Food Sec.
DOI 10.1007/s12571-016-0616-4

ORIGINAL PAPER

Preferences for legume attributes in maize-legume cropping systems in Malawi

Kurt B. Waldman[1] **· David L. Ortega**[2] **· Robert B. Richardson**[3] **· Daniel C. Clay**[3] **· Sieglinde Snapp**[4]

Received: 20 November 2015 / Accepted: 20 September 2016

Abstract Adoption rates of leguminous crops remain low in sub-Saharan Africa despite their potential role in improving nutrition, soil health, and food security. In this study we explored Malawian farmers' perceptions of various legume attributes and assessed how these perceptions affected allocation of land to legume crops using a logit link model. We found high regional variation in both consumption- and production-related preferences, but relatively consistent preferences across samples. While scientific understanding and farmer perceptions were aligned on some topics and for some legumes, there were discrepancies elsewhere, particularly in terms of soil fertility and nutrition. Understanding why these discrepancies exist and where there were potential biases are critical in explaining the extent of adoption. In many cases perceptions of legume attributes may be influenced by the cultural role of the crop in the household, particularly in terms of food security or market-orientation. The findings also suggest that researchers need to look beyond both the agronomic properties and farmers' preferences to fully understand the extent of adoption. Socioeconomic factors, biases, and marketing concerns may also influence integration of legumes into maize-based cropping systems.

✉ Kurt B. Waldman
kbwaldma@iu.edu

[1] Ostrom Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, USA

[2] Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing, USA

[3] Department of Community Sustainability, Michigan State University, East Lansing, USA

[4] Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, USA

Keywords Legumes · Adoption · Crop attributes · Africa · Malawi · Logit link model

Introduction

Maize was introduced into Africa around 1500 and by the early 1900s had replaced sorghum to become the dominant staple crop in southern Africa (Smale and Jayne 2003). Wide-scale continuous maize cultivation requires fertilizer inputs that many farmers in the region struggle to afford and can deplete soils over time (Lal 1997). Incorporating nitrogen-fixing legumes into smallholder cropping systems has the potential to improve soil fertility and mitigate the nutrient mining impact of maize (Bezner Kerr et al. 2007). Despite the centrality of their role in soil rehabilitation there has been limited adoption of crop legumes, undermining the production potential of cereals. The goal of this study is to examine characteristics of legume adoption in Malawi to better understand why adoption remains low despite serious soil fertility issues.

Integrating legumes into maize based cropping systems can also improve household nutrition (Bezner Kerr et al. 2007). Legumes provide protein and micronutrients such as iron, zinc, or vitamin A, which are often lacking in maize based diets (Messina 1999). Farmers often choose crops for food security and nutritional considerations (Berti and Jones 2013). Intercropping maize with legumes allows rural households in Africa to meet multiple objectives, one of which is a more balanced diet through increased protein consumption (Isaacs et al. 2016). Dietary diversity is associated with improved nutritional status and can be a critical component of food security (Arimond and Ruel 2004).

Explanations for low rates of cultivation of legumes include thin markets, high labor requirements, or poorly adapted varieties (Snapp et al. 2002). However, there has been little attention

Published online: 05 November 2016

given to examining why different legume crops are adopted at different levels of intensity. Across Sub Saharan Africa there is a prevalence of some legume crops such as groundnuts over other legume crops such as pigeonpea. The variation in adoption levels may be due to agronomic factors such as the relative competition between maize and the different legume crops when intercropped. Or alternatively, low adoption may be related to farmers' perceptions (or misperceptions) of different legumes, which vary across regions. In this study we explored legume adoption in terms of farmers' perceptions of the various characteristics attributed to legume crops.

Preferences for particular legume attributes

According to Lancastrian consumer theory, demand for a good can be described by the sum of the characteristics that generate utility for the user (Lancaster 1966). Lancastrian theory has spawned a suite of practical applications, which can be generally characterized as hedonic consumer good characteristic models. The most ubiquitous such model is the hedonic pricing model, where a good is defined by a set of attributes and the good's market price is the sum of the marginal implicit prices of each of those attributes. More broadly, we can look at the value of a good in terms of the importance of the attributes of that good to consumers. Hedonic consumer good characteristic models have been applied to durable goods including homes and cars (Court 1939; Griliches 1961) and non-durable goods including food products such as wine (Combris et al. 2000), coffee (Teuber and Herrmann 2012) and cheese (Waldman and Kerr 2015) or agricultural commodities such as pork (Melton et al. 1996), rice (Dalton 2003), and wheat (Lambert and Wilson 2003).

Few applications of consumer good characteristic models have covered agricultural commodities in developing countries. Consumer good characteristic models can be challenging in a developing country context in that most farmers are interested in both consumption and production characteristics, being both consumers and producers of goods themselves. Using both input characteristic and consumer goods characteristic models, Dalton (2003) found that a combination of production and consumption characteristics explained the willingness to pay for new upland rice varieties and that yield was not a significant explanatory variable of the willingness to pay for seed. Lunduka et al. (2012) explored the attributes of hybrid, open pollinated, and local maize varieties in Malawi using a hedonic approach. Tano et al. (2003) used a conjoint analysis approach to assess farmer preferences for cattle traits in Burkina Faso and found that disease resistance, fitness for traction and reproductive performance were more important than beef and milk production.

While there is a range of related methodological approaches employed in the literature on consumer preferences for crop attributes but much of the literature cited above finds that farmer preferences in developing countries are more focused on consumption characteristics than on production traits. Yet, the overwhelming focus of breeding and development efforts is on the latter. Research on farmer utilization of legumes is sparse but there is evidence from Malawi that some legumes are grown for consumption attributes and others for production traits, depending on local agronomic and market outlets for the particular crop. For example, research with farmers in Northern Malawi documented a range of uses from home consumption to sales, in addition to specialty uses such as forage, soil fertility enhancement and nutritional supplements for young children (Mhango et al. 2013).

There is increasing awareness of the role that gender plays in understanding the-household dynamics of farm management decisions in developing countries (Elson 1993). With respect to legume crops, Snapp et al. (2002) found that female-headed households in Malawi tended to experiment with legume varieties and had more information about legume crops than did male-headed households. However, Orr (2003), found that women tended to experiment less with legume varieties they perceived to have higher labor requirements. Different preferences and perceptions between men and women reflect the division of responsibilities in the household and the difference in resources available to the decision maker.

The primary objective of this study was to explore if there are heterogeneous preferences for legume crops in Malawi and if so, why that might be the case. We explored whether geographic differences may shape preferences and the relationship between socioeconomic variables and legume cropping intensity.

Methods

Study area

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 (Fig. 1). Together these three districts have a total land area of about 8009 km^2, a total population of 1,675,673, and population density of approximately 209 persons per square kilometer, the majority living in rural areas. Located between −14.17 and −15.17 degrees latitude and with an elevation ranging from approximately 500 m to 1600 m above sea level, the study area crosses several distinct agro-ecological and climatic zones. Rain-fed agriculture predominates in this area and is dependent on a single rainy season between November and March.

