the ‘best’ strategy depends on the objectives of governments and development organisations promoting CSA. Our study provides relevant recommendations towards adoption of CSA and demonstrates that land ownership plays a key role in the preferences of smallholders, which may also apply to other agricultural development programs.

If the aim for CSA is to increase overall yields in line with SDG 2, organisations may mainly be interested in reaching out to as many smallholders as possible by offering the most attractive package. In our study, this was a package offering pigeon pea-maize intercropping with considerable maize yield gains. However, if the aim is to increase soy production, then our results suggest that farmers will require significant incentive payments to overcome the perceived utility losses. In the case of soy, the need for self-sufficiency in maize combined with the lack of market access, considerably reduced the attractiveness of soy-maize rotation techniques.

However, to achieve poverty and inequality reduction in line with SDG 1 and 10, strategies that target relatively poorer smallholders (i.e. those with a single plot) may require different agricultural techniques. Farmers with multiple plots were more likely to prefer soy-maize rotation schemes, whilst single-plot owners preferred groundnut-maize intercropping more often. Groundnuts have a local market and are used for self-consumption. Tree adoption, often promoted to improve or maintain soil quality, is also restricted by land ownership. Our study hence shows that for CSA to be pro-poor, options are necessary that do not lead to reduced staple food yields in the short-term, irrespective of (financial) compensation or long-term benefits. A wider CSA strategy focused on SDG 1 and 10 should also consider off-farm activities to involve landless community members.

If the aim is to increase climate resilience of farmers (SDG 13) through increasing the adoption of crops that are more drought resistant, offering sorghum-maize intercropping packages does not appear to be an effective strategy. Low marketability, limited use in current diets or perhaps the stigma of a ‘poor man’s crop’ may explain this. Governments and development organisations may want to consider other drought resilient crops. Further research would have to assess farmers’ preferences towards other crops or drought tolerant maize varieties.

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References


