World Development Vol. xx, pp. xxx–xxx, 2016
0305-750X/© 2016 Elsevier Ltd. All rights reserved.

ELSEVIER
www.elsevier.com/locate/worlddev

http://dx.doi.org/10.1016/j.worlddev.2016.06.007

Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions

DAVID L. ORTEGA [a], KURT B. WALDMAN [b], ROBERT B. RICHARDSON [a], DANIEL C. CLAY [a] and SIEGLINDE SNAPP [a,*]

[a] *Michigan State University, East Lansing, USA*
[b] *Indiana University, Bloomington, USA*

Summary. — Low soil fertility is a limiting factor to farm productivity, household nutrition, and economic development in many parts of Africa due to the continuous cultivation of maize over centuries. Diversifying maize monocrop with legumes has been proposed as one solution to declining soil fertility. Adoption of legumes in Africa remains low despite the much needed soil fertility and nutrition benefits provided by the crops. We employ choice experiments to examine farmers' preferences for groundnut, soybean, and pigeon pea intercropped with maize and explore barriers and drivers to adoption in Central and Southern Malawi. Overall, farmers significantly discount legume yields in favor of maize yields despite the additional benefits provided by legumes. Labor constraints and market access are potentially more important barriers to legume adoption than previously thought. Results identified three types of farmers with varying preferences for grain yields, the largest group (48%) associated with strongly positive preference for both legume and maize grain yield, a medium-sized group (35%) that values only maize yield, and the smallest group (17%) having preferences only for legume yield. The medium group may be growing legumes for other benefits such as enhanced maize productivity, and the smallest group may be primarily subsistence producers. These findings suggest that uptake of legume maize intercrop systems might be improved if practitioners focus on legumes that have lower labor requirements and better marketability.

Key words — Africa, Malawi, farmer preferences, legumes, maize

1. INTRODUCTION

Low soil fertility is a severe problem in many parts of Africa, often limiting yield potential and creating poverty traps for farmers (Marenya & Barrett, 2009). Soil fertility is particularly limiting in Southern Africa due to the continuous cultivation of maize over centuries. In Malawi, the problem of declining soil fertility is particularly severe since maize is the dominant staple crop and Malawi has one of the highest population densities in Africa. At the same time nutrient deficiencies, most notably vitamin A and iron, are widespread in Malawi (World Bank, 2015), especially for limited resource farmers whose diet largely consists of maize and whom lack income for a more diversified diet.

Diversifying maize monocrop with legumes has been proposed as one possible solution to declining soil fertility as well as improving household nutrition in Malawi (Bezner Kerr, Snapp, Chirwa, Shumba, & Msachi, 2007). Legumes have the capacity to grow in low fertility environments, replenish stocks of soil nitrogen, and recycle nutrients from deep in the subsoil (Phiri, Kanyama-Phiri, & Snapp, 1999). Snapp, Blackie, Gilbert, Bezner-Kerr, and Kanyama-Phiri (2010) found that maize-legume intercrops of longer duration provided stable grain production and used fertilizer inputs more effectively than monocultured maize. Legumes can also link agricultural and nutritional benefits, providing a staple food with much needed protein and micronutrients such as iron, zinc, or vitamin A (Messina, 1999). Legumes vary in their role on a farm, some are primarily grain producers and others are highly vegetative with edible leaves for vegetable use, as well as protein rich fodder for animals and green manure for soil improvement (Snapp & Silim, 2002).

Despite a myriad of benefits, adoption of legumes remains low in Southern Africa. After a decade of promotion, farm area devoted to grain legumes remained below 25% in a Northern Malawi study (Mhango, Snapp, & Kanyama-Phiri, 2013). Home consumption and cash sales remain the major production goals for the most widely grown legumes, groundnut (peanut), soybean, common bean, and pigeon pea (Gilbert, 2004). There are severe land limitations imposed by an average farm size of less than 1 ha, and it is likely that farmers prioritize production of maize and tobacco over legumes. Previous household survey findings from Malawi have identified the high cost of legume seed as one barrier to greater production of pulses, along with pest-susceptibility, limited land availability and variable access to input and output markets for legumes (Snapp, Rohrbach, Simtowe, & Freeman, 2002). A synthesis and review of the conservation agriculture [1] literature finds no consistent determinants of farmer adoption of sustainable agricultural practices and notes that efforts to promote such practices need to be tailored to reflect local context and conditions (Knowler & Bradshaw, 2007).

* This study was prepared as a contribution to USAID/Malawi's Feed the Future activity Integrating Nutrition in Value Chains (INVC), and Africa RISING in Malawi with generous funding from the United States Agency for International Development (USAID). Dr. Regis Chikowo and team in Malawi are gratefully acknowledged for advice and assistance. This research was also supported by funds from the Center for Global Connections at Michigan State University. Final revision accepted: June 12, 2016.

Choice experiments (CE) have become an increasingly important tool used to study preferences and behavior regarding the adoption of sustainable intensification practices, since it overcomes limitations of previously used statistical methods. Given that most adoption studies are conducted ex post (after a sufficient time lapse to allow for the accumulation of behavioral data), CEs allow for the ex ante study of adoption of sustainable farming practices to better inform project design (Knowler, 2015). In this study we use choice experiments (CE) to examine farmer adoption of legumes, through intercropping, in the dominant maize cropping systems. We explore the heterogeneity in farmers' preferences for different varieties of legumes (groundnut, soybean, and pigeon pea) and identify barriers and drivers of adoption. The article is organized as follows: Section 2 provides a brief background of legume adoption in Africa. Section 3 describes the data and sample selection. Section 4 presents the choice experiment rationale and procedure. Section 5 reports the results and section 6 concludes.

2. BACKGROUND

In Southern Africa, maize has became the dominant staple crop and is now grown by 97% of farming households and accounts for 60% of total caloric consumption (Denning *et al.*, 2009). Over the last hundred years maize achieved rapid growth and in many areas replaced traditional cereals like sorghum and millet (Smale & Jayne, 2003). This may be due to advantages such as the very high grain yield potential of maize, a C_4 grass adapted to high heat and light that can produce approximately twofold more grain than other staple food crops, when provided sufficient fertility (Egli, 2008). Further, maize is one of the most labor efficient staple food crops with plant traits that include a weed suppressing architecture, and an ear covering that protects the grain from birds and other pests. The development of modern varieties in conjunction with the implementation of Malawi's Farm Input Subsidy Program in 2005 has led to broad access to hybrid maize seeds among smallholder farmers (Lunduka, Fisher, & Snapp, 2012). Maize has been heralded as providing an engine for growth, and the foundation for the green revolution in Africa (Byerlee & Eicher, 1997).

Despite all the benefits maize has brought to Africa, there have also been many tradeoffs. The maize plant is highly sensitive to deficiencies in water, and nitrogen. The grain does not store well and is attacked by weevils and other pests and diseases. Wide-scale production of maize has slowly mined the soil of nitrogen, and ultimately created a reliance on external inputs to maintain previous yields (Snapp *et al.*, 2010). Moreover, maize has one of the highest erosivity factors (*C*-values) among crops grown in the region, contributing significantly to soil loss on susceptible slopes (Lewis, Clay, & Dejaegher, 1988). The crop is largely grown without irrigation in a single growing season and is particularly susceptible to dry spells during flowering, rainfall variability, and growing season length (Rao, Ndegwa, Kizito, & Oyoo, 2011). Additionally, maize lacks essential amino acids, vitamin A, and can be associated with poor nutritional outcomes.

