  

ADOPTION AND IMPACT OF IMPROVED BEAN VARIETIES ON FOOD SECURITY IN MALAWI

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ADOPTION AND IMPACT OF IMPROVED BEAN VARIETIES ON FOOD SECURITY IN MALAWI[1]

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Executive summary

Common bean is one of the important food security crops in Malawi and increasingly grown for income. The crop, however faces several production constraints that keep its productivity low. For over three decades, the department of Agricultural Research services of Malawi and its collaborators especially CIAT have been conducting bean improvement research to address production constraints with the aim of contributing to the national objective of improving the quality of the population. This long commitment resulted in over 30 varieties which were released for the farming community to increase farm level bean productivity.

This report documents findings of a study that was conducted to a) understand farmers' access to improved bean varieties, their adoption and dis-adoption); (b) identify factors that influence the adoption of improved bean varieties including the supply factors, and; (c) assess food security impacts resulting from improved bean technology adoption (or lack thereof). The analysis used primary data collected through a survey of 611 bean growing households in 48 villages which were systematically selected from 12 bean producing districts across the three regions (northern, central and southern) of Malawi. Descriptive statistics were used to show proportions and magnitudes of socioeconomic variables, while a Probit model was run to estimate the probability of adopting the improved varieties and provide insights into factors that influence adoption decisions. The impact of improved bean varieties, was analysed using a propensity score with stratification method.

Results show a remarkable achievement in terms of varietal output, proportion of households using the improved bean and the number of improved bean varieties being used by farmers. Approximately 69% of the surveyed households cultivated improved varieties in 2013 while 15 out of thirty varieties released since 1980 were used. Overall, improved varieties occupy 46% of the bean area, which is equivalent to 1.4% annual growth in area planted with improved varieties. However, a bigger proportion of this area is under old varieties, i.e. those developed and released in 1990s as varieties released after 2000 occupy only 9% mainly because of limited access to seed. There are new varieties such as Kholophethe that have achieved relatively high level of diffusion and are widely known by farmers including those farmers that are not using it. Lack of seed was the most common reason given for not growing a variety for those who know but not adopted as well as for dis-adoption of an improved variety. The study findings provide

important lessons for seed systems on varieties that are desired by farmers and barriers that hinder adoption. For example, it was found that diffusion starts with well-to do farmers before diffusing to poorer farmers, who need these varieties most to overcome food insecurity. This is perhaps because the well –off farmers are able to overcome high transaction costs of obtaining seed for improved varieties. While grain market might be the main external source of seed for new varieties, the study found that very few villages have grain markets where farmers can buy seed. Moreover, farmers in villages without a grain market or seed distribution centres must travel long distances; thus face high transaction costs.

On average, growing improved varieties was found to be associated with positive impacts. Adopters reported having obtained higher yields from each kg of bean planted in 2013. For each kg bean planted, adopters also experienced less yield loss compared with non-adopters, thus providing evidence that new varieties released after 2000 are indeed better adapted to the environmental stresses. The results also reveal that growing improved varieties, especially those released recently and hence have not yet lost efficacy, increase the household dietary diversity score by 14.7%. This is evidence that investment in bean improvement contributes significantly to improving wellbeing of the smallholders in Malawi. Therefore, policies aimed at enhancing bean productivity and promoting adoption of new improved bean varieties by providing information, strengthening seed systems and seed marketing should be central to the food security strategies in the country.

1.0. INTRODUCTION

1.1 Background

Malawi is one of the least developed countries in the world, in which 2.83 million people face acute food insecurity (WFP, 2016). Agriculture is the main source of livelihoods for the people and the engine of economic growth toward supporting food security in the country (Anríquez and Stamoulis, 2007; Fan and Chan-Kang, 2005). Although currently not one of the priority crops, common bean (*Phaseolus vulgaris*) is one of the important food crops grown in Malawi. It is consumed by all the Malawian people, but is highly valuable to the poor households who have limited consumption of the more costly animal protein where, on average, only 5g per capita per day is consumed compared with 78g per capita per day consumed globally (UNDP, 2013)). Beyond its nutritional importance, common bean is relied upon by smallholders as a bridging source of income before the main crops. The bean crop is sold in various forms including green and dry leaves, fresh pods, and both fresh and dry grain. Bean is thought to have been brought into Malawi from the eastern coast of Africa over 300 years ago by traders and merchants (Mughogho et al., 1979). The crop spread rapidly among the small-holder farmers replacing groundnuts in 1990s as the single most widely grown legume in the country.

Due to over reliance on rainfall, high population pressure and low input systems, bean producers face a wide range of biotic and abiotic constraints that lead to low bean productivity levels (Wortmann and Allen, 1994). The national average bean yield in Malawi is extremely low, estimated at about 500kgha^{-1}, which is far below the yield potential of 5,000kgha^{-1} under optimal water and nutrient supply regime (Verdoodt et al, 2004). Major constraints limiting bean productivity include: drought, pests and diseases (e.g. bean stem maggot & bruchids), poor soil fertility and quality seed. Addressing the various constraints that affect the bean productivity, largely lies on use of cost-effective technologies such as low-input resistant varieties and good agronomic practices. To meet the challenges, the government of Malawi through its institutions i.e. Lilongwe University of Agriculture and Natural Resources (LUANAR), and the Department of Agricultural Research (DARS) in collaboration with the International Centre for Tropical Agriculture (CIAT)) has been conducting research on bean improvement since 1980. The goal is to increase the yields of common bean and contribute to the national objective of reducing malnutrition, food insecurity and poverty.