Maize is the predominant crop in Malawi comprising 53 %, 38 %, and 51 % of total farmed land in Dedza, Ntcheu, and Zomba, respectively. District extension officers reported average maize yields of less than 2 tons/ha, below the average for Sub-Saharan Africa. Much of the crop land in Malawi is intercropped and legumes are a common intercrop choice (Snapp et al. 2010). Groundnuts are most common in Dedza

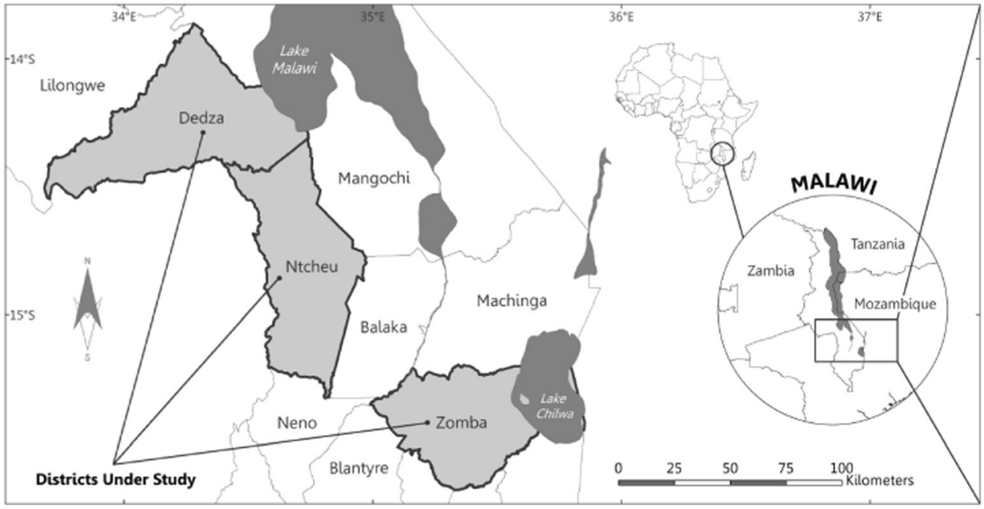


Fig. 1 Map of Malawi and districts where study took place

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. Pigeonpea is the most common legume in Zomba district, occupying 18 % of land and the highest average yields are reported from this region.

The study sites included areas where agricultural extension and development projects have been actively promoting legume production through workshops and other outreach efforts.

The three districts represent different patterns of farmer participation in legume and labor markets, as well as different levels of economic development. While the districts that encompass our study area cover a relatively diverse agroecological region they are not intended to be representative of the entire country. Within a single district there is also variation in various factors such as distance to markets, elevation and soil type. Although we do not claim to characterize entire districts, in the remainder of this paper, we discuss the districts as distinct entities.

Sample

Our sample consisted of farmers from 488 village households that were interviewed in September and October 2014 by trained enumerators. A multistage sampling approach within each district was used to select farm households. In the first stage we selected four Extension Planning Areas (EPAs) where we knew legume production was prevalent. In the second stage, we randomly selected two administrative sections from each EPA and worked with Agriculture Extension Development Officers (AEDO) to randomly sample approximately 20 farmers from village rosters in each section. Our sample consisted of 162, 165, and 161 farm households from Dedza, Ntcheu and Zomba districts, respectively.

As a part of the household survey, we collected data on farm household characteristics including household assets, non-farm income, field crops produced and harvested, seed availability as well as farmer preferences for legume attributes. We asked farmers what the total land area they planted to each legume crop was in the previous growing season. This information and the relationships between specific factors of interests are relevant for further understanding farmer behavior, especially as it pertains to preferences for various attributes of legume crops.

Model

We employed a similar approach to Lunduka et al. (2012) to evaluate both consumption and production attributes of various legume crops and to assess the factors that influence adoption with some adjustments to the methodological approach. While numerous approaches are available to understand preferences we chose to use a quantitative household survey in order to capture a relatively large sample of farmers, understand the relationship of underlying socioeconomic factors, as well as to characterize the tradeoffs farmers perceive between different crop choices (reported in Ortega et al. 2016). We used a multivariate regression to examine the degree to which various attributes of common legumes in Malawi influence how much land farmers allocate to each legume crop. Attributes included in the model cover various production and consumption characteristics of legume crops. The main legume crops found in Malawi that we studied were groundnut (*Arachis hypogaea*), soybean (*Glycine max*), pigeonpea (*Cajanus cajan*), cowpea (*Vigna sinensis*), and common bean (*Phaseolus vulgaris*). The dependent variables used in the regressions were the proportions of total cultivated land area farmers allocated to each of the legume crops.

Using a proportion in a multivariate regression model will generally yield nonsensical predictions for extreme values of the regressor. Since proportion data have values that fall between zero and one, ideally the predicted values should also fall between zero and one (Baum 2008). One way to accomplish this is to use a logit transformation of the data. There are multiple ways to make this transformation. We chose to estimate a generalized linear model (GLM) with a logit link function and a binomial family specification as described by Papke and Wooldridge (1993). Using this logit transformation we were able to map the original dependent variable *y*, from a standard ordinary least squares (OLS) regression that was bound between 0 and 1 onto the real line (i.e. a logit transformation of the response variable values strictly within the units interval):

$$y_{ij}{*} = \log\left(\frac{y_{ij}}{1-y_{ij}}\right) = X\beta + \varepsilon_j \qquad (1)$$

where y_{ij} is the amount of land planted by person i to legume crop j; X is a vector of dummy variables for the common attributes of the legume crop and a vector of socio-demographic characteristics; β is a parameter vector to be estimated; and ε_j is a random error term. We obtained robust standard errors, which are useful if we have unintentionally misspecified the distribution family.

This model accommodates extreme values better than other options although there is some complication in the interpretation of extreme values with the transformation. We were not concerned with values of 1 since no farmers in the sample had devoted their entire farms to legumes. There are, however, two possible interpretations when values are zero. First, zero values could be sampling zeros in the sense that farmers chose not to plant any legume crop that season but may have grown that crop in the past or may do so in the future. The second possibility is a structural zero in the sense that these farmers have never and will never plant a given legume. In the present study all sampled farmers reported planting some amount of at least one legume crop so we interpret the zeros as sampling zeros.

We ran a series of Heckman selection equations (Heckman 1976) to test for the possibility of sample selection bias. A Heckman selection model is the correct specification if there are different reasons for a) someone deciding to plant a given legume, and b) how much of their land they would devote to that legume. We tested for the comparison of the joint likelihood of an independent probit model for the selection equation (whether a given legume was planted) and a regression model on the observed data (intensity of a given legume produced) against the Heckman model likelihood. Likelihood-ratio tests were not significant indicating that there is no justification for the Heckman selection equation with these data.

The explanatory variables included a set of dummy variables of attributes that farmers positively associate with each legume crop. The variables covered consumption attributes including taste and nutrition. There were also dummy variables across a range of production attributes, including seed accessibility, access to information about the crop, labor requirements, and storage quality. Another series of variables covered general agronomic performance of the legume crops, such as yield, marketability, contribution to soil fertility, adaptability, pest resistance, and weed suppression.

The agronomic attributes included in the model were based on the assumption that there are traits that are relatively consistent across the crops regardless of the variety of each crop. We recognized this as an oversimplification, particularly of some of the agronomic variables such as yield or good marketability, which might vary significantly between different varieties of the same crop. This poses some risk that the variation could be so wide that we would be unable to capture the overall effect of that attribute. For example this would likely be the case with the maturation period of pigeonpea which can be either short or long duration (although medium to long duration pigeonpea is most commonly grown in Malawi). Our approach assumes that, despite variation in characteristics among multiple varieties of a crop, farmers still have an association with the crop. For example, a farmer might have experience with one variety of groundnuts that is pest resistant and another that is not, but overall they think that groundnuts are more pest resistant than other leguminous crops.