Legumes appear to be a natural response to the deleterious impact that continuous production of cereals has on African soils, and in particular Malawi given the numerous location specific edaphic problems (Snapp, 1998). The agricultural and nutritional benefits of the crop are a potential solution to address problems faced in Malawi, improving the soil and providing much needed protein. Farmer production of legumes, however, remains surprisingly low across most of sub-Saharan Africa and is particularly on the decline in many maize-dominated cropping systems of Southern Africa, including Malawi (Snapp & Silim, 2002). In the low-input, low-output production system that is common across Africa, intercropping certain legumes with maize may make economic sense in certain contexts. In Malawi, research has demonstrated that various legume crops can increase the nitrogen content of residues with a relatively small negative impact on maize yields (Snapp *et al.*, 2002). It is possible that low adoption of legume intercrops is based on a misperception that maize yields are significantly impacted by legume intercropping or it is possible that maize yields are negatively impacted by intercropping with specific legumes in certain contexts. Previous research has suggested that lack of local markets for grain legumes, and household labor constraints may also be a significant factor for low adoption of legumes into maize intercrop (Snapp *et al.*, 2002).

Farmer preferences are likely associated with the differences in the major legume crops cultivated in Malawi. Longer duration legumes like pigeon pea (*Cajanus cajan*) are more efficient at fixing nitrogen, enhancing phosphorus availability and thus maize yields in crop rotations. Shorter duration legumes such as groundnuts (*Arachis hypogaea*) or soybeans (*Glycine max*) tend to have higher yield potential but contributes fewer nutrients for soil enhancement (Giller & Cadisch, 1995). Legume crops that are short duration and early yielding are more amenable to market oriented production whereas the longer duration nature and higher nitrogen fixing properties of pigeon pea make it more suitable for enhancing soil fertility in a subsistence production system (Bezner Kerr *et al.*, 2007). While there are advantages in terms of soil fertility enhancement and food security mitigation, many farmers prefer to cultivate maize for household food security and often grow legumes with the intention of selling them. Legume market prices are typically higher than maize. At the time of the study maize was selling for an average of 60 Kwacha (MWK)[2] per kg, while reported average groundnuts, soybeans, and pigeon pea prices were 112, 138, and 139 MWK per kg, respectively. There are significant spatial dimensions of markets for various legumes in Malawi. Pigeon pea production is common in the Southern parts of the country around the cities of Zomba and Blantyre, where traders purchase pigeon pea for export to India. Smaller regional markets for groundnuts and soybeans exist in Ntcheu and Dedza and via large processors based in Lilongwe such as Transglobal, Global Trading, and Farmers' World.

Given the dominance of monoculture maize production in Malawi and land, labor, and market constraints, legume adoption remains limited. Improving legume performance attributes and soil fertility enhancement through breeding is one possibility for wider scale adoption. Legume yields continue to lag behind those of cereals and are in need of breeding improvements that focus on disease resistance, enhanced nitrogen fixation, and tolerance to soil constraints (Graham & Vance, 2003). Evidence from the applied economics literature point to a mix of (significant and insignificant) results regarding the effects of labor constraints and market access on the adoption of sustainable agricultural practices and highlights the importance of conducting regional studies of these factors on farmer adoption (Knowler & Bradshaw, 2007). Questions remain as to the extent to which legume adoption is constrained in various parts of Malawi and what these constraints are. This study explores these constraints using

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

household surveys and choice experiments to quantify tradeoffs farmers perceive among various legumes in maize-legume cropping systems.

3. STUDY AREA AND DATA

The data used in this study are derived from farm household surveys conducted in three districts in Malawi's Central and Southern Regions: Dedza, Ntcheu, and Zomba (Figure 1). These are districts in which undernutrition and malnutrition are known to be high and where the opportunities for expansion of legume intercropping to address these problems are significant. Dedza district located south of the capital, Lilongwe, has a total land area of 3,570 km^2 and a population of 624,445 according to the 2008 Malawi population Census. Ntcheu district, located to the south of Dedza district, covers an area of 2,500 km^2 and has a population of 471,589. Zomba district, located in Southern region, has a total land area of 1,939 km^2 and a population of 579,639. The respective average population density of Dedza, Ntcheu, and Zomba districts is 175, 189, and 299 persons per square kilometer, the majority living in rural areas. Located between −14.17 and −15.17 degrees latitude and with an elevation difference ranging up to 1,600 m above sea level, the study area covers various agro-ecological and climatic zones. Rain-fed agriculture predominates in this area, dependent on a single rainy season between November and March. Additionally, these three districts exhibit different patterns of participation in legume and labor markets, as well as levels of economic development. The study sites include areas where agriculture extension and development projects have been actively promoting legume production through workshops and other outreach efforts.

Our sample consists of farmers from 488 village households that were interviewed in September and October 2014. A multistage sampling approach within each district was used to

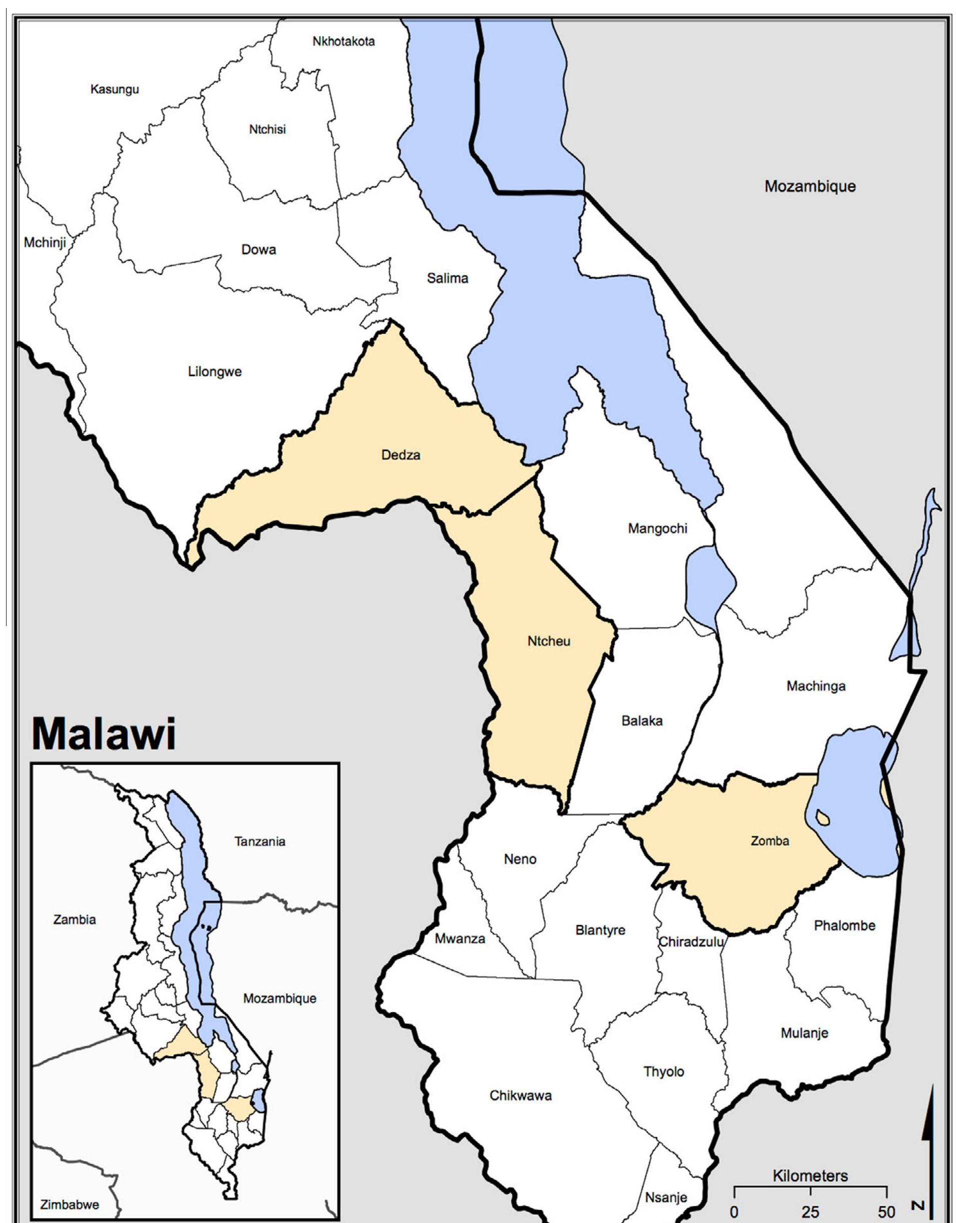

Figure 1. *Study area.*

form the survey sample. In the first stage we selected four Extension Planning Areas (EPAs) that were dependent on legume production.[3] In the second stage we randomly selected two sections from each EPA where we worked with Agriculture Extension Development Officers (AEDOS) to randomly sample approximately 20 farmers from village rosters in each section. Where village rosters were not available through the section offices, we worked with village leaders to draw a random sample of farmers within each section. After eliminating observations with missing data, our final sample consists of 162, 165, and 161 farm households from Dedza, Ntcheu, and Zomba districts, respectively. Given the specification of our choice experiment, which we discuss in the following section, the size of our sub samples are sufficient to identify the effects of interest at the district level (see Bliemer & Rose, 2005).