1.2 Brief historical perspective of bean improvement in Malawi

Research on bean improvement in Malawi started in earnest in 1969 when formal bean research programme was initiated at the Lilongwe University of Agriculture. National Agricultural Research Systems' (NARS) scientists preoccupied themselves with screening of local varieties to identify superior high yielding ones under good agronomic practices. Six varieties were selected from the land races and released in 1981. Around the same time, CIAT in collaboration with the national bean research programme of Malawi joined other internationally sponsored initiatives, notably, the US funded bean / cowpea project to improve bean productivity on small-holder farms through developing high yielding bean varieties and building capacity of the national scientists. The first CIAT bean scientist was posted to Malawi in 1980 (Johnstone et al., 2003) and two years later, the USAID funded bean / cowpea improvement project was initiated (Kambewa, 1997). The coming in of the international scientists with more expertise and funding enhanced the efforts as well as the rigour of the breeding programme. In 1993, three varieties; one based on CIAT lines were released (Chirwa and Rubyogo, 2014; Kambewa, 1997).

The bean research in Malawi was consolidated in 1994, when the Department of Agricultural Research (DARS) included bean on their commodities for research. This corresponds with the government's effort to diversify export crops in response to anti-tobacco campaigns in mid 1990s (Chirwa and Rubyogo, 2014). The bean breeding approach under the DARS–CIAT collaboration was adjusted and embraced as a strategy of addressing major biotic and abiotic production constraints, while integrating breeders' and farmers' variety selection criteria. Six more CIAT variety lines were evaluated and released in 1996, increasing the total number of improved bean varieties released since 1980 to 15 (Kambewa, 1997). It is important to note that by this time, although farmers' preferences were taken into account, the process of selecting varieties was not yet participatory in nature and interventions in the informal bean seed system were almost non-existent.

In the year 2000, further adjustments in the breeding strategy were adopted that integrated methods of participatory variety selection (PVS) to allow farmers influence variety selection processes (Chirwa and Rubyogo, 2014). Participatory variety selections have since become the main entry points for integrating and analysing differences between men and women preferences for bean traits. Men and women are invited and actively involved in selecting varieties based on their own preferences. Sex disaggregated data are collected and analysed to enable identification of important traits favourable to each sex group, which enable researchers to constantly update their priority setting at early stages of the breeding process. Since 2000, scientists have been equipped with modern innovations in breeding and are able to develop varieties that are resistant to multiple stresses (such as drought, low soil fertility and diseases). Hence, varieties released during 2002-2013 are better adapted to the physical production environment (PABRA, 2015). In 2005, the Alliance for a Green Revolution in Africa (AGRA) supported yet another breeding initiative under a PhD study programme whose major thrust was focused on resistance to bruchids. The initiative resulted in seven bred lines that were released in 2011 (Chirwa and Rubyogo, 2014). Overall, a total of 30 varieties of improved common bean were released between 1980 & 2012 (Table 1).

Table 1: List of Improved Varieties released in Malawi since 1980

Variety	Plant type	Year released	Institution	Yield potential (kg/ha)	Altitude (masl)	Maturity period (days)
Namajengo	Climber	1980	LUANAR	2500	1000-1200	90
Saperekedwa	Bush	1980	LUANAR	2000	1000-1200	90
Kanzama	Climber	1980	LUANAR	2500	1000-1650	95
Kalimtsiro	Climber	1980	LUANAR	2500	1000-1200	90
Nasaka	Bush	1980	LUANAR	1500	1000-1200	80
Bwenzilana	Bush	1980	LUANAR	1500	1000-1200	85
Kalima	Bush	1993	LUANAR	2000	1000-1400	90
Bunda 93	Climber	1993	LUANAR	2000	1000-1400	90
Chimbamba	Climber	1993	LUANAR	2500	1000-1650	90
Kambidzi	Bush	1996	DARS/BIP	3000	1400-1650	85
Mkhalira	Bush	1996	DARS/BIP	2500	1400-1650	85
Maluwa	Bush	1996	DARS/BIP	2000	1000-1300	90
Napilira	Bush	1996	DARS/BIP	2000	1400-1650	90
Sapatsika	Bush	1996	DARS/BIP	2000	1000-1300	90
Nagaga	Bush	1996	DARS/BIP	2000	1000-1300	90
Kholophethe	Bush	2002	DARS/BIP	2500	1000-1650	90
Kabalabala	Intermediate	2002	DARS/BIP	3000	1000-1650	90
NUA 45	Bush	2009	DARS/BIP	1500	1000-1200	65
Bunda 2	Climber	2005	LUANAR	2000	1000-1200	85
Bunda 1	Bush	2005	LUANAR	2000	1000-1200	80
Bunda 3	Climber	2005	LUANAR	2000	1000-1650	85
NUA 59	Bush	2009	DARS/BIP	1700	1000-1200	65
VTTT924/4-4	Bush	2009	DARS/BIP	2500	1000-1650	80
Mnyambitira	Bush	2011	DARS	2500	1000-1650	80-90
Chitedze BN3	Bush	2011	DARS	2500	1000-1650	70-80
Chitedze BN5	Intermediate	2011	DARS	2500	1000-1650	80-90
Chitedze BN1	Bush	2011	DARS	2500	1000-1650	70-80
Namtupa	Bush	2011	DARS	3000	1000-1650	70-80
Chitedze BN2	Bush	2011	DARS	2500	1000-1650	70-80
Chitedze BN4	Bush	2011	DARS	2500	1000-1650	70-80

Source: Monyo and Laxmipathi (2014)

Approximately 15 of the varieties were released between 2001 and 2012, thus selected with the active participation of farmers as well as containing resistance to several constraints. Table 1 shows that the released varieties have a yield potential of 1.5-3 tons/ha under optimal agronomic conditions. Most of the bush varieties take 70-80 days to mature, which enables farmers to grow at least two crops in the unimodal rainfall regime. However, nearly all varieties are adapted to the medium altitude agro-ecological zones, which account for about 43% of the national bean area. More breeding research is still needed to develop varieties that are tailored to the conditions of low-altitude where production takes place under residual moisture and high-altitude conditions, where soils are considered to be acidic (Chirwa and Rubyogo, 2014).