We also controlled for a set of socioeconomic variables. These independent variables included the district in which the household resided, whether the female or male in the household made decisions about planting legumes, the amount of labor available to the household, the reported size of land holdings, the frequency of extension visits a household received and the distance the household resided from the market. A wealth index was constructed for each household by conducting a principal component analysis of all reported household assets including livestock holdings.

Results

Farm household characteristics/descriptive statistics

Table 1 summarizes the basic descriptive statistics on sampled households by region. Slightly over half of our respondents were females (58 %), with significantly more women (73 %) participating in our study in Zomba district. Our average respondent was 41 years of age with slightly over 6 years of formal education. Household size averaged approximately five persons across the three districts, with only minor district-level variation from this mean. Households in our sample have been farming for approximately 18 years on average, and farm size averaged 2.4 acres, or just under one hectare, with modestly larger holdings in Dedza and decreasing in size in the more southerly districts. On average, farmers in Ntcheu and Zomba reported having greater access to markets (residing closer to markets) where they could sell maize and markets where they could sell various legumes compared to those in Dedza, which is located in the central highlands. The majority of households use only their own labor with approximately 40 % of households hiring outside farm workers in the 2013–2014 growing season.

Based on the household asset data we constructed a wealth index using a procedure similar to that developed by the

Table 1 Farm household characteristics by district

Characteristic	Dedza	Ntcheu	Zomba	Mean
Household size (mean persons)	5.25	5.06	4.88	5.07
Female respondents (%)	49	54	73	58
Female headed households (%)	11	17	19	16
Age of respondent (mean years)	40.27	42.72	39.06	40.70
Education (mean years)	4.94	7.00	6.41	6.12
Under 16 (mean persons)	2.45	2.32	2.35	2.38
Farming experience (mean years)	17.99	19.34	17.45	18.27
Landholding size (mean acres)	2.79	2.27	2.03	2.37
Distance to nearest market (mean km)	7.1	4.62	4.22	5.32
HH Labor (previous yr. in mean persons)	3.05	3.18	3.06	3.09
Hired labor (% reporting)	43	34	40	39
N	162	165	161	488

Demographic and Health Surveys (DHS) Program and the World Bank (Rutstein and Johnson 2004). A wealth index is particularly useful in contexts where reliable data on income and household expenditures are difficult to capture, which are the more traditional indicators used to measure household economic status. The index is calculated based on household ownership of assets and livestock that were owned by between 5 % and 95 % of the households. A common method of constructing a wealth index from a list of household assets is to use the first principal component from a principal components analysis (PCA) as the aggregating weight (Filmer and Pritchett 2001; McKenzie 2005). Each household asset for which information is collected is assigned a factor score generated through the PCA yielding a continuous scale of wealth for the households. The factor score or first principal component is then ranked from high to low and this variable is divided into terciles as a proxy for low-, medium-, and high-income households.

Maize and legume land area

Farmer land allocation by crop in each district in the 2013–2014 growing season is presented in Table 2. We adjusted for average planting density by assuming an "additive" intercrop relationship. The recommended seeding rate for a sole crop of maize and a sole crop of pigeonpea is 44,000 plants per hectare (slightly higher for some maize varieties) and the recommended maize and pigeonpea intercrop seeding rate is also 44,000 each, or a combined 88,000 (Malawi Ministry of Agriculture 2012). However, on-farm research in Malawi has found intercropped maize and beans to have a Land Equivalency Ratio (LER) ranging from 1.3 to 1.5 (Mhango 2011), and as wide as 0.6 to 1.7 for a maize-pigeonpea intercrop (Ofori and Stern 1987). LER is a method used to calculate the relative yield of two crops when intercropped together in order to make yield comparisons with a sole crop (Oyejola and Mead 1982). LER values can vary greatly depending on water and other limiting resources. For simplicity we assume an LER of 1.5, or that intercropped maize is planted at the same density and obtains the same yield as in a sole crop and intercropped legume crops are planted at 50 % of the density and thus obtain 50 % of yield that they would as a sole crop. In other words, for analysis we convert all reported intercropped land area to sole crops using a fixed LER in order to look at the effective amount of land in each crop. Based on these estimates from the literature, the amount of land area is effectively greater than 100 % (sole maize cultivation) because of the additive relationship between maize and legumes in the Malawi context.

Under these assumptions, we found that slightly more than half of all land was allocated to some variety of maize (slightly more in Ntcheu and less in Zomba). The highest hybrid maize production area was Zomba (37 % of all land area). The predominant legume crop in Dedza was groundnuts. In Ntcheu, farmers predominantly grew common beans and similar amounts of groundnut, soybean and pigeonpea. The most

Table 2 Percentage of land area under each crop by district, adjusted for intercropping

	Dedza	Ntcheu	Zomba	Total
Maize	21 %	28 %	16 %	22 %
Hybrid	30 %	29 %	37 %	32 %
Recycled maize	2 %	2 %	2 %	2 %
Groundnut	16 %	9 %	11 %	12 %
Soybean	6 %	8 %	2 %	5 %
Pigeonpea	3 %	7 %	18 %	9 %
Cowpea	9 %	2 %	6 %	6 %
Common bean	9 %	16 %	8 %	11 %
Pea (green)	0 %	0 %	1 %	0 %
Velvet bean	0 %	0 %	1 %	0 %
Sorghum	0 %	1 %	2 %	1 %
Tobacco	5 %	1 %	4 %	4 %
Cotton	2 %	1 %	1 %	2 %
	104 %	104 %	109 %	

In cases where land is intercropped we assumed that the maize crop was planted at the same density as a sole crop and effectively occupied the same area while the legume crop was planted at 50 % of the density it would have been as a sole crop and so effectively occupied 50 % of the land area common legume crop in Zomba was pigeonpea where there is a higher concentration of buyers and exporters. Across the sample, farmers allocated approximately 6 % of their land to cash crops (cotton and tobacco).

Gender differences

Gender emerged as a significant determinant of legume adoption including gender differences in on-farm decision making as well as in preferences for various legume attributes. Table 3 reports the proportion of females that make planting decisions regarding legumes and maize. Overall we found that 45 % of women were responsible for making legume-planting decisions and 27 % made maize-planting decisions. Moreover, we found statistical evidence of differences in land area planted in households where women made decisions regarding legume planting (Table 4). On average, households in which women made legume-planting decisions tended to allocate less land to groundnut and common bean than did households where men made the planting decisions.

Preferences for legume attributes were also disaggregated by the gender of the respondent. We found significant differences across male and female farmers with regard to legume crop preferences and performance expectations. On average, women found soybean to have good marketability and also had better access to soybean seed than did men. Women indicated more frequently than men that pigeonpea was high yielding had better adaptability, and that there was better access to seed. They also found common beans to be significantly more nutritious than did their male counterparts (who anecdotally preferred meat) and this may be because beans typically replaced meat as a source of protein when meat was not available.

Perceptions of legume attributes

To understand perceptions of various legumes, farmers were asked to indicate positive attributes of specific legumes from a list of characteristics (Table 5). The list of attributes was generated using focus groups with a random sample of farmers prior to the household survey. Farmers were asked to report only values for crops they were familiar with. The attributes were ranked from most important on average (most frequently mentioned) to least important (or least mentioned as positive attributes). Nutrition was the most frequently mentioned attribute, followed by good marketability, taste, soil fertility, and yield/adaptability.