Maize cultivation is extensive in the three districts chosen for this study. Maize cultivation takes up 53%, 38%, and 51% of total farmed land in Dedza, Ntcheu, and Zomba, respectively (Table 1). Average maize yields reported by district extension officers are low in these districts; at less than 2 tons/hectare, they are below the average for Sub-Saharan Africa (~2 tons/ha) and less than one quarter of the average yield in developed countries (~8 tons/ha) (FAOSTAT, 2015). Groundnuts are most common in Dedza district where yields are highest, occupying 12% of farmed land compared to 9% and 7% in Ntcheu and Zomba. Soybeans are a less common legume crop overall in Malawi but are highest in Dedza with some production in Ntcheu. Pigeon pea is the most common legume in Zomba district, occupying 18% of land and the highest average yields of pigeon pea are reported from this region.

4. METHODS

Experimental choice modeling is used to study farmers' preferences for select legume-maize intercropping system characteristics. Choice modeling has become an increasingly popular tool for studying economic behavior in a development context since this methodology allows the researcher to incorporate various policy dimensions into the analysis and calculate marginal values for various attributes embodied in different goods or services, many of which are difficult or impossible to measure by examining revealed preferences. While there are four main choice modeling alternatives (choice experiments, contingent ranking, contingent rating, and paired comparisons), only the choice experiment method provides results that are consistent with standard welfare economics (Hanley, Mourato, & Wright, 2001; see also Hanemann, 1982, 1984).

Choice experiments (CE) have been widely used in the agricultural and environmental economics literature and their use in development economics and cross-disciplinary research is rising. Advantages of using CEs in a developing country context include the ability to estimate the economic benefits or costs generated by non-market goods and services (such as sustainable intensification) or policies and programs that have not been introduced. Moreover, CEs avoid two major drawbacks of using revealed preference data (which often are not readily available in developing countries), namely, the invariance of attribute levels over time in a single cross-section and the multicollinearity among the attributes of what is being valued. Moreover, CEs are often more practical and cost effective relative to other experimental approaches, such as randomized experiments which are being increasingly employed in the development economics literature (Bennett & Birol, 2010). While disadvantages of CEs have been documented in the literature (see Louviere, Hensher, & Swait, 2000) specific challenges associated with the implementation of CEs in developing countries include the appropriate identification of a payment vehicle as a monetary attribute, as well as the importance of thoroughly evaluating the design, formulation, and presentation of the choice questions to respondents, who often have low literacy levels and little experience with surveys.

Recently, several studies have used choice experiments to evaluate farmer behavior and preferences. Ward, Bell, Parkhurst, Droppelmann, and Mapemba (2016) studied farmer preference for conservation agriculture in Malawi using a CE approach and found that farmers perceive certain practices to interact with one another, sometimes complementing and sometimes degrading the benefits of the other practices and find that exposure to risk (e.g., flooding and insect infestation) often constrains adoption. Birol, Villalba, and Smale (2009) estimate Mexican farmers' preferences for biodiversity and genetically modified maize in the *milpa* system using number of crop species, maize varieties richness, presence of a maize landrace, whether the maize was genetically modified (GM), and maize yield as relevant attributes. Through a latent class modeling approach they are able to identify characteristics of farmers who are most likely to continue to grow maize landraces, as well as those least likely to grow GM maize and find significant preference heterogeneity. Richardson, Kellon, Leon, and Arvai (2013) analyzed farm household tradeoffs regarding pineapple production and environmental management in Costa Rica highlighting the effectiveness of the choice experiment approach in a rural development context. Other applications of choice experiments to farmer behavior in a development context include: Filipino farmer's willingness to pay for Bt maize seed (Birol, Smale, & Yorobe, 2012), Kenyan cattle producer and trader preferences for indigenous breeds in the pastoral livestock market (Ruto, Garrod, & Scarpa, 2008),

Table 1. *District level crop yields*

		Dedza	Ntcheu	Zomba
Total arable land	Area (ha)	187,635	175,098	164,924
Maize	Area (ha)	96,704	67,286	84,058
	Yield (kg/ha)	1,936	1,672	1,729
Groundnut	Area (ha)	21,899	16,062	12,170
	Yield (kg/ha)	901	833	627
Soybean	Area (ha)	14,441	4,784	NA
	Yield (kg/ha)	928	920	NA
Pigeonpea	Area (ha)	214	2,783	29,764
	Yield (kg/ha)	645	880	931

Source: District extension offices in Dedza, Ntcheu, and Zomba districts.

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

Chinese aquaculture farmer's willingness to adopt good agricultural practices (Ortega, Wang, Olynk Widmar, & Wu, 2014), and Indian farmer preferences for drought tolerant rice in alternative backgrounds (Ward, Ortega, Spielman, & Singh, 2014).

Following standard convention, we assume that farmers maximize the utility derived from a given legume-maize intercropping system, which is the unit of choice. As in previous applications, we suppose that farmer n faces K alternatives contained in ψ during choice set s. We can define an underlying latent variable V^*_{njs} that denotes the indirect utility function associated with farmer n choosing option $j \in \psi$ during choice set s. Farmer n will choose alternative j so long as $V^*_{njs} > V^*_{nks} \forall k \neq j$. Indirect utility V^*_{njs} is not directly observed; what is observed is the actual utility maximizing choice V_{njs}, where

$$V_{njs} = \begin{cases} 1 & \text{if } V^*_{njs} = \max(V^*_{n1s}, V^*_{n2s}, \ldots, V^*_{nKs}) \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

Following standard practice, indirect utility is assumed linear, ensuring that marginal utility is strictly monotonic in the specified cropping system characteristics and yields corner solutions in which only one cropping system is chosen (Useche, Barham, & Foltz, 2013). We can therefore write farmer n's utility function as

$$V^*_{njs} = X'_{njs}\beta + \varepsilon_{njs} \quad (2)$$

where X'_{njs} is a vector of cropping system characteristics for the jth alternative, β is a vector of taste parameters (i.e., a vector of weights mapping attribute levels into utility), and ε_{njs} is a stochastic component of utility that is independently and identically distributed (iid) across individuals and alternative choices, and takes a predetermined (Gumbel or extreme value type I) distribution. This stochastic component of utility implies that predictions cannot be made with certainty and captures unobserved variations in tastes as well as errors in farmer's perceptions and optimization.

In designing discrete choice experiments researchers must find a proper balance between the ability to estimate desired effects, the cognitive complexity of the experiment and choice task realism (Louviere *et al.*, 2000). This requires, among other things, selecting attributes or characteristics that are relevant to farmers' choices and conveying this information according to their cognitive abilities. A series of focus groups with farmers in Malawi's Central and Southern regions were conducted in July 2014 to identify the most important agro-economic factors that play a role in deciding which legume crops to intercrop with maize. The tradeoff between maize and legume yield was identified as a key factor in farmers' decision-making process. This is mainly driven by the predominant role that maize has in Malawian agriculture, diets, and culture. Distance to the nearest market, marketability of the crop, and labor requirements were also identified as major economic factors influencing farmers' decisions.