Besides developing varieties, seed systems development to support quick diffusion of improved varieties is another major thrust of bean improvement within PABRA. Seed systems specialists in PABRA, adopted decentralized seed systems approach, which fosters strategic partnerships with key actors to develop more integrated seed supply systems and reach millions of farmers. Over the past two decades, several interventions on dissemination of improved bean varieties have been designed and implemented with various NGOs in their impact zones and beyond. Notably, Action Aid, Plan International, World Vision International, CARE, and Concern Universal have contributed to the dissemination of improved bean varieties[2]. Between 1995 and 1999, Action Aid with the financial support of the UK Department for International Development (DFID) implemented a small-holder seed multiplication project. Under this project, small groups of farmers were trained to produce good quality seed and sell to fellow farmers (Ng'ambi and Maliro, 2004). In 2000, the Ministry of ministry of Agriculture, Irrigation and Water development (MAIWD); formerly the ministry of Agriculture and Food Security (MoAFS)), alongside the NGOs[3], introduced some mechanisms of supplying seed to various beneficiaries through a Targeted Farm Inputs Programme (TFIP). Through this program, information about improved varieties was disseminated through various channels namely: farm radio programs, on-farm demonstrations, and field days (Phiri et al., 2012)[4].

[2] This NGO widely disseminated two bean varieties called Napilira (CAL 143) and Maluwa (CAL113) in Dedza District (the NGO impact area) and everywhere in the district the variety is known as "Concern''.

[3] NGOs, like Plan International, World Vision International, CARE, and Concern Universal had also been engaged in varied seed production programmes for smallholders, helping to disseminate improved bean varieties mainly in their impact zones and beyond. As one example, Concern Universal widely disseminated two bean varieties called Napilira (CAL 143) and Maluwa (CAL113) in Dedza District (the NGO impact area) and as a result everywhere in the district the variety is known as "Concern''.

[4] Under the subsidy program, farmers are given vouchers to buy seed at reduced cost from agro-dealers.

Between 2007 and 2014, AGRA attempted to catalyse the private sector investment into the seed production and supply systems, using direct incentives. More than six emerging seed companies benefited from the Malawi small grants (AGRA, 2015). However, this did not significantly benefit legumes as the seed companies maintained their emphasis on the lucrative maize hybrid seed business (Mabaya et al, 2013). In 2008, CIAT and NARS in Malawi, Mozambique and Tanzania directed a project supported by the McKnight Foundation aimed at strengthening linkages between the informal seed acquisition systems routinely used by farmers and seed delivery channels designed for improved germplasm innovations. Through PVS processes, farmer-preferred varieties were popularized among farmer groups, private grain traders and seed producers in addition to training them in seed quality (Chirwa et al., 2008).

1.3 Objectives of the study

In light of the considerable efforts and achievements in bean variety development and several interventions to disseminate improved bean varieties in the country, this study was designed and conducted as part of the overall effort towards measuring the achievements of PABRA interventions in selected countries. Although an adoption study was carried out by the DARS and CIAT in 2004 in selected districts of Dedze, Dowa and Rumphi (Mwenda and Chirwa, 2007), this is the first study to formally assess adoption and the impact of varieties with multiple resistance in Malawi. The study provides an up-to-date information on dissemination, adoption of improved bean varieties and their associated benefits. The study uses data gathered through a survey that was undertaken in 2013/2014 in the major bean producing districts of Malawi. Unlike the study by Mwenda and Chirwa (2007) that was confined in project sites, this study uses data collected from a sample of households that was systematically designed to enable identification of adopters and non-adopters and draw inferences based on comparisons of the two groups while controlling for confounding factors. Thus, the current study also examines the effects of adoption of the bean technologies on food security status of the adopters based on treatment effects framework.

Specific objectives of the survey were formulated to: (a) understand farmers' access to improved bean varieties as well as the various components of adoption, (i.e. the proportion of farmers currently planting improved varieties, the proportion of bean area currently under improved varieties, spatial diffusion patterns and dis-adoption); (b) identify factors influencing adoption of improved bean varieties including the supply factors, and; (c) assess food security impacts resulting from adoption of improved bean varieties or lack thereof.

1.4 Organization of the report

This report is organized into seven sections. After the introduction, section two provides an overview of the materials and methods used in the study. This includes the empirical context of the study area, methods used in sampling and implementation of the survey. In section three, the characteristics of the sampled households, their access and utilization of bean technologies based on bivariate analysis are presented. The econometric analysis of farmers' behaviour towards new bean technologies and the benefits associated with adoption are presented in sections three and four respectively. Results and discussions of the impact analysis are presented in section five, while the report is concluded with an extended summary of the results and implications for future interventions.

2.0 MATERIALS AND METHODS

2.1 Study area

Malawi is divided into three regions (northern, central and southern) and four agro-ecological zones. Based on altitude levels, these zones are: (a) Lower Shire Valley (<200 m), (b) Low Altitude (200-760 m), (c) Mid-altitude (761-1300 m), and (d) High-altitude (>1300 m). Beans are grown in all the three regions and in mainly two agro-ecological zones: the Mid-altitude (761-1300 m) and High altitude (>1300masl). The mid altitude zone, which covers 75% of the country geographical area accounts for 43% of the bean area concentrated in environments at altitude above 1000 masl and soil pH also above 5.5 (Katungi et al., forthcoming). High-altitude zone contribute about 47% of the national bean area (Wortman et al. (1998) concentrated at altitude above 1500masl characterised by mild to cooler temperatures with unimodal type of rainfall. Approximately 10% of the national bean area is in the lower altitude zone, below 1000 masl and is normally cultivated during dry season, also referred to as *dimbas*[5].