Most farmers indicated that groundnuts are nutritious (more than the other legumes), are known to increase soil fertility (the most of any crop), are associated with good marketability, store well, taste good, are suitable to their region (adaptable), and are high yielding. Farmers also noted that they had sufficient “extension information” on the crop. Similarly, farmers indicated that soybean is nutritious, increases soil fertility, stores well, is high yielding and is suitable to their region (adaptable). Positive characteristics of pigeonpea included increasing soil fertility, good taste, good as a forage crop, and adaptability. On average, most farmers indicated a positive taste for cowpea. Common bean was rated positively for good marketability, nutrition, and good taste. Farmers reported having the most information (an indicator of extension efforts) for groundnut, followed by soybean, common bean, pigeonpea and cowpea.

Table 3 Percentage of females making crop decision

Variable	Mean	Std.
Legume decision	0.45	(0.50)
Maize decision	0.27	(0.44)
N	488	

Table 4 Land area planted (acres) in legumes by crop and gender of decision maker

	Male	Female
Groundnut	0.40*	0.31*
Soybean	0.20	0.15
Pigeonpea	0.29	0.32
Cowpea	0.17	0.19
Common bean	0.44*	0.30*

* indicates a significant gender difference at the 0.10 confidence level

Characteristics of legume adoption

To understand the drivers and barriers to legume adoption, we examined the degree to which various crop-specific attributes influenced smallholder farmers’ decisions to plant legumes. We measured adoption as the intensity of legume production where the dependent variable was measured as the proportion of the area planted to each legume crop relative to the total area planted to legumes, as reported for the 2014 growing season, among the surveyed farmers. We drew on Lancastrian consumer theory, which postulates that preferences and demand for a given good/product are a function of the traits possessed by that good, rather than the good itself.

As described above, we used logit link regression to estimate the attributes (from the list in Table 5) along with various socioeconomic variables on the proportions of a households’ area planted to each legume crop. Each dummy variable has a value of 1 if the farmer stated that the given attribute was a positive characteristic of the crop, and 0 otherwise. Additionally, we controlled for household labor, assets, number of visits by extension personnel, distance to market, land area, and gender of the decision maker regarding legume crops. Likelihood ratio tests confirmed our ability to pool the data across the three districts so we present pooled estimates in this analysis controlling for district regions.

We present marginal effects in the tables for easier interpretation (Table 6). Because the logit link function transforms the predictions back into the units of the response variable, we do not present odds ratios as if we had simply estimated a logit

Table 5 Mean values of attributes noted by farmers familiar with the crop

Attributes	Ground nut	Soy bean	Pigeon pea	Cow pea	Common bean	Mean
Nutritious	0.98	0.96	0.72	0.75	0.87	0.83
Good marketability	0.87	0.80	0.72	0.75	0.86	0.77
Good taste	0.84	0.33	0.82	0.82	0.95	0.76
Increases soil fertility	0.92	0.86	0.87	0.69	0.71	0.76
High yielding	0.83	0.81	0.74	0.66	0.72	0.71
Good adaptability	0.80	0.80	0.80	0.66	0.67	0.71
Good storage	0.90	0.84	0.61	0.58	0.72	0.69
Low labor requirements	0.69	0.72	0.76	0.70	0.70	0.69
Good seed accessibility	0.79	0.64	0.69	0.75	0.79	0.69
Good forage	0.79	0.62	0.80	0.68	0.64	0.66
Sufficient information	0.81	0.72	0.63	0.58	0.66	0.64
Pest resistant	0.64	0.72	0.62	0.41	0.52	0.56
Good weed suppression	0.48	0.49	0.58	0.44	0.44	0.45

Values in the table represent the average value of that attribute across all participants (where 1 = mentioned as a positive attribute)

model; rather, we report the relative proportion ratios. We derived marginal effects at the means (the marginal effects when all other variables equal their means) for a continuous variable—in this case the fraction of total land in legumes planted to each individual legume. Marginal effects in this case measure the instantaneous rate of change. This can be interpreted as farmers choosing a given positive attribute of that legume crop (e.g. as the value of a given attribute changes from 0 to 1) resulting in an *x* % increase (or decrease) in the proportion of land planted to a legume crop for an otherwise "average" individual. For example, if we look at groundnuts in Dedza, we see that as "high yielding" goes from 0 to 1 (a person perceives that groundnuts to be high yielding), there is a 13.6 % increase in the proportion of land that is planted to groundnuts (relative to the total land planted to legumes). We present the results from the pooled regression in Table 6 as well as mention relevant results from district specific regressions, which can be found in the Appendix.

Groundnuts are more likely to be grown where markets are more distant, suggesting they are more of a consumption crop in those areas. Groundnuts are also more likely to be grown in

Table 6 Marginal effects from a Logit link GLM regression of the proportion of land area in each legume crop

Pooled	Groundnut		Soybean		Pigeonpea		Cowpea		Common bean	
	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|
Dedza	0.095**	0.027	0.132***	0.000	-0.233***	0.000	0.011	0.554	0.076*	0.087
Ntcheu	-0.024	0.591	0.183***	0.000	-0.178***	0.000	-0.094***	0.000	0.175***	0.000
Female legume decision	0.054	0.125	0.020	0.281	-0.087***	0.001	-0.025*	0.101	0.033	0.282
Household labor	-0.002	0.873	0.005	0.534	-0.007	0.467	0.002	0.679	-0.008	0.514
Extension visits	-0.007	0.208	-0.003	0.263	0.001	0.737	0.001	0.366	0.002	0.372
Asset Index_2	0.042	0.342	0.019	0.418	-0.003	0.916	0.023	0.278	-0.021	0.576
Asset Index_3	0.029	0.547	-0.043*	0.103	0.010	0.785	0.043*	0.078	-0.012	0.785
Non agr. Income†	0.000	0.693	-0.001	0.364	0.000	0.732	-0.002***	0.008	0.002*	0.084
Market distance	0.013***	0.000	-0.002	0.341	-0.004*	0.096	0.000	0.751	-0.011***	0.001
Land area	0.014	0.196	0.000	0.953	0.011	0.214	0.005	0.338	-0.030**	0.025
Increases soil fertility	0.076	0.194	0.025	0.414	-0.037	0.453	0.051**	0.038	-0.019	0.593
Good marketability	-0.038	0.498	0.031	0.263	0.128***	0.010	0.051**	0.022	0.185***	0.002
Nutritious	0.102	0.368	-0.045	0.470	-0.013	0.703	0.011	0.621	-0.014	0.775
Good storage	0.110*	0.087	0.038	0.330	-0.042	0.154	-0.002	0.880	-0.112***	0.003
Good taste	-0.016	0.749	0.008	0.689	-0.028	0.548	-0.055**	0.027	0.197	0.139
Good seed accessibility	0.029	0.498	0.025	0.247	0.001	0.979	0.046**	0.052	-0.020	0.703
Low labor requirements	0.009	0.836	0.004	0.862	0.020	0.582	-0.027	0.150	-0.027	0.458
Pest resistant	-0.015	0.697	0.001	0.957	0.016	0.600	-0.035**	0.038	0.039	0.231
Good forage	0.038	0.429	-0.017	0.415	-0.013	0.766	0.014	0.467	-0.032	0.343
Good adaptability	0.048	0.293	0.063**	0.027	-0.011	0.814	0.020	0.286	0.068	0.107
High yielding	0.136**	0.020	-0.039	0.212	0.079*	0.068	0.031*	0.088	0.099**	0.054
Good weed suppression	-0.068*	0.073	-0.023	0.241	-0.037	0.181	0.034**	0.048	0.124***	0.000
Sufficient information	0.010	0.850	0.064**	0.025	0.077**	0.023	0.022	0.191	0.015	0.695
Log pseudolikelihood	-191.56		-118.67		-133.89		-100.25		-160.21	
AIC	1.0778		0.7187		0.8181		0.6369		0.9234	
N	400		397		386		392		399	