In consultation with crop scientists, development scholars, and in-country experts, we used our findings from the focus groups to formulate four attributes to be incorporated into the choice experiment: legume yield, distance to market, labor requirements, and maize yield. In particular, three legume-maize intercropping systems were evaluated in this study: groundnut, soybean and pigeon pea. The legume and maize yield attributes were defined as the expected yield that farmers could expect to receive from planting a particular alternative. The levels of the yield attributes were chosen to capture the trade-off farmers make when deciding to plant a particular legume crop. Following Birol *et al.* (2009), a percentage change in yield from the previous year's harvest was utilized since it is difficult to include individual farm-level yield measures in the choice experiment due to wide variation among farms and study sites with regards to yields, area planted, and intensity of crop production. As such, the levels of the yield attributes used in the design were 80, 100, 120, and 140 for legumes and 60, 80, 100, and 120 for maize, with 100 representing the base or previous year's yield from which percent changes were calculated. Distance to market represents the distance in kilometers from the farmer's household to a market where they can sell or trade their crops; levels for this attribute included 1, 5, 10, and 20 km from the household[4]. Labor requirement was included as a binary variable that captures household specific labor constraints; high/low labor corresponds to a 50% increase/decrease of current requirements or roughly five person days for planting and harvest requirements. Maize yield was included in the choice experiment to capture the fact that due to land constraints in Malawi the legumes under consideration are typically planted as a legume-maize intercrop. Further, given the prevalence and importance of maize production in Malawi, this attribute serves as a substitute for a cost or price variable when evaluating tradeoffs among the other attributes since maize is effectively a currency in rural parts of Malawi. This indirect measure is preferred over a direct monetary variable, as many farmers are not able to accurately assess the monetary value of their output given the subsistence nature of agriculture in the region (Birol *et al.*, 2009).

A labeled, efficient, and nearly orthogonal experimental design comprising the aforementioned attributes and their associated levels was constructed using the software Ngene. A total of 40 choice sets were generated and blocked into eight groups of five choice scenarios preserving orthogonality of the change alternatives. Each choice set was comprised of a groundnut-maize, soyabean-maize, pigeon pea-maize, and sole maize alternative. Inclusion of a sole maize alternative best reflects farmer's current choice and serves as a baseline alternative since nearly all farmers plant at least some portion of their land with sole maize. Attribute levels for the sole-maize alternative were recorded by the enumerators. Inclusion of a baseline alternative is important for the interpretation of respondent choices and is consistent with economic theory (Louviere *et al.*, 2000). To increase comprehension of the choice task, accommodate different farmer literacy levels and reduce the cognitive burden of this exercise, the choice tasks were illustrated and presented to farmers in laminated cards (Figure 2).

Because farmers are a heterogeneous group, their preferences for various cropping system characteristics may also be heterogeneous. A common method of evaluating preference heterogeneity is the estimation of random parameters logit (RPL) models, also called mixed logit. Following the RPL specification in Train (2003), the probability that individual n chooses alternative j in choice set s is given by

$$\text{Prob}(V_{njs} = 1 | X'_{n1s}, X'_{n2s}, \ldots, X'_{nKs}, \Lambda) = \int \frac{\exp(X'_{njs}\beta)\Lambda}{\sum_{k=1}^{K}\exp(X'_{nks}\beta)} f(\beta|\Lambda)d\beta \quad (3)$$

where $X'_{njs}\beta$ and $X'_{nks}\beta$ are the attribute levels and the marginal utility parameters, and the vector refers collectively to the parameters characterizing the distribution of the random parameters (e.g., mean and covariance of β), which the researcher can specify. For our purposes, we allow the coefficients corresponding to all attributes to vary, taking a normal

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

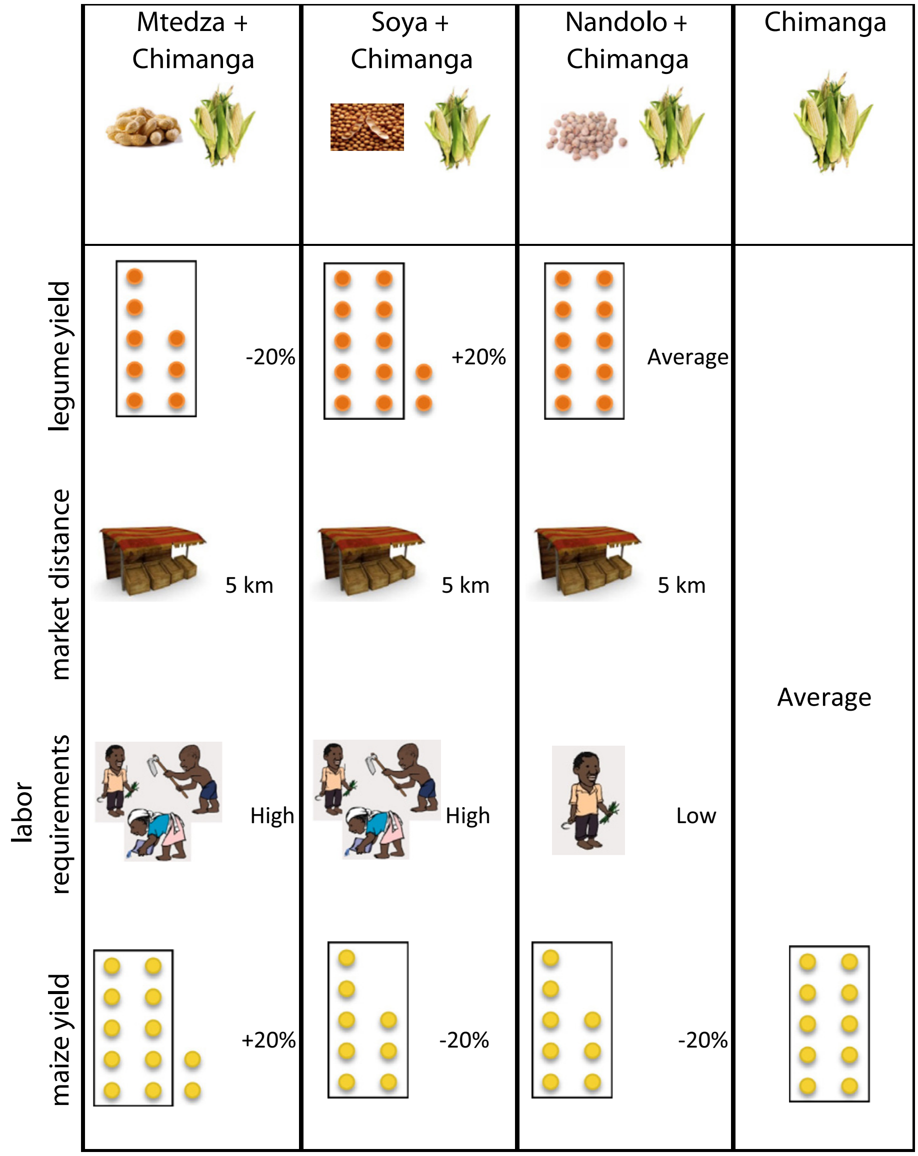

Figure 2. *Sample choice set.*

distribution.[5] Specifying a normal distribution for the random parameters allows for the possibility of positive and negative preferences for each of the attributes.