The three regions are further divided into 28 districts: 6 districts in the northern, 9 in central and 13 in the southern region. The southern region is the most densely populated in the country, accounting for about 50% of the population, followed by the central region with 39%. Thus, landholding is very small in the southern region and common bean is grown under intensive mixed cropping systems[6] primarily for home consumption. The region is ranked the least bean producing among the three. The central and northern regions have good climate, good rainfall patterns and good soils that are favourable for bean production. Central region also has relatively bigger landholding per household, with better access to key bean markets. These regions are relatively more exposed to

[5] The other two agro-ecological zones less important for bean production are: the shire valley hot and semi-arid lies and 30-40 meters above sea level with mean annual rainfall of 500-700mm and 2) Lake shores at 450-600masl with annual mean rainfall of 750-1000mm.

[6] competition among crops on small plots of land

bean promotional interventions from researchers and other organizations. In contrast, the northern region comprises of even larger landholdings with high potential for rain-fed as well as irrigated bean production. However, the northern region is also characterised by poor road infrastructures that hinder implementation of agricultural promotional activities and challenge transportation of farm produce. Markets are poorly functioning as a result of long distances from major bean producing areas to consumption hubs, and farmers suffer from information asymmetries among other constraints.

In the dry lands, bean is grown under rain-fed conditions whilst in most wetlands it is grown under residual moisture after the rainy season, in the cool months of the year. Accordingly, farmers operating in dry lands are advised to plant bean immediately at the onset of the rains when the crop is inter-planted with maize. However, larger plots of a pure stand of bean is planted later, usually early December in the southern region, early to mid-January in central region and late January to early February in northern region. This is to make sure that the crop matures towards the tail end of the rainy season, for ease of harvesting. Otherwise if the pure crop is planted early, it will most likely mature in the middle of the rainy season, and much of the crop will be wasted in the field, as grains will either rot or germinate in the field.

As a short season crop, taking approximately 3 months to maturity, bean can be grown more than once in areas with either extended rainfall season or wetlands or irrigation. Under extended rainfall season, the first system usually is an intercrop of bean with maize (planted at the onset of the rains and harvested in the middle of the rainy season), where the bean plant population density is usually low, which makes it possible to harvest in the middle of the rainy season. The second system, is when bean is planted as relay crop, by stripping the lower leaves on maize plants and sowing the bean under the maize. When the maize matures, it is harvested, leaving the bean crop in the field, to be harvested after the rainfall season. This is the most important system for bean in areas with extended rainy season. The third system occurs off the rainy season, in low lying areas with excessive moisture during the rainy season - wetlands (*dimbas*) where bean is planted after the rainy season, when water levels recede, and the crop survives on residual moisture or in areas where there is irrigation.

2.2 Sampling

The study was conducted in twelve districts that were purposively selected from all the three regions by the research team in DARS and CIAT office in Malawi. The districts listed in Table 2 were selected based on their importance for bean production, ranked based on expert opinion.

Table 2. Selected districts and their respective agro-ecological zones

Regions	District	Agro-ecological zone
South	Thyolo Chiradzulo	medium altitude: *Subhumid 1000-1500masl*
	Mangochi	partly in medium and low altitudes
Central	Dedza	Hig altitude: *Subhumid, > 1500masl,*
	Lilongwe	medium altitude: *Subhumid 1000-1500masl*
	Mchinji	medium altitude: *Subhumid 1000-1500masl*
	Dowa	medium altitude: *Subhumid 1000-1500masl*
	Ntchisi	Hig altitude: *Subhumid, > 1500masl,*
	Kasungu	medium altitude: *Subhumid 1000-1500masl*
North	Chitipa Ntcheu	High altitude: *Subhumid, > 1500masl,* partly in medium and high altitudes
	Mzimba	partly in medium and high altitudes

Source: Adapted from Chinsinga, 2009.

The second stage of the sampling process dealt with the selection of the extension planning areas (EPAs). Researchers from CIAT and DARS at Chitedze Research Station worked with the Department of Agricultural Extension Services (DAES) under the ministry of Agriculture, Irrigation and Water development (MAIWD) in each of the selected districts to compile the lists of EPAS. A total of 111 EPAS were compiled from 13 districts and after eliminating those that did not grow bean, four EPAs were randomly selected per district. Thirdly, two villages were randomly selected from each selected EPA making a total of 96 villages that were surveyed. Finally, from each village at six households were randomly selected. A total of 624 households were selected for the survey across the three regions. Figure 1 shows the distribution of the households that were selected for the survey.