***, **, *, represent significance at the 0.01, 0.05 and 0.10 levels, respectively

† Reported in 10,000 MWK

Dedza, which is closest to Lake Malawi and generally has a sandier soil. The nutrition provided by groundnuts is a determinant of how much land is planted to the crop in Dedza and Ntcheu (but not Zomba) and overall storage qualities were important, suggesting that groundnuts are mostly grown for home consumption. Groundnuts are also favored for being high yielding (especially in Dedza and Ntcheu). Possible barriers to adoption of groundnuts include the perception of poor weed suppression.

Soybean is the least common legume crop in the sample. There is evidence that soybean is grown predominantly by resource-poor households as it is not popular with households in the wealthiest income bracket or those with higher off farm income (in Ntcheu). Perceived benefits of growing soybean include increasing soil fertility (in Ntcheu) and lower labor requirements (in Dedza). Barriers to adoption potentially include low yield (Ntcheu) and a perception that soybean is less nutritious and is poor at suppressing weeds (in Dedza). Overall the most important attribute of soybean is its adaptability and the abundance of extension information available on the crop.

Pigeonpea is most common in Zomba and among household where men grow the crop (particularly in Zomba, where they are grown commercially). Pigeonpea is less likely to be grown where markets are distant (in Dedza and Zomba). Overall positive attributes of pigeonpea include good marketability (especially in Dedza and Ntcheu), high yield, and sufficient information in Dedza and Zomba (where the most farmers cultivate it). Potential barriers to pigeonpea adoption at the district level include storability (Dedza and Ntcheu) adaptability (in Dedza), low soil fertility improvement (in Ntcheu), and weed suppression (in Zomba).

Similar to soybean, a large segment of the sample does not grow cowpeas and this is especially true in Ntcheu. Cowpea is less common in households where women make the legume planting decisions. There is a wealth dimension to the cultivation of cowpea in the sense that farmers in the highest income bracket (especially in Dedza) and with higher off-farm income are less likely to grow cowpea (in Dedza and Zomba). Farmers perceive many benefits from cowpea. Overall, positive farmer perceptions include good marketability, increased soil fertility, seed accessibility, and weed suppression (in Dedza). Taste and pest resistance are barriers to cowpea adoption.

Common bean was the dominant legume crop in Dedza, increasing on farms with off farm income, and less frequently found where markets are distant. As land area increases farmers were less likely to grow common bean. Female legume decision makers in Zomba were more likely to plant common bean than men. Overall, common bean was perceived to be the most marketable legume crop. Taste was cited as a positive attribute for common bean (in Dedza and Ntcheu), although adaptability (Dedza), high yield (Ntcheu), good marketability (Zomba) and weed suppression (all regions) were also significant. Storage appears to be the biggest barrier to common bean adoption.

Discussion

Some of the attributes farmers positively associate with a given legume crop align well with scientific understanding of the crop while other attributes perhaps illustrate some areas where farmers' perceptions may differ from scientific evidence. For example, farmers indicated that soybean is poor tasting, which makes biological sense since soybean requires extensive processing before consumption. Pigeonpea received the highest ratings for weed suppression, which aligns well with agronomic evidence demonstrating that pigeonpea branches out late in the growing season during times of high weed development (Snapp and Silim 2002).

Other associations with legume attributes suggest discrepancies between farmers' perceptions and scientific findings or a farmer bias. For example, farmers associated groundnut with increased soil fertility although longer duration legume crops like pigeonpea are known to be more effective at biological nitrogen fixation. Similarly, pigeonpea is associated with high grain yields by women in the sample although other grain legumes in this study are known to produce higher yields. This is, however, on a per unit area basis and farmers may be using other criteria, such as yield per laborer. Women may view pigeonpea as higher yielding since the pigeonpea shrub produces vegetable pods and grain over a longer period than other legume crops and plays an important food security role for some households (Snapp et al. 2003). These discrepancies suggest areas where dissemination of more information and interaction with farmers are needed through extension or participatory research.

Other associations may simply reflect the role of the crop in a cultural context. The attribute of "high yielding" was cited less frequently than "increases soil fertility"—suggesting there are strong, positive associations of legume crops with soil fertility. The perception of legume crops as increasing soil fertility may reflect the role of legumes in maize-legume intercrop systems in Malawi. This result is supported by Orr and Ritchie (2004) who found that soil fertility was more important than pest management in Malawi as the first order of crop management. Groundnuts are a preferred food for home consumption in many parts of Malawi and groundnut is a nutrient-dense food, so it is not surprising that farmers associate groundnut with good nutrition. Farmers also associated storability with groundnuts, which is a crop they often keep in storage at the home. Farmers' perceptions may be a function of the importance of the crop to household food security (Freeman et al. 2002).

Another factor affecting perceptions of legume attributes may be information communicated to farmers through interventions from government extension and non-governmental programs. Information availability seemed to be sufficient for most crops and soybean in particular. This likely reflects the history of extension efforts for soybean in Malawi, which appears to be increasing the area of soybean cultivated. However, the total area in soybeans remains low suggesting that this may be an uphill battle, particularly given the low associations with good taste.

Cowpea is an example where strong negative associations may outweigh numerous positive associations. Cowpea is associated with the most positive attributes by farmers yet remains a small share of the total legume production area. Breeding programs, which focus solely on yield or farmer preferences, can overlook important market factors that determine adoption. In Ghana, Quaye et al. (2014) have found that cowpea-breeding efforts have not taken into account marketability or trader perspectives to nearly the degree that farmer perceptions have been. While there may be strong preferences for cowpea, widespread adoption could be curtailed by a strong negative association such as a lack of pest resistance. Barriers like pest resistance may present too great a burden for widespread cowpea cultivation, which may be a function of the generally low adoption of pest management strategies in Africa for lower value food crops (Orr 2003).

Conclusions

The significance of various legume crops differs geographically and by socioeconomic factors such as income and gender but farmers' perceptions of their attributes are relatively consistent across the country and may be critical in understanding adoption intensity. The perception of groundnuts reflects their role as a food security crop, grown in remote areas and mostly intended for household consumption since they are considered to be nutritious, high yielding and easily stored. While soybean is often promoted through extension efforts because it is adaptable and nutritious, it is not widely produced because of taste preferences. Pigeonpea is marketable, relatively high yielding, and is considered to be a market-oriented crop largely driven by male farmers. Cowpea could be considered a home consumption crop grown by poorer households and has a wide variety of associated positive attributes but more widespread cultivation is hindered by pest problems and marketability. Common bean is favored for both consumption properties (i.e. taste) and various agronomic attributes (e.g., yield, weed suppression and marketability) and remains popular.