Furthermore, in order to segregate farmers into groups with similar underlying characteristics, a latent class specification was also employed. In latent class analysis, $f(\beta)$ is discrete, taking C distinct values (Train, 2003). The probability that farmer n selects option j in a given choice set s unconditional on the class is represented by

$$P_{njs} = \sum_{c=1}^{C} \frac{\exp(X'_{njs}\beta_c)}{\sum_k \exp(X'_{nks}\beta_c)} R_{nc} \quad (4)$$

where β_c is the specific parameter vector for class c, and R_{nc} is the probability that producer n falls into class c. This probability can be conditioned by a vector of household characteristics z_n and coefficient vector corresponding to membership in class c, θ_c, in a similar logit function:

$$R_{nc} = \frac{\exp(z'_n\theta_c)}{\sum_c \exp(z'_n\theta_c)} \quad (5)$$

We can therefore re-write Eqn. (4) as

$$P_{njs} = \sum_{c=1}^{C} \left[\left(\frac{\exp(X'_{njs}\beta_c)}{\sum_k \exp(X'_{nks}\beta_c)} \right) \left(\frac{\exp(z'_n\theta_c)}{\sum_c \exp(z'_n\theta_c)} \right) \right] \quad (6)$$

The latent class analysis allows for the identification of groups of farmers that are heterogeneous across classes and homogenous within a group. This facilitates the identification of producers with similar preference structures enabling policy recommendation that targets individual farmer groups.

Our choice experiment approach allows for estimation of the tradeoffs farmers make when choosing to adopt a given cropping system. In choice experiment data analysis, estimation can be performed in either preference space or in willingness-to-pay space (WTP-space). Coefficients obtained from models in preference space represent individual's preferences or marginal utilities for the various attributes. The vector of parameters β defining preferences over the attributes can be interpreted as marginal utilities. The marginal rate of substitution (MRS) of one attribute for the other is simply the ratio of the two marginal utilities. In addition to estimating our models in preference space, where we obtain marginal utilities, we take advantage of recent advancements in choice modeling and estimate this MRS trade off directly in willingness-to-pay space (Scarpa, Thiene, & Train, 2008). Models estimated in WTP-space are reparameterized so that the coefficients estimated directly represent trade-offs individuals are willing to make; in this case the trade off is calculated terms of maize yield. This approach facilitates direct control of the distribution of MRS estimates (as opposed to relying on the ratio of two marginal utility estimates with potentially undefined properties) and allows researchers to distinguish variation in preference (or MRS) versus scale heterogeneity. [6]

5. RESULTS

The characteristics of the households surveyed are presented in Table 2. Average household size was largest in Dedza at 5.25 and smallest in Zomba at 4.88 but not significantly different between districts (p-value of 0.28). There was wide variation in farming experience in all districts with a slightly higher mean in Ntcheu where the average exceeded 19 years. The average farm size in Dedza was 1.13 ha, 0.92 ha in Ntcheu and smallest in Zomba at 0.82 ha. On average farmers in Dedza were furthest from markets at 7.10 km, followed by those in Ntcheu (4.62 km) and Zomba (4.22 km). Reported household labor was slightly larger in Ntcheu but roughly consistent across districts (average of three persons) with a larger proportion of households reported hiring labor in Dedza. There was wide variation in the number of extension and informal trader visits received across all districts with slightly more in Zomba and Dedza than Ntcheu.

Results from our choice experiment data are presented in Tables 3 and 4. To explore heterogeneity in farmer preferences, we present results from a basic conditional logit model (homogenous preference model), a random parameters specification- both with and without free correlation of the random parameters- [7] and a latent class model. We first estimated the models ignoring the possible influences of the various regions or district in conditioning choice probabilities, followed by a similar set of regressions in which these influences are taken into account. Results from the models in preference-space are robust to the various model specifications. We find that that maize and legume yields have a significant and positive effect on utility, with maize yield providing higher utility than legume yield. As expected, market distance and high labor requirements have a significant and negative effect on utility. The standard deviation estimates on the RPL model specification assert our hypothesis of preference heterogeneity. Estimation results of the RPL model allowing for free correlation of the random parameters shows a significant covariance between maize and legume yields implying that farmers who value maize yield are also motivated by legume yield (correlation of 0.40) (Table 4).

Model results from estimation in WTP-space allow us to capture farmers' valuation of cropping system attributes. Our findings indicate that producers are willing to trade a 0.44% increase in legume yield for a one percent increase in maize yield. [8] This result highlights the fact that maize output is more than twice preferred to legumes in legume-maize

Table 2. *Summary statistics of farm households in sample*

Variable	Dedza	Ntcheu	Zomba	p-Value
Household size (persons)	5.25	5.06	4.88	0.28
	(2.11)	(1.94)	(2.1)	
Under 16 (persons)	2.45	2.32	2.35	0.75
	(1.52)	(1.45)	(1.86)	
Years farming	17.99	19.34	17.45	0.37
	(11.97)	(12.69)	(12.97)	
Landholding size (ha)	1.13	0.92	0.82	<0.01
	(0.63)	(0.57)	(0.57)	
Distance to nearest market (km)	7.1	4.62	4.22	<0.01
	(8.09)	(3.02)	(3.23)	
Hh Labor (previous year in persons)	3.05	3.18	3.06	0.70
	(1.38)	(1.32)	(1.62)	
Hired labor (%)	43%	34%	40%	0.18
Extension visits	3.82	3.27	3.53	0.52
	(3.9)	(3.85)	(5.25)	
Informal trader visits	5.18	4.73	6.62	0.58
	(8.84)	(10.58)	(25.75)	
Food Security				0.02
Shortage throughout	4%	1%	0%	
Occasional food shortage	44%	32%	41%	
No shortage or surplus	41%	51%	43%	
Surplus	11%	17%	16%	
Farm Risk Attitude				0.27
Not willing to take risks at all	2%	1%	1%	
Unwilling to take risks	12%	7%	4%	
Somewhat willing to take risks	14%	12%	11%	
Willing to take risks	46%	49%	52%	
Fully willing to take risks	26%	31%	32%	
Sub-sample size	162	165	161	

Note: Numbers in parenthesis are standard deviations. p-Values presented are for joint tests of significance (F or Chi-squared) for variables across the three districts. *Source:* author's calculations.

Table 3. *Model results in preference and WTP-space*

	CL		RPL		RPL-Corr		WTP-Space	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Random parameter means								
Legume yield	0.015	0.001***	0.018	0.002***	0.018	0.002***	0.441	0.041***
Market distance	−0.020	0.004***	−0.025	0.005***	−0.023	0.005***	−0.547	0.122***
Labor requirement	−0.316	0.055***	−0.355	0.066***	−0.344	0.072***	−8.401	1.723***
Maize yield	0.031	0.002***	0.039	0.002***	0.040	0.002***	0.035	
Alternative-specific parameters								
Groundnut-maize	1.874	0.093***	2.035	0.123***	2.036	0.128***	2.010	0.089***
Soyabean-maize	1.704	0.095***	1.860	0.124***	1.856	0.129***	1.843	0.090***
Pigeon pea-maize	1.563	0.097***	1.667	0.126***	1.678	0.134***	1.655	0.089***
Random parameter standard deviations								
Legume yield			0.015	0.003***	0.015	0.003***	0.261	0.070***
Market distance			0.032	0.010***	0.022	0.014	0.884	0.175***
Labor requirement			0.591	0.118***	0.618	0.742	13.943	2.676***
Maize yield			0.029	0.002***	0.029	0.016*	0.006	0.067
N	2,419		2,419		2,419		2,419	
No. of parameters	7		11		17		11	
Log-Likelihood	−2729		−2681		−2677		−2692	
Adjusted Pseudo *R*-squared	0.120		0.200		0.200		0.197	
AIC	5472		5385		5388		5406	

Note: ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively. Cholesky and correlation matrix for RPL with correlations are presented in Table 4. Maize yield coefficient estimate in WTP-space model denotes scale factor. Models presented were estimated in NLOGIT 5.0. *Source*: author's computations.