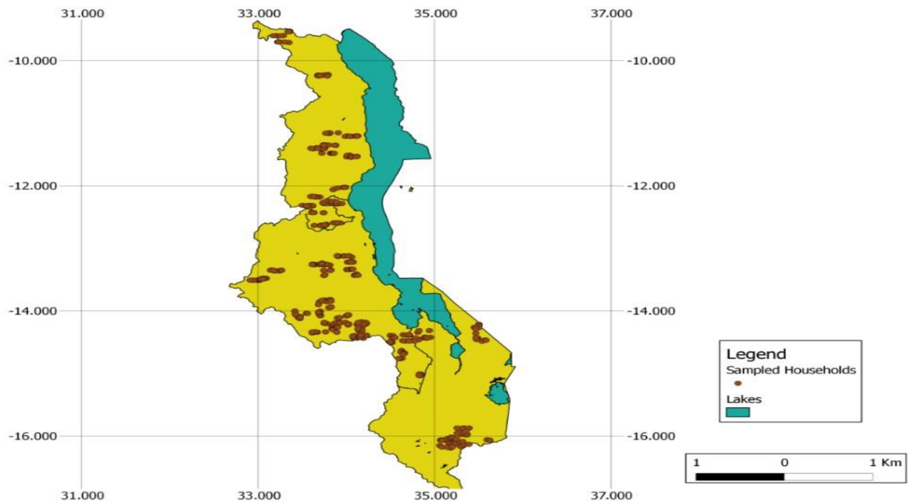

Figure 1: Map showing locations of sampled households in Malawi

2.3 Survey materials and data collection

The data were elicited through direct interviews using semi-structured household and community level questionnaires. The household level questionnaire was designed to elicit data on household characteristics, bean production levels, constraints faced in bean production, social capital and networking, input usage, decision making on common bean as well as marketing and use of revenue from bean sales. Additional information was collected on access to institutional services, credit and agricultural inputs; food security and other important crops cultivated in the household farms. Field plots were defined by the major crops grown by farmers and the physical measurement of the plot size was done with the help of GPS gadgets.

The survey also included a community questionnaire, which was administered to key informants (KIs) that included relevant lead farmers, chiefs and extension workers, among others. The community questionnaire gathered data on community level variables such as general village information, market access, service access, production shocks affecting the villages five years prior to the survey and information about cultivar changes over time.

Six enumerators and two GPS experts fluent in English and at least one local language were recruited and conducted the interviews. The interviewing processes were supervised by two researchers, one each from CIAT and DARS. The enumerators and GPS experts were trained for a week in order to internalize and master the study objectives & questions, interview ethics and data quality management while in the field. The enumerators were also trained on how to develop a rapport with respondents. Questionnaires were pretested for one day to ensure that wording and coding matched field situation, and also to test how long questionnaires take to complete with respondents. All mismatches were adjusted appropriately before the actual questionnaire administration. Before administering the household questionnaires, verbal consents were obtained from the household heads or representatives to ensure that the respondents were willing to share their experiences without fear or force. The data collection took a period of five weeks from 15th October 2013 to 14th November 2013.

2.4 Variety identification and definition

Proper identification of bean varieties grown by farmers is a major concern in any adoption study and requires robust methods like DNA finger printing to distinguish landraces from improved varieties, if they look alike. For lack of sufficient resources, DNA supported variety identification was not possible. Even without DNA based methods, a systematic process was followed to ensure reliable identification of the varieties. Information on improved bean varieties was obtained from researchers at CIAT Malawi and DARS and this was used to design a variety list that was included as an annex to the questionnaire for the enumerators' reference. The annex indicated the name of the variety as labelled by researchers and the name(s) given by farmers as the variety diffuses. Then, samples of the improved varieties were provided to enumerators for use during variety identification with farmers.

During interviews, each enumerator was asked to present samples to the respondent and ask him /her to select those that resemble the ones mentioned. Then, follow up questions on the variety history – introduction, period it has been in the community and a few phenotypical and agronomic properties such as colour, and duration to maturity were added to guide on classification of the variety. For instance, if a respondent indicated that a variety had been grown by grandfathers and been passed on from generation to generation that variety was take as local[7].

A variety was categorized as improved if derived from research and underwent through a formal release process. The improved varieties were further subdivided into two categories based on the period when it was released. The first category consisted of varieties that were derived from research and released in the year 2001 and afterwards (Table 1). Included in the second category were varieties also derived from research and released earlier than 2001 (Table 1). The uptake of the varieties released earlier before 2001 was previously assessed by Mwenda and Chirwa (2007) in three bean growing districts of Dezda, Dowa and Rumphi. From the study, it was noted that modest uptake of the improved varieties (23%) within the targeted farming communities in the three districts was achieved.

[7] However, it is possible that an improved variety could be phenotypically similar to a local variety that the grand father used to grow, and farmers would not be able to distinguish the two if they buy improved seed from local markets because the variety looks much like their parents used to grow.

2.5 Measuring food security

Food security is a broad concept involving three domains – availability, utilization and access to quality food. The multi-factorial nature of food security makes it a complex and difficult phenomenon to measure, hence no “gold standards” exist to measure it. Nevertheless, a number of approaches have been suggested with the most common measures revolving around consumption, poverty and anthropometric indicators (Kabunga et al., 2014, Shiferaw et al., 2014; Goshu et al., 2013; and Cogil, 2003). A household dietary diversity score (HDDS) was used as a measure of household food security status. The HDDS is based on a number of food groups consumed over a specified period of time (Haddinot, 1999). This measure stems from the observation that as households become well-off, they tend to consume a wide range of foods. Therefore, a higher dietary diversity index reflects higher food security of the household. To obtain this score, the respondent in each household was asked about different food items that the individuals living in the household had consumed over a seven-day period prior to the interviews. Then, the HDDS was computed based on the total count of different food groups that persons in the household consumed over the seven-day recall period.

2.6 Estimating the effect of improved bean technologies on HDDS

Estimating the impact of improved bean varieties on the household food security with causal interpretation from observational data is complicated because adoption decisions may be confounded with household characteristics. Propensity score analysis (PSA) can be used to mimic randomized studies and remove the effect of cofounding factors when estimating the effect of treatments (i.e. adoption in our case) on outcome. Compared with parametric techniques, PSA poses neither an exclusion restriction nor requires specification of particular selection equation to construct the counterfactual or reduce selection problems (Kessie et al., 2010).