The cultural context of legume production in Southern Africa includes the role of maize. Intercropping maize and legumes is common in Malawi and legume adoption appears to be relatively high on a per area basis, effectively covering almost half the currently farmed land in the sample. Anecdotally, however, there is a marked decline in legume intercropping from near complete adoption historically. There are some notable geographical differences in maize production and intercropping of legumes. Farmers in Zomba grew the most hybrid maize, which allowed them to grow less maize overall to "fill their maize basket" while freeing land to grow more legumes (Snapp and Fisher 2015). Pigeonpea markets are robust in this area so farmers maximize returns to smaller land holdings by producing pigeonpea as a cash crop. Farmers in Dedza appear to be slightly poorer and more remote (relative to markets) than farmers in the other districts and this may also be an important motivation for growing groundnuts for household consumption. This also may explain why farmers in Dedza produce less hybrid maize, which has higher input costs. Comparatively, farmers in Ntcheu are slightly better off than in Dedza, with greater assets and non-farm income, higher education, and less distance to output markets. In Ntcheu, common beans are the most frequently grown legume crop, probably because conditions are the most favorable.

In the analysis we combined associations of legume-specific attributes with geographic and socioeconomic factors and looked beyond agronomic performance and farmer preferences, particularly at the role of biases. Farmers' perceptions and biases about crops are important and often unexplored factors in adoption decisions. This paper demonstrates that while scientific understanding and farmer perceptions are aligned on some topics and for some legumes there are discrepancies elsewhere, including a lack of understanding of the role of legumes in soil fertility processes. Understanding these discrepancies is critical to understanding the extent to which legumes are adopted. Results suggest that biases related to nutrition, soil fertility, and the cultural role of legume crops may influence perceptions of the agronomic properties of the crops and lead to less than optimal decisions on cropping systems.

Legumes are important for myriad reasons and adoption decisions are driven by factors that include gender, wealth/income, geographical location, farm size, and distance to market. One important policy implication from this research is that legumes comprise a "versatile" set of crops and are able to meet the needs of farmers in various ways. Maize and other staple cereal crops are not likely to have the same degree of versatility yet they dominate the landscape in Southern Africa. This is important from a food security and development perspective as it suggests that adaptation and resilience are more likely to emerge from crops such as legumes that are diverse in attributes and in the roles they fulfill in household production systems. If, as suggested by Bellprata et al. (2015), legumes are not as sensitive to climatic variation and changing climatic conditions as cereals, it is likely that they will play a greater role in Southern Africa in the future where drought and food shortages have latterly become increasingly common and more severe.

Acknowledgments This research was supported by the Bill and Melinda Gates Foundation under grant OPP1076311 titled "Perennial Grains Crops for African Smallholder Farming Systems" and by the United States Agency for International Development (USAID) Feed the Future Integrating Nutrition in Value Chains program. The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

Table 7 District level marginal effects from a Logit link GLM regression of the proportion of land in each legume crop

Dedza	Groundnut		Soybean		Pigeonpea		Cowpea		Common bean	
	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|
Female legume decision	0.093	0.20	0.034	0.27	-0.028	0.15	-0.041	0.37	-0.037	0.24
Household labor	0.012	0.68	0.002	0.85	0.003	0.57	-0.012	0.39	-0.013	0.16
Extension visits	-0.027	0.00	-0.003	0.54	0.001	0.30	0.010**	0.04	0.006**	0.02
Asset Index_2	-0.018	0.83	0.005	0.89	0.001	0.93	-0.002	0.97	0.005	0.90
Asset Index_3	0.015	0.89	-0.105**	0.03	0.022	0.30	0.101*	0.09	0.049	0.27
Non agr. Income†	-0.003	0.42	0.003**	0.03	0.000	0.83	-0.005**	0.05	0.001	0.45
Market distance	0.016***	0.00	-0.002	0.39	-0.001***	0.07	-0.002	0.32	-0.008***	0.00
Land area	0.009	0.68	0.008	0.48	0.003	0.24	-0.006	0.54	-0.008	0.35
Increases soil fertility	0.004	0.97	-0.028	0.44	-0.007	0.62	0.153	0.24	0.003	0.93
Good marketability	-0.042	0.67	0.035	0.47	0.030***	0.01	0.189	0.17	0.052	0.28
Nutritious	3.525***	0.00	-0.123**	0.03	-0.004	0.74	-0.030	0.64	0.042	0.32
Good storage	0.065	0.66	0.030	0.53	-0.028**	0.02	-0.001	0.98	-0.081**	0.02
Good taste	-0.131	0.12	-0.041	0.16	0.004	0.71	-0.113	0.12	1.142***	0.00
Good seed accessibility	0.060	0.42	0.038	0.32	0.008	0.36	0.212***	0.01	0.021	0.57
Low labor requirements	0.014	0.85	0.070*	0.10	-0.022	0.15	-0.102	0.11	-0.046	0.18
Pest resistant	-0.004	0.96	-0.022	0.52	-0.011	0.47	-0.051	0.22	-0.002	0.94
Good forage	0.063	0.54	0.002	0.95	0.015	0.34	0.011	0.83	0.031	0.33
Good adaptability	0.042	0.64	0.059*	0.09	-0.016*	0.10	0.000	1.00	0.079**	0.03
High yielding	0.385***	0.00	0.011	0.83	0.037*	0.09	0.046	0.48	-0.026	0.51
Good weed suppression	-0.005	0.94	-0.073***	0.01	0.002	0.84	0.088**	0.04	0.055*	0.07
Sufficient information	0.006	0.96	0.052	0.22	0.025*	0.08	-0.016	0.74	-0.002	0.94
Constant	-16.832***	0.00	-2.679***	0.00	-5.472***	0.00	-4.456***	0.00	-15.997***	0.00
Log pseudolikelihood	-62.59		-34.38		-17.38		-41.21		-42.90	
AIC	1.3115		0.8741		0.6618		1.0033		1.0062	
N	129		129		119		126		129	

***, **, *, represent significance at the 0.01, 0.05 and 0.10 levels, respectively

† Reported in 10,000 MWK

Table 8 District level marginal effects from a Logit link GLM regression of the proportion of land in each legume crop