Table 4. *Cholesky and Correlation Matrix for RPL model in Table 3*

Cholesky matrix	1	2	3	4
Legume yield (1)	**0.0152**			
Market distance (2)	0.0032	0.0064		
Labor requirement (3)	0.0024	0.0034	0.3969	
Maize yield (4)	**0.0002**	0.0034	0.0033	0.0123
Correlation matrix	1	2	3	4
Legume yield (1)	1.0000			
Market distance (2)	0.9560	1.0000		
Labor requirement (3)	0.2500	0.0250	1.0000	
Maize yield (4)	0.4020	0.5240	0.1830	1.0000

Note: Bold figures in Choleksy matrix are statistically significant with at most 5% probability of a Type 1 error. *Source:* author's computations.

cropping systems in Malawi. Given that farmers in the study region are very resource and time constrained, we find a significantly large negative trade-off value (−8.43) associated with high labor requirements of growing certain (legume-maize) cropping systems. The reduced labor requirement relative to producing two crops has been highlighted by farmers rating of lower labor in pigeon pea-maize mixed systems in earlier participatory research in Kenya and Malawi (see Snapp & Silim, 2002 and Twomlow, Rusike, & Snapp, 2001). We also find that farmers are very sensitive to market access constraints as captured by the coefficient for the market distance attribute (−0.60). With an average distance to market of 5.3 km in our sample, a lack of market access, transportation, and road infrastructure represents a significant cost to farming households in Malawi.

Estimated coefficients for each legume-maize crop system alternative, or alternative-specific constant, indicate that overall, relative to planting sole maize, farmers prefer a groundnut-maize intercrop system, followed by soybean-maize and pigeon pea-maize (Tables 3 and 4). The positive coefficients associated with each of the legume-maize alternatives denote the difference in utility or value that farmers receive from a specific legume intercropping relative to planting sole maize. They capture the average additional value associated with each legume-maize alternative arising from factors not controlled for in the model. To explore how preferences for crop system alternatives vary by region, we also estimate the models in preference-space and condition the choice probabilities with district specific variables (Tables 5 and 6). Estimates indicate that groundnut-maize systems provide the most value to farmers in Dedza, soybean-maize to famers in Ntcheu and pigeonpea-maize systems are most valued in Zomba. These results parallel existing crop-level data and suggest that farmer preferences are also shaped by regional differences in agro-climatic and market conditions.

In concordance with our hypothesis of preference heterogeneity, our latent class analysis results (Table 7) identify three types of farmers with different preferences for crop system

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

Table 5. *Model results in preference space with districts conditioning choice probabilities*

		CL		RPL		RPL-Corr	
		Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Random parameter means							
	Legume yield	0.015	0.001***	0.018	0.002***	0.018	0.002***
	Market distance	−0.020	0.004***	−0.026	0.005***	−0.024	0.005***
	Labor requirement	−0.317	0.056***	−0.354	0.066***	−0.345	0.069***
	Maize yield	0.031	0.002***	0.040	0.002***	0.041	0.003***
Alternative−specific parameters							
Groundnut maize	Dedza	1.901	0.149***	2.120	0.209***	2.127	0.204***
	Ntcheu	1.867	0.150***	2.005	0.209***	2.009	0.208***
	Zomba	1.861	0.148***	2.005	0.179***	2.015	0.177***
Soybean maize	Dedza	1.645	0.150***	1.786	0.213***	1.774	0.210***
	Ntcheu	1.962	0.149***	2.184	0.204***	2.200	0.205***
	Zomba	1.472	0.151***	1.581	0.181***	1.579	0.179***
Pigeon pea maize	Dedza	1.365	0.154***	1.477	0.219***	1.492	0.216***
	Ntcheu	1.544	0.154***	1.613	0.205***	1.629	0.203***
	Zomba	1.766	0.153***	1.909	0.186***	1.927	0.185***
Random parameter standard deviations							
	Legume yield			0.016	0.003***	0.016	0.003***
	Market distance			0.032	0.010***	0.023	0.014
	Labor requirement			0.564	0.122***	0.597	0.262**
	Maize yield			0.030	0.002***	0.031	0.011***
N		2,419		2,419		2,419	
No. of parameters		13		17		23	
Log-Likelihood		−2712		−2661		−2655	
Adjusted Pseudo R-squared		0.128		0.200		0.210	
AIC		5450		5356		5356	

Note: ***, **, * represent statistical significance at 1%, 5%, and 10% level, respectively. Models presented were estimated in NLOGIT 5.0. Cholesky and correlation matrix for RPL with correlations is presented in Table 6. *Source:* author's computations.

Table 6. *Cholesky and correlation matrix for RPL model in Table 5*

Choleksy matrix				
	1	2	3	4
Legume yield (1)	**0.0157**			
Market distance (2)	0.0003	0.0075		
Labor requirement (3)	0.0023	−0.0005	0.3084	
Maize yield (4)	**0.0002**	0.0004	0.0032	0.0126
Correlation matrix				
	1	2	3	4
Legume yield (1)	1.0000			
Market distance (2)	0.9460	1.0000		
Labor requirement (3)	0.2460	−0.0350	1.0000	
Maize yield (4)	0.4070	0.5040	0.1750	1.0000

Note: Bold figures in Choleksy matrix are statistically significant with at most 5% probability of a Type 1 error. *Source:* author's computations.

attributes. Class 1 comprises 48% of decision makers. Legume grain yield positively affects utility, while labor requirements and market distance negatively affect utility for this group of farmers. By examining the sign of the marginal utility coefficients, we hypothesize that these farmers grow legumes for both consumption and maize yield benefits. In addition to class one, are two groups of farmers with differing preferences. Class 2 was characterized by indifference for market access and maize yield (17% of the population) and class three by a lack of preference for legume yield (35%). Farmers in Class 2 are assumed to adopt legume crops for own consumption as market distance and changes in maize yield does not affect their decision making. Farmers in Class 3 are thought to grow legumes only for the benefits they provide to their maize crop, as noted by the lack of significance on the legume yield coefficient. The estimated coefficients for each crop system alternative are different across these 3 groups of farmers. While farmers in Class 1 and 2 have positive preferences for all three types of crop system alternatives over sole maize, those in Class 1 derive significantly more utility from legume-maize intercrops. Farmers in Class 3 only prefer groundnut-maize and pigeon pea-maize over sole maize.

Unlike previous work employing latent class analysis on farmer or buyer behavior that finds socio-demographic or farm-level characteristics to affect class membership (Birol *et al.*, 2009; Ruto *et al.*, 2008), we find district regions to be

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

Table 7. *Results from latent class analysis*

	Class 1		Class 2		Class 3	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Utility parameters						
Legume yield	0.028	0.006***	0.012	0.005**	0.005	0.004
Market distance	−0.027	0.010***	−0.018	0.016	−0.020	0.011*
Labor requirement	−0.251	0.138*	−0.398	0.213*	−0.311	0.160*
Maize yield	0.051	0.012***	−0.003	0.007	0.034	0.007***
Alternative-specific parameters						
Groudnut-maize	3.741	0.657***	1.326	0.567**	1.149	0.441***
Soyabean-maize	3.489	0.704***	1.698	0.375***	0.689	0.430
Pigeon pea-maize	3.046	0.580***	0.986	0.492**	1.172	0.356***
Thetas in class probability model						
Ntcheu	0.478	0.485	1.880	0.646***	–	–
Zomba	−0.941	0.451**	−0.657	0.804	–	–
Class probability	0.476		0.172		0.353	
N	2,419					
No. of parameters	27					
Log-Likelihood	−2,643					
Adjusted Pseudo R-squared	0.211					
AIC	5,341					

Note: ***, **, * represent statistical significance at 1%, 5%, and 10% level, respectively. Models presented were estimated in NLOGIT 5.0. *Source:* author's calculations.

the only factor explaining class membership. Farmers in Zomba district are more likely to belong to class three, while those in Ntcheu district are more likely to belong to class two. This is further supported by comparing statistical differences across profiles of farmers in each class (Table 8). Our profiling analysis also reveals that risk attitudes and labor constraints can help differentiate farmers in each segment. Farmers in class one, which receive benefits from both legume and maize yield, are less willing to take risks on their farms (relative to farmers in the other classes), indicating that adoption of legume-maize intercropping may not be seen as a risky endeavor. We also find that farmers in class three, which receive negative utility from high labor requirements and no benefits from legume yield, are reported to have less labor resources than farmers in the other classes. Although we find some observable differences across farmer profiles, additional research is needed to assess how risk attitudes and labor constraints affect adoption of legume-maize intercropping and overall adoption of sustainable intensification practices.