A PSA method was used in estimating the impact of improved bean variety adoption on food security represented by HDDS. The method uses the propensity score matching framework to identify a control group that is similar to the treatment group in terms of observable characteristics, and use it to infer what would have happened to the treated group without the treatment. The validity of the PSA is based on two assumptions of weakly unconfoundedness and balancing property being fulfilled. The conditional independence assumption (CIA) implies that after controlling for some set of covariates in vector X, the potential outcomes for treated and untreated (control) groups are independent of treatment status (Wooldridge 2002). The balancing property basically says that the control group should have some overlap with the treated group in terms of unit characteristics. If otherwise, for example after matching, it means that the treatment is not random. Once these two conditions are met, then the PSA produces unbiased estimates.

The PSA methodology, conceptualised in the context of potential outcomes, is widely applied in the literature and we shall present a brief summary of the method here. Denote Z, the observed indicator of improved bean variety adoption (Z=1 if the household adopts and Z=0 if not) and X a vector of covariates that are not affected by the adoption decisions (our treatment). Each household is assumed to have an associated random vector (*Y*0*; Y*1) where Y_0 *and* Y_1 are potential outcomes under control or treatment state but never observed simultaneously because the individual can only be in one state. The observed outcome Y is formalized as:

$$Y = ZY_1 + (1-Z)Y_0 \qquad 1$$

The impact attributable to the treatment that we seek to estimate is the difference between the two potential outcomes if an individual was to be observed in the two states: adoption (treatment) and non-adoption (control).

$$\Delta = E(Y_1) - E(Y_0) \qquad 2$$

In reality, the individual's both counterfactual outcomes are never observed and the estimation of Δ requires identification of $E(Y_0)$*and* $E(Y_1)$ from the data. This is on assumption that if the vector ***X*** contains all confounding factors, then, for individuals sharing a particular value of ***X***, there would be no association between the adoption (treatment exposure) and the values of potential responses; i.e. treatment among individuals with a particular ***X*** is essentially at random. Thus, Y_0 *and* Y_1 are independent of the treatment Z conditional on X, the assumption of strongly ignorable treatment assignment (Rosenbaum and Rubin, 1983) formally stated as:

$$(Y_0, Y_1) \coprod Z \mid X \qquad (3$$

To identify similar controls, PSA approach uses the propensity score, (p (Z)), of adopting improved bean varieties estimated from observed indicator characteristics and other factors (Khandker at al., 2010). The propensity score is defined to be the probability of treatment assignment (e_i=Pr (Zi)=1|Xi), estimated using probit or logit model. Rosenbaum and Rubin (1983) showed that when the treatment is binary, the choice between probit and logit is less debatable (Caliendo and Kopeining, 2008). This study therefore uses probit model to estimate propensity scores.

Based on propensity score, the sample was stratified into five equal size quintiles following a procedure described in Austin (2011). Households were first ranked according to their estimated propensity score before stratified into five quintiles. According to Rosenbaum and Rubin (1984), stratification based on propensity score can reduce up to 90% of the biases and hence a robust method when estimating the treatment effect. In each stratum, the treated and untreated subjects are expected to have a similar distribution of observed baseline covariates (i.e. covariates that are not influenced by the treatment). To estimate the pooled average treatment effects on the treated (ATT), we use the stratum-specific weights which are computed as the proportion of treated subjects that lie within each stratum (Imbens, 2004). In our case, this is the proportion of observations in the stratum that are clarified as adopters.

3.0 RESULTS AND DISCUSSIONS

3.1 Sample Characteristics

3.1.1 Characteristics of bean-growing households

Household demographic characteristics are shown in Table 3. It was observed that household heads were predominantly men (84%) with an average age of 45 years old and about 6 years of formal education. Although the education levels of household heads in southern region (8 years of school) was relatively higher than those of their counterparts in the northern and Central regions, the differences were not that meaningful. However, in the literature, education attainment (Schults, 1975) is considered to affect adoption of new agricultural technologies, which could be a barrier to fast adoption of bean technologies in Malawi.

The majority of the households do farming as their primary occupation and, on average, respondents indicated that their households had about 5.34 persons with dependents (children < 15 years of age and adults > 64 years of age) constituting about 54% of the household size. For every one economically able person, there was 1.37 economically inactive persons to be supported. In the Central and northern regions, where bean production was more favourable, they had more dependents per given economically active person than in the southern region. This implies that households in the study areas faced high risks of starvation and hence the importance of improving productivity of food security crops like bean and maize.

Important assets of the bean growing households included: (a) farm land, (b) livestock, (c) household durable consumer goods (radios, bicycles, and motorcycles), (d) agricultural equipment, (e) financial assets or credit, and (f) social capital. Land was regarded as the most important asset owned by farming households in Malawi. Land is managed under customary land system, where first user rights are assigned to households by the village heads. Over the decades, these user rights have been inherited through generations, in which it is reflected that majority of the households (91.25%) cultivate bean on their own land. In spite of this, land renting appears to be important in some places, especially in the southern and Central regions (Table 3). Households in southern region owned relatively smaller farm sizes (2 ha), which were relatively large in the northern region (2.74ha).

Livestock that includes cattle, chicken, goats, sheep and pigs, is another commonly owned assets by households as a store of wealth. It is shown in Table 3 that livestock contributed the highest overall value (MK163922.2) of the three categories of household assets (i.e. agriculture equipment and durable consumer goods). Households in the northern and central regions had a higher value of livestock compared with those in the southern region.