Ntcheu	Groundnut		Soybean		Pigeonpea		Cowpea		Common bean	
	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|
Female legume decision	-0.029	0.50	0.001	0.98	-0.017	0.52	0.000	0.49	0.009	0.85
Household labor	-0.026	0.16	0.009	0.68	-0.010	0.40	0.000	0.70	0.009	0.62
Extension visits	-0.002	0.76	-0.006	0.35	-0.006	0.15	0.000	0.22	0.008*	0.08
Asset index_2	0.036	0.50	0.061	0.36	0.013	0.69	0.000*	0.10	0.008	0.90
Asset index_3	-0.003	0.96	-0.048	0.49	0.047	0.18	0.000	0.04	-0.059	0.30
Non agr. income†	-0.001	0.34	-0.005**	0.02	0.000	0.65	0.000	0.31	0.002	0.21
Market distance	0.003	0.70	-0.002	0.75	0.002	0.66	0.000	0.46	-0.002	0.80
Land area	0.027*	0.08	-0.009	0.70	0.013	0.16	0.000	0.67	-0.049**	0.04
Increases soil fertility	0.049	0.48	0.382***	0.01	-0.080*	0.08	0.000	0.26	-0.096*	0.08
Good marketability	-0.128*	0.09	0.012	0.88	0.229***	0.00	0.000	0.41	0.132	0.14
Nutritious	1.889***	0.00	0.226	0.27	-0.033	0.37	0.000	0.08	-0.013	0.86
Good storage	0.126	0.18	0.097	0.55	0.002	0.94	0.000	0.34	-0.083	0.17
Good taste	-0.015	0.81	0.032	0.58	-0.042	0.26	0.000	0.85	2.064***	0.00
Good seed accessibility	0.071	0.26	0.052	0.40	-0.044	0.28	0.000	0.86	-0.055	0.54
Low labor requirements	-0.014	0.80	-0.019	0.77	0.008	0.81	0.000	0.14	0.002	0.97
Pest resistant	-0.020	0.69	-0.016	0.80	-0.030	0.23	0.000	0.81	0.059	0.25
Good forage	-0.063	0.31	-0.010	0.89	0.027	0.56	0.000	0.60	-0.046	0.39
Good adaptability	0.182***	0.01	0.111	0.23	-0.003	0.95	0.000	0.49	0.003	0.97
High yielding	0.038	0.60	-0.240***	0.01	0.026	0.53	0.000**	0.03	0.149**	0.04
Good weed suppression	-0.034	0.43	-0.014	0.81	-0.012	0.65	0.000	0.45	0.135***	0.01
Sufficient information	0.099	0.14	0.091	0.32	0.005	0.86	0.000*	0.10	0.025	0.66
Constant	-18.380***	0.00	-4.774**	0.03	-3.511***	0.00	-27.457***	0.00	-16.340***	0.00
Log pseudolikelihood	-59.33		-59.70		-38.52		-12.26		-66.15	
AIC	1.1536		1.1756		0.8771		0.4930		1.2592	
N	141		139		138		139		140	

***, **, *, represent significance at the 0.01, 0.05 and 0.10 levels, respectively

† Reported in 10,000 MWK

Table 9 District level marginal effects from a Logit link GLM regression of the proportion of land in each legume crop

Zomba	Groundnut		Soybean		Pigeonpea		Cowpea		Common bean	
	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|	dy/dx	P > |z|
Female legume decision	0.133**	0.03	0.001	0.70	-0.266***	0.00	-0.045	0.16	0.068*	0.08
Household labor	0.012	0.52	0.001	0.30	-0.026	0.13	0.004	0.74	-0.002	0.84
Extension visits	0.004*	0.07	-0.001	0.21	-0.001	0.87	0.001	0.83	-0.010	0.11
Asset Index_2	0.047	0.47	0.004	0.30	-0.091	0.28	0.035	0.44	-0.009	0.82
Asset Index_3	0.071	0.34	-0.012	0.20	-0.124	0.18	0.018	0.69	0.025	0.60
Non agr. Income†	0.002	0.19	0.000	0.22	-0.002	0.23	-0.003**	0.02	0.001	0.51
Market distance	0.014	0.17	0.001	0.35	-0.026**	0.05	0.004	0.38	-0.003	0.72
Land area	0.011	0.59	-0.001	0.50	0.007	0.78	0.020	0.17	-0.025	0.14
Increases soil fertility	0.089	0.29	0.003	0.54	0.071	0.57	0.037	0.42	0.032	0.33
Good marketability	0.015	0.87	0.001	0.44	-0.046	0.74	0.034	0.35	0.154***	0.00
Nutritious	0.143	0.24	-0.021	0.20	0.041	0.59	0.027	0.62	0.022	0.80
Good storage	0.093	0.31	0.003	0.36	-0.111*	0.08	0.000	0.99	-0.048	0.18
Good taste	0.093	0.15	0.001	0.77	-0.100	0.43	-0.063	0.17	-0.066	0.72
Good seed accessibility	-0.087*	0.10	-0.004	0.45	0.032	0.77	0.008	0.84	0.006	0.90
Low labor requirements	-0.045	0.49	-0.004	0.33	0.047	0.60	-0.027	0.44	-0.018	0.69
Pest resistant	-0.063	0.31	0.004	0.47	0.100	0.17	-0.042	0.23	0.037	0.36
Good forage	0.084	0.18	-0.004	0.32	-0.071	0.41	0.019	0.59	-0.043	0.19
Good adaptability	-0.060	0.35	0.004	0.73	-0.079	0.57	0.035	0.28	0.023	0.52
High yielding	0.042	0.60	0.004	0.36	0.167	0.14	0.039	0.22	0.061	0.14
Good weed suppression	-0.088	0.16	0.002	0.39	-0.105*	0.10	0.049	0.18	0.052*	0.09
Sufficient information	-0.121	0.12	0.006	0.18	0.216***	0.01	0.041	0.17	0.010	0.80
Constant	-3.540***	0.00	-3.470**	0.02	0.690	0.49	-4.200***	0.00	-3.670	0.31
Log pseudolikelihood	-55.83		-11.34		-64.32		-35.21		-38.95	
AIC	1.1974		0.5169		1.3383		0.9009		0.9377	
N	130		129		129		127		130	

***, **, *, represent significance at the 0.01, 0.05 and 0.10 levels, respectively

† Reported in 10,000 MWK

References

Arimond, M., & Ruel, M. T. (2004). Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *Journal of Nutrition, 134*, 2579–2585.

Baum, C. F. (2008). Modeling proportions. *Stata Journal, 8*, 299–303.

Bellprata, O., Lott, F., Guliziac, C., Parkerd, H., Pampuche, L., Pintof, I., Ciavarellab, A., & Stott, P. (2015). Unusual past dry and wet rainy seasons over Southern Africa and South America from a climate perspective. *Weather and Climate Extremes, Volume, 9*(September 2015), 36–46. doi:10.1016/j.wace.2015.07.001.

Berti, B. R., & Jones, A. D. (2013). Biodiversity's contribution to dietary diversity. In J. Fanzo, D. Hunter, T. Borelli, & F. Mattei (Eds.), *Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health*. Abingdon: Routledge.

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.

Combris, P., Lecocq, S., & Visser, M. (2000). Estimation of a hedonic price equation for Burgundy wine. *Applied Economics, 32*(8), 961–967. doi:10.1080/000368400322011.

Court, A. T. (1939). Hedonic price indexes with automotive examples. In *the Dynamics of Automobile Demand*. New York: The General Motors Corporation.

Dalton, T. J. (2003). A hedonic model of rice traits: economic values from farmers in West Africa. In *25th International Conference of Agricultural Economists*.

Elson, D. (1993). Gender-aware analysis and development economics. *Journal of International Development, 5*(2), 237–247. doi:10.1002/jid.3380050214.

Filmer, D., & Pritchett, L. (2001). Estimating wealth effects without expenditure data or tears: An application to educational enrollments in states of India. *Demography, 38*, 115–132.

Freeman, H. A., van der Merwe, P. J. A., Subrahmanyam, P., Chiyembekeza, A. J., & Kaguongo, W. (2002). Assessing adoption potential of new groundnut varieties in Malawi. *Experimental Agriculture, 38*(2), 211–221.

Griliches, Z. (1961). Hedonic price indexes for automobiles: An econometric analysis of quality change. In The Price Statistics of the Federal Goverment (pp. 173–196). NBER.

Heckman, J. (1976). The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement, 5*, 475–492.