6. POLICY IMPLICATIONS AND CONCLUSIONS

This study uses discrete choice experiments to investigate Malawian farmers' valuation of legume-maize cropping system characteristics, understand tradeoffs involved in decision making and explore heterogeneity in preferences. We provide a novel approach to modeling farmer behavior by integrating economic and agronomic factors and incorporate preference heterogeneity using recent advances in choice modeling. The results provide robust measures of economic preferences and behavior, and our findings underscore the utility of the choice experiment method in a developing country context.

Our results quantify and corroborate preliminary findings from field visits to the region: among legumes, the highest preference is for groundnut-maize systems (groundnuts are an important cash crop), and lowest for pigeon pea-maize systems (which has lowest market penetration). At the same time, preferences for pigeon pea was greatest in Zomba, where legume markets are better developed (pigeon pea exports, in particular). The results are consistent across various modeling strategies and conditional on districts/regional differences. We find that farmers' preferences seem to be already reflected in what they are growing in their fields and those preferences may be heavily conditioned by what grows best and sells best in the districts. Most importantly, the results from this study reinforce the findings of Knowler and Bradshaw (2007), that there are few if any universal variables or observable characteristics that regularly explain the adoption of sustainable intensification practices and that efforts to adopt these practices will have to be tailored to reflect the particular conditions of individual locales or districts in Malawi. Further, our CE approach allows us to quantify the tradeoffs that farmers are making when it comes to adoption of sustainable intensification practices and to examine sample heterogeneity by modeling the response behavior of subgroups or like-minded classes, which is difficult to do with revealed preference data. Our findings confirm that farmers highly value maize yield and discount legume yields significantly despite the additional benefits provided by the latter. This suggests that regional and cultural values such as strong preferences for maize are major drivers of behavior. Farmers either require improvements in legume yields or less competition with maize in order to increase adoption of legume-maize intercrop systems.

Results from this study also have implications for agricultural development and the introduction of new crops. While development efforts have tackled agronomic and nutrition aspects of legume adoption they have possibly downplayed the importance of labor constraints and market access (Snapp *et al.*, 2002). Preferences seem to be driven largely along regional and market lines. For example, pigeon pea (a longer-duration legume) has the potential for higher soil fertility contribution, but in a region like Dedza widespread adoption may suffer from thin markets. These findings suggest that uptake of legume maize intercrop systems might be improved

Table 8. *Profiles of farm households in each latent class*

Variable	Class 1	Class 2	Class 3	*p*-Value
District				<0.01
Dedza	44%	12%	30%	
Ntcheu	37%	78%	15%	
Zomba	19%	10%	55%	
Household size (persons)	5.11	5.29	4.95	0.49
	(1.99)	(2.31)	(4.95)	
Under 16 (persons)	2.35	2.69	2.29	0.19
	(1.43)	(1.63)	(1.78)	
Years farming	18.71	18.95	17.65	0.62
	(12.61)	(11.92)	(12.73)	
Landholding size (ha)	2.4	2.7	2.29	0.12
	(1.45)	(1.78)	(1.41)	
Distance to nearest market (km)	5.18	5.71	5.48	0.78
	(5.35)	(5.48)	(5.56)	
Hh Labor (previous year in persons)	3.08	3.56	2.96	<0.01
	(1.48)	(1.41)	(1.39)	
Hired labor (%)	38%	36%	40%	0.75
Extension visits	3.36	3.63	3.68	0.74
	(3.64)	(4.44)	(5.01)	
Informal trader visits	4.42	9.21	5.28	0.58
	(7.67)	(37.82)	(9.81)	
Food Security				0.12
Shortage throughout	2%	0%	1%	
Occasional food shortage	33%	39%	45%	
No shortage or surplus	47%	51%	40%	
Surplus	17%	10%	14%	
Farm Risk Attitude				0.06
Not willing to take risks at all	2%	0%	1%	
Unwilling to take risks	9%	3%	9%	
Somewhat willing to take risks	14%	10%	11%	
Willing to take risks	51%	44%	48%	
Fully willing to take risks	23%	44%	31%	
Sub-sample size	208	73	205	

Note: Numbers in parenthesis are standard deviations. *p*-Values presented are for joint tests of significance (F or Chi-squared) for variables across the three classes. *Source:* author's calculations.

if practitioners focus on legumes that have lower labor requirements and better local marketability.

The results highlight the role of additional research in explaining the determinants of these choices (e.g., role of dietary preferences, market access, risk aversion, and uncertainty in crop selection decisions). It has proved challenging to identify and quantify preference traits of smallholder farmers. This has posed a substantial barrier to adoption of technologies, which has led to development of client-oriented, participatory research (Johnson, Lilja, & Ashby, 2003). A case in point is the adoption of agroforestry and soil conservation practices in South Asia, where a strong positive relationship of uptake to participatory research approaches was found in a study of cassava-based systems (Dalton, Lilja, Johnson, & Howeler, 2011). In Malawi previous studies have also found participatory action research and extension as drivers of adoption of grain legume species, although no evidence has emerged for adoption of agroforestry legumes (Bezner Kerr *et al.*, 2007; Snapp *et al.*, 2010). Conducting participatory research with farmers to evaluate the context specific tradeoff in yields between various legumes in maize intercrop could increase adoption, and is left as an area of further inquiry.

NOTES

1. Conservation agriculture refers to a set of practices aimed at achieving sustainable and profitable agriculture, and improving farmer livelihoods through the application of three principles: minimal soil disturbance, permanent soil cover, and crop rotations/intercropping.

2. Market prices are based on reported statistics from farmers in our sample. 1 MWK = 0.0026 US at the time of the study in September 2014.

3. EPAs sampled in this study include Chafumbwa, Golomoti, Kayama, and Mtakataka in Dedza district; Bilira, Manjawira, Njolomole, and Nsipe in Ntcheu district; and Chingale, Malosa, Mpokwa, and Thondwe in Zomba district.

4. Another specification of this attribute based on travel time required to reach the nearest market was tested in focus group discussions and we found that famers were better able to use and relate distance to market access when evaluating multiple scenarios.

5. Various distributions of the random parameters were tested and the normal distribution outperformed other empirical specification (e.g., log-normal, triangular) using the Akaike information criterion.

6. Interested readers are pointed to Scarpa *et al.* (2008) and Sonnier, Ainslie, and Otter (2007) for a more in-depth discussion of the advantages of estimating choice models in WTP-space.

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

7. The random parameters model is free of the independence of irrelevant alternatives assumption and our analysis explicitly accounts for the fact that the variation in coefficients over farmers induces correlation in unobserved utility over adoption decisions by the same farmer (Revelt & Train, 1998; Train, 1998).

8. While contextual reasons support the use of maize yield as an indirect monetary measure, our results can be converted into actual monetary units using secondary crop price data.

REFERENCES

Bennett, J. W., & Birol, E. (Eds.) (2010). *Choice experiments in developing countries: Implementation, challenges and policy implications*. Cheltenham, UK: Edward-Elgar Publishing.

Bezner Kerr, R. B., Snapp, S., Chirwa, M., Shumba, L., & Msachi, R. (2007). Participatory research on legume diversification with Malawian smallholder farers for improved nutrition and soil fertility. *Experimental Agriculture, 43*(04), 437–453.

Birol, E., Smale, M., & Yorobe, J. M. Jr, (2012). Bi-modal preferences for Bt maize in the Philippines: A latent class model. *AgBioForum, 15*(2), 175–190.