Table 3: Demographic and socio-economic characteristics of bean farmers by region

Variables	Regions			
	All	Southern	Central	Northern
Sample size (No. of HHs)	(N=610)	(n=84)	(n=364)	(n=162)
Household size (No.)	5.34 (2.02)	5.20 (2.29)	5.35 (1.96)	5.41 (2.04)
Household head age (years)	45.21 13.07)	46.48 (14.09)	43.93 (12.49)	47.38 (13.52)
Education in years[23]	6.71 (3.82)	6.26 (3.64)	6.15 (3.89)	8.22 (3.32)**
Gender of HH head (1= male)[13, 23]	0.84 (0.37)	0.79 (0.41)	0.84 (0.37)	0.85 (0.36)***
Dependency ratio [12, 13]	1.37 (1.05)	1.07 (0.82)	1.36 (1.01)*	1.55 (1.20)***
Member in organisations (1 = Yes)[23]	0.48 (0.50)	0.50 (0.50)	0.44 (0.50)	0.54 (0.50)*
Value of agricultural equipment owned (MK)[13, 23]	18540.35 (47938.1)	7868.16 (18416.68)	16069.59 (45158.92)	29625.67 (61016.01)***
Value of livestock owned (MK)[13, 23]	163922.2 (467841.5)	85477.38 (188970.4)	120534.1 (295667.3)	302086.7 (765334.1)***
Value of durable goods owned (MK)	59921.14 (283550.5)	33654.76 (69367.16)	63721.01 (357011)	65002.78 (117703.8)
Landholding	2.035 (2.900	1.134 (0.958	1.923 (3.093	2.740 (2.932)
Owned farmland size (acres)[12,13, 23]	5.02 (7.14)	2.83 (2.33)	4.74 (7.64)*	6.77 (7.25)***
Percentage of land owned	91.25	84.11	90.13	96.64

Notes: Figures in brackets are standard deviations; ***, **, and * imply significance at 1, 5 and 10% levels respectively; MK=Malawian Kwacha

Chicken were the most popular livestock category, kept by the majority of the households in the three regions. On average, households in northern, central and southern region owned 11.7, 6 and 5.6 chickens per household respectively. Cattle ownership was limited with only the northern region having an average of about two heads of cattle per household (Figure 2). Donkeys were also rare across the regions.

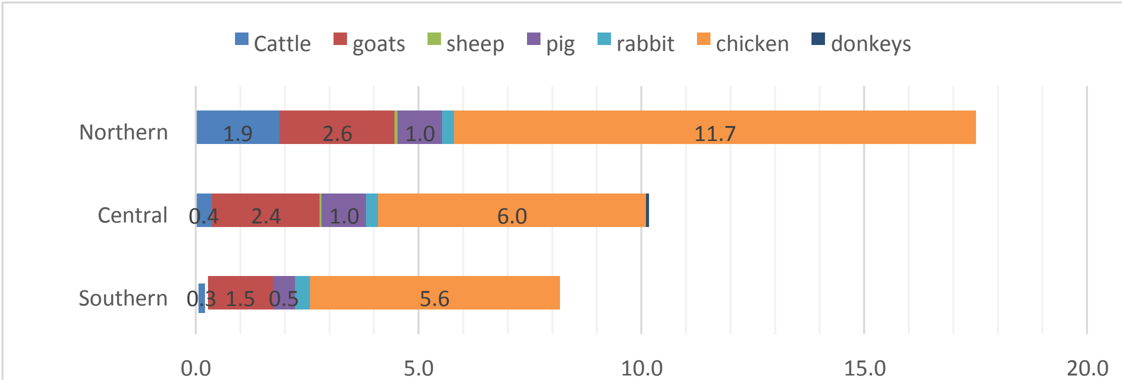

Figure 2: Average number of livestock heads owned household by type and region

The most common farm equipment owned by households was the grain bag (Fig 3) because of their critical importance for maize storage and transportation in the farming system. Grain bags were, however, most common in the central and northern regions where the average number owned per household was about 20 and 21, respectively. Grain bags are used for storage and transportation of crop produce during harvesting and marketing operations. It is also important to note that almost every household owned about four hoes for performing various farm operations. The average number of hand hoes owned per household in the southern region was 4, while in the central and northern regions, the households owned about 3.8 and 4.2 hoes respectively. Other farm equipment owned by the households, although to a less extent, included ox-drawn ploughs, oxcarts, sprayers, motorized water pumps and treadle pumps (some of them not shown in Figure 3).

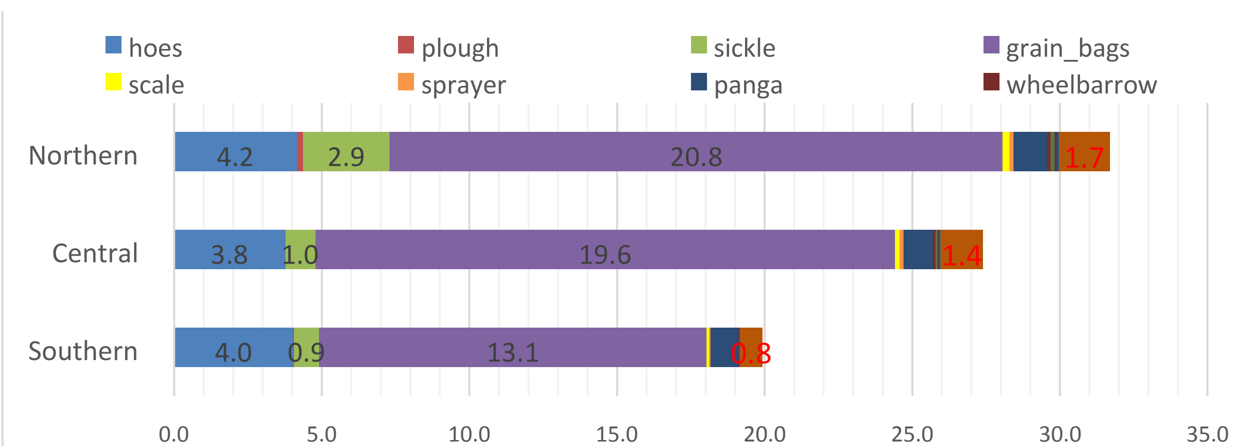

Figure 3: Average number of agricultural equipment owned by households by type and region