Isaacs, K. B., Snapp, S. S., Chung, K., & Waldman, K. B. (2016). Assessing the value of diverse cropping systems under a new agricultural policy environment in Rwanda. *Food Security, 8*(3), 491–506 http://doi.org/10.1007/s12571-016-0582-x.

Lal, R. (1997). Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. II. Soil chemical properties. *Soil and Tillage Research, 42*(3), 161–174. doi:10.1016/S0167-1987(97)00007-X.

Lambert, D. K., & Wilson, W. W. (2003). Valuing Varieties with Imperfect Output Quality Measurement. *American Journal of Agricultural Economics, 85*(1), 95–107 http://doi.org/10.1111/1467-8276.00105.

Lancaster, K. (1966). A new approach to consumer theory. Journal of Political Economy, 74(April), 132–157.

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. doi:10.1016/j.foodpol.2012.05.001.

Malawi ministry of Agriculture (2012). *Malawi Guide to Agriculture 2012 edition*. Lilongwe, Malawi: Malawi ministry of Agriculture.

McKenzie, D. (2005). Measuring inequality with asset indicators. *Journal of Population Economics, 18*, 229–260.

Melton, B. E., Huffman, W. E., Shogren, J. F., & Fox, J. A. (1996). Consumer preferences for fresh food items with multiple quality attributes: Evidence from an experimental auction of pork chops. *American Journal of Agricultural Economics, 78*(4), 916–923. doi:10.2307/1243848.

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

Mhango, W. G. (2011). *Nitrogen budgets in legume based cropping systems in Northern Malawi*. USA: PhD thesis, Michigan State University. Michigan.

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.

Ofori, F., & Stern, W. R. (1987). Cereal-Legume Intercropping Systems. *Advances in Agronomy, Volume, 41*.

Orr, A. (2003). Integrated pest management for resource-poor African farmers: Is the emperor naked? *World Development, 31*(5), 831–845.

Orr, A., & Ritchie, J. M. (2004). Learning from failure: smallholder farming systems and IPM in Malawi. *Agricultural systems, 79*(1), 31–54.

Ortega, D. L., Waldman, K. B., Richardson, R. B., Clay, D. C., & Snapp, S. (2016). Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions. *World Development*. doi:10.1016/j.worlddev.2016.06.007.

Oyejola, B. A., & Mead, R. (1982). Statistical Assessment of Different Ways of Calculating Land Equivalent Ratios (LER). *Experimental Agriculture, 18*(02), 125–138. doi:10.1017/S0014479700013600.

Papke, L. E., & Wooldridge, J. M. (1993). *Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates* (Working Paper No. 147). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/t0147.

Quaye, W., Jongerden, J., Essegbey, G. O., Frempong, G., & Ruivenkamp, G. (2014). The Social Construction of Cowpea Variety Development in Ghana: What is Missing? *OIDA International Journal of Sustainable Development, 7*(1), 77–90.

Rutstein, S. O., & Johnson, K. (2004). *The DHS wealth index*. Calverton, Maryland, USA: ORC Macro Retrieved from http://dhsprogram.com/pubs/pdf/CR6/CR6.pdf.

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

Snapp, S. S., & Fisher, M. (2015). "Filling the maize basket" supports crop diversity and quality of household diet in Malawi. *Food Security, 7*(1), 83–96. doi:10.1007/s12571–014–0410-0.

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

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., Jones, R. B., Minja, E. M., Rusike, J., & Silim, S. N. (2003). Pigeon pea for Africa: a versatile vegetable and more. *Hortscience, 38*, 1073–1078.

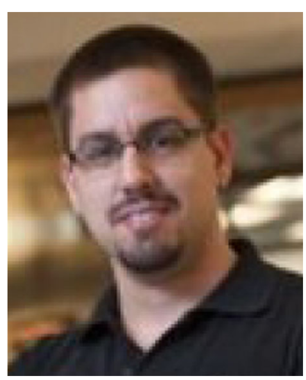
Snapp, S. S., Blackie, M. J., Gilbert, R. A., Bezner-Kerr, R., & Kanyama-Phiri, G. Y. (2010). Biodiversity can support a greener revolution in Africa. *Proceedings of the National Academy of Sciences, 107*(48), 20840–20845.

Tano, K., Kamuanga, M., Faminow, M. D., & Swallow, B. (2003). Using conjoint analysis to estimate farmer's preferences for cattle traits in West Africa. *Ecological Economics, 45*(3), 393–407 http://doi.org/10.1016/S0921-8009(03)00093-4.

Teuber, R., & Herrmann, R. (2012). Towards a differentiated modeling of origin effects in hedonic analysis: An application to auction prices of specialty coffee. *Food Policy, 37*(6), 732–740 http://doi.org/10.1016/j.foodpol.2012.08.001.

Waldman, K. B., & Kerr, J. M. (2015). Is Food and Drug Administration policy governing artisan cheese consistent with consumers' preferences? *Food Policy, 55*, 71–80 http://doi.org/10.1016/j.foodpol.2015.06.004.

Kurt Waldman is a post-doctoral researcher at the Ostrom Workshop in Political Theory and Policy Analysis working on adoption of sustainable agricultural technologies in Africa. He earned a PhD from Michigan State University in Food and Agricultural Policy and an MS in Applied Economics from Cornell University. His research concerns how people evaluate tradeoffs around production and consumption decisions related to food and the environment. The core of his research uses experimental methods such as experimental auctions and choice experiments to elicit preferences and quantify tradeoffs.



David Ortega is Assistant Professor of Agricultural, Food and Resource Economics at Michigan State University. His research interests are international development, agribusiness decision-making, the economics of food safety, and consumer and producer behavior. Dr. Ortega earned a PhD and MS from Purdue University in Agricultural Economics and a BS in Food and Resource Economics from the University of Florida.

Robert Richardson is an ecological economist with interests in the study of environment and development, particularly the contribution of ecosystem services and natural resources to socioeconomic well-being. He holds a PhD in agricultural and resource economics from Colorado State University, and his teaching, research, and outreach program focuses primarily on sustainable development. Dr. Richardson uses a variety of methods from the behavioral and social sciences to study decision-making related to the use of natural resources and the protection of ecosystem services. His research has included assessments of the role of natural resources in poverty alleviation and food security, agricultural-environmental linkages, vulnerability to climate change, and tradeoffs in decision-making about environmental management.

Daniel Clay is Professor and Director, Global Programs in Sustainable Agri-food Systems in the Department of Community Sustainability. He is a contributor to the CSUS International Development thematic area. His work in agricultural and rural development focuses on issues of sustainable food and agricultural value chain development (high value exports), food security, food aid impacts, household livelihood strategies, relief-development linkages, conservation investments, sustainable agricultural intensification, and household survey methodologies. Dan regularly serves as an advisor to the World Bank, World Trade Organization, the European Union and other international organizations and agencies as an expert in food security, export market development, data systems, and agricultural policy.

Sieg Snapp is a soils and cropping systems ecologist at Michigan State University and Associate Director of the Center for Global Change and Earth Observations. She has edited two books and published more than a 100 journal articles and extension bulletins on sustainable intensification, agricultural systems, and participatory action research. Her research interests include international agricultural system design for a changing climate and understanding factors driving land management in tropical Africa and processes that can be harnessed for sustainable production. She has pioneered the development of multipurpose crops for food and environmental security, including the first agronomic reports on perennial wheat and perennial pigeonpea.