Birol, E., Villalba, E. R., & Smale, M. (2009). Farmer preferences for milpa diversity and genetically modified maize in Mexico: A latent class approach. *Environment and Development Economics, 14*(4), 521.

Bliemer, M. C., & Rose, J. M. (2005). *Efficiency and sample size requirements for stated choice studies*. Institute of Transport Studies and Logistics Working Paper (ITLS-WP-05-08).

Byerlee, D., & Eicher, C. K. (Eds.) (1997). *Africa's emerging maize revolution*. Lynne Rienner Publishers.

Dalton, T. J., Lilja, N. K., Johnson, N., & Howeler, R. (2011). Farmer participatory research and soil conservation in Southeast Asian cassava systems. *World Development, 39*(12), 2176–2186.

Denning, G., Kabambe, P., Sanchez, P., Malik, A., Flor, R., Harawa, R., ... Sachs, J. (2009). Input subsidies to improve smallholder maize productivity in Malawi: Toward an African green revolution. *PLoS Biology, 7*(1) e1000023.

Egli, D. B. (2008). Comparison of corn and soybean yields in the United States: Historical trends and future prospects. *Agronomy Journal, 100*, S79–S88.

FAOSTAT. (2015). Food and Agriculture Organization of the United Nations, Statistics Division. Production Dataset. http://faostat3.fao.org/.

Gilbert, G. A. (2004). Best bet legumes for smallholder maize based cropping systems of Malawi. In M. Eilittä, J. Mureithi, & R. Derpsch (Eds.), *Green manure/cover crop systems of smallholder farmer: Experiences from tropical and subtropical regions* (pp. 153–174). Netherlands: Kluwer Academic Publishers.

Giller, K. E., & Cadisch, G. (1995). Future benefits from biological nitrogen fixation: An ecological approach to agriculture. In *Management of biological nitrogen fixation for the development of more productive and sustainable agricultural systems* (pp. 255–277). Netherlands: Springer.

Graham, P. H., & Vance, C. P. (2003). Legumes: Importance and constraints to greater use. *Plant Physiology, 131*(3), 872–877.

Hanemann, W. M. (1982). *Applied welfare analysis with qualitative response models* CUDARE Working Papers. UC Berkeley: Department of Agricultural and Resource Economics, UCB.

Hanemann, W. M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics, 66*(3), 332–341.

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice modeling approaches: a superior alternative for environmental valuation? *Journal of Economic Surveys, 15*(3), 436–462.

Johnson, N., Lilja, N., & Ashby, J. A. (2003). Measuring the impact of user participation in agricultural and natural resource management research. *Agricultural Systems, 78*, 287–306.

Knowler, D. (2015). Farmer adoption of conservation agriculture: A review and update. In *Conservation agriculture* (pp. 621–642).

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy, 32*, 25–48.

Lewis, L. A., Clay, D. C., & Dejaegher, Y. (1988). Soil loss, agriculture and conservation in Rwanda: Toward sound strategies for soil management. *Journal of Soil and Water Conservation*, 418–421, Sept–Oct.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). *Stated choice methods*. New York: Cambridge University Press.

Lunduka, R., Fisher, M., & Snapp, S. (2012). Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi? *Food Policy, 37*(5), 504–510.

Marenya, P. P., & Barrett, C. B. (2009). Soil quality and fertilizer use rates among smallholder farmers in western Kenya. *Agricultural Economics, 40*(5), 561–572.

Messina, M. J. (1999). Legumes and soybeans: overview of their nutritional profiles and health effects. *The American Journal of Clinical Nutrition, 70*(3), 439s–450s.

Mhango, W., Snapp, S. S., & Kanyama-Phiri, G. Y. (2013). Opportunities and constraints to legume diversification for sustainable cereal production on African smallholder farms. *Renewable Agriculture and Food Systems, 28*, 234–244.

Ortega, D. L., Wang, H. H., Olynk Widmar, N. J., & Wu, L. (2014). Reprint of: "Chinese producer behavior: Aquaculture farmers in southern China". *China Economic Review, 30*, 540–547.

Phiri, A. D. K., Kanyama-Phiri, G. Y., & Snapp, S. (1999). Maize and sesbania production in relay cropping at three landscape positions in Malawi. *Agroforestry Systems, 47*(1–3), 153–162.

Rao, K. P. C., Ndegwa, W. G., Kizito, K., & Oyoo, A. (2011). Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture, 47*(2), 267–291.

Revelt, D., & Train, K. (1998). Mixed logit with repeated choices: Households' choices of appliance efficiency level. *Review of Economics and Statistics, 80*(4), 647–657.

Richardson, R. B., Kellon, D., Leon, R. G., & Arvai, J. (2013). Using choice experiments to understand household tradeoffs regarding pineapple production and environmental management in Costa Rica. *Journal of Environmental Management, 127*, 308–316.

Ruto, E., Garrod, G., & Scarpa, R. (2008). Valuing animal genetic resources: A choice modeling application to indigenous cattle in Kenya. *Agricultural Economics, 38*(1), 89–98.

Scarpa, R., Thiene, M., & Train, K. (2008). Utility in willingness to pay space: A tool to address confounding random scale effects in destination choice to the Alps. *American Journal of Agricultural Economics, 90*(4), 994–1010.

Smale, M., & Jayne, T. (2003). *Maize in Eastern and Southern Africa: 'Seeds' of Success in Retrospect* (p. 97). Washington, DC: International Food Policy Research Institute, Washington (EPTD Discussion Paper No. 97).

Snapp, S. S. (1998). Soil nutrient status of smallholder farms in Malawi. *Communications in Soil Science and Plant Analysis, 29*(17–18), 2571–2588.

Snapp, S. S., Blackie, M. J., Gilbert, R. A., Bezner-Kerr, R., & Kanyama-Phiri, G. Y. (2010). Biodiversity can support a greener revolution in Africa. *Proceedings of the National Academy of Sciences, 107*(48), 20840–20845.

Snapp, S. S., Rohrbach, D. D., Simtowe, F., & Freeman, H. A. (2002). Sustainable soil management options for Malawi: Can smallholder farmers grow more legumes? *Agriculture, Ecosystems & Environment, 91*(1–3), 159–174.

Snapp, S. S., & Silim, S. N. (2002). Farmer preferences and legume intensification for low nutrient environments. *Plant and Soil, 245*, 181–192.

Sonnier, G., Ainslie, A., & Otter, T. (2007). Heterogeneity distributions of willingness-to-pay in choice models. *Quantitative Marketing and Economics, 5*(3), 313–331.

Train, K. E. (1998). Recreation demand models with taste differences over people. *Land Economics*, 230–239.

Train, K. (2003). *Discrete choice methods with simulation*. New York: Cambridge University Press.

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007

Twomlow, S. J., Rusike, J., & Snapp, S. S. (2001). Biophysical or economic performance – Which reflects farmer choice of legume 'Best bets' in Malawi? In *Seventh Eastern and Southern Africa Regional Maize Conference*, 11th–15th February, 2001.

Useche, P., Barham, B. L., & Foltz, J. D. (2013). Trait-based adoption models using ex-ante and ex-post approaches. *American Journal of Agricultural Economics, 95*(2), 332–338.

Ward, P. S., Bell, A. R., Parkhurst, G. M., Droppelmann, K., & Mapemba, L. (2016). Heterogeneous preferences and the effects of incentives in promoting conservation agriculture in Malawi. *Agriculture, Ecosystems & Environment, 222*, 67–79.

Ward, P. S., Ortega, D. L., Spielman, D. J., & Singh, V. (2014). Heterogeneous demand for drought-tolerant rice: Evidence from Bihar, India. *World Development, 64*, 125–139.

World Bank (2015). *Nutrition at a glance: Malawi*. Washington, DC: The World Bank.

Please cite this article in press as: Ortega, D. L. *et al.* Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.06.007