Social capital in form of membership to a formal or informal organization is another form of asset for households. Nearly half of the households **(**48%**)** held membership to a formal or informal group**.** The number of households holding membership to such organisations was more in the northern region (54%) than in the central region (44%). Popular organizations where the households held membership in the study area included: (a) crop / seed producer and marketing group cooperatives (with 26.61% membership), (b) farmers' associations (20.73%), and (c) Input supply / farmer cooperative / union (17.93%).

3.1.2 Access to and use of credit

Use of credit among bean growers was low with only about 7.7% of the interviewed households reporting to have used credit facilities for agricultural production during the study season (Table 4). Of these households, only 36.17% used the credit either fully or partly for bean, implying that the majority of the households did not use the credit for common bean production or marketing. The agricultural credit was used mostly to purchase seed and fertilizer. Other uses of credit on bean included paying for labour costs and investing in common bean trade (business).

Table 4: Access to and use of agricultural credit

Variables	Responses	Regions			
		All	Southern	Central	Northern
Obtained agricultural credit (%)	Yes	7.7	7.14	7.69	8.02
	No	92.3	92.86	92.31	91.98
Use of credit on bean (%)	Yes, all	14.89	0.00	17.86	15.38
	Yes, partly	21.28	16.67	28.57	7.69
	No	63.83	83.33	53.57	76.92
Purpose of credit if used on beans	Buy seed	52.94	0.00	53.85	66.67
	Buy fertilizer	47.06	100	46.15	33.33
	Paid labor cost	23.53	100	15.38	33.33
	Business	5.88	0.00	7.69	0.00

Several factors hindered sampled households from accessing agricultural credit in Malawi. Important among these factors were lack of collateral and fear of crop failure (reported by > 25% of the households). The high dependence on rain-fed agriculture in Malawi, which is also not reliable because of climate change and variability, probably increases the risk of providing / lending credit to agriculture. Additionally, majority of the farmers are smallholders with limited access to productive assets such as land, which is a major source of collateral for credit (Republic of

Malawi, 2011). Consequently, up to about 25% of the sampled households do not borrow because they consider use of agricultural credit as too risky (Figure 4).

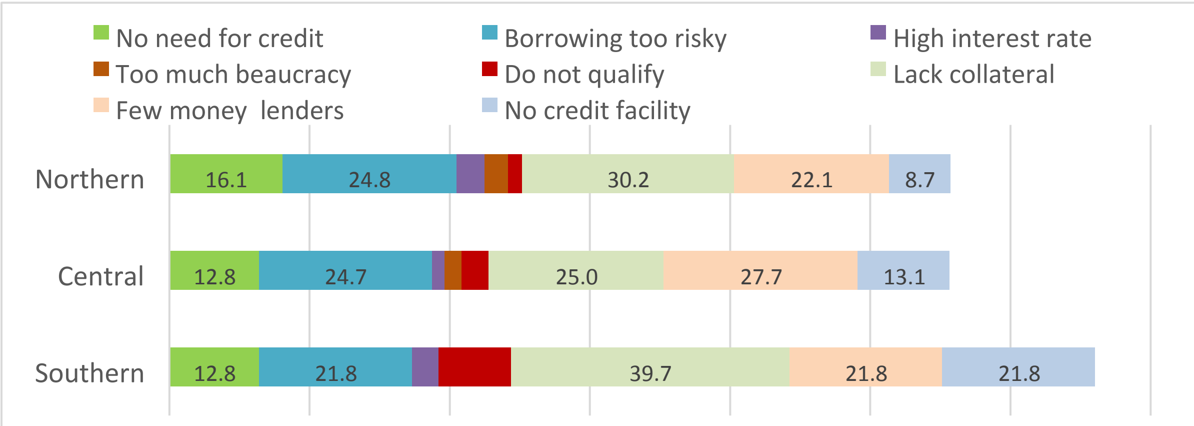

Figure 4: Reasons why farmers did not obtain credit by region (%)

3.1.3 Access to agriculture information

Agricultural extension services in Malawi had for long been done by the government only, through the Ministry of Agriculture, Irrigation and Water Development, to extend agricultural information to farmers across the country. However, in 1990s, alongside the wind of political changes in Malawi, came changes to decentralize some services including the agricultural extension services which are done by various agricultural extension service providers (NGOs, farmer-based organizations (FBOs), multilateral organizations and private sector). The changes necessitated a shift of providing agricultural information from the centralized to a pluralistic and demand-driven extension service provision by the various agricultural extension actors (Masangano and Mthinda, 2012). In spite of the shift in agricultural information provision, access to extension service in Malawi still continued to have challenges.

Across the study area, the majority of sampled households obtained agricultural-related information from the local input stores and/or media. As indicated in Figure 5, agricultural extension itself as a source of information is used by only a few farmers, less than 9% of the sample. Further, the majority of those who use extension services access it less frequently (1 to 10 times per year). Farmers in the southern region were more likely to access extension advice and obtain information from other farmers, while those in the northern region mostly preferred to seek information from the local input store, and those from the central region mostly relied on getting agricultural information from the media (Figure 5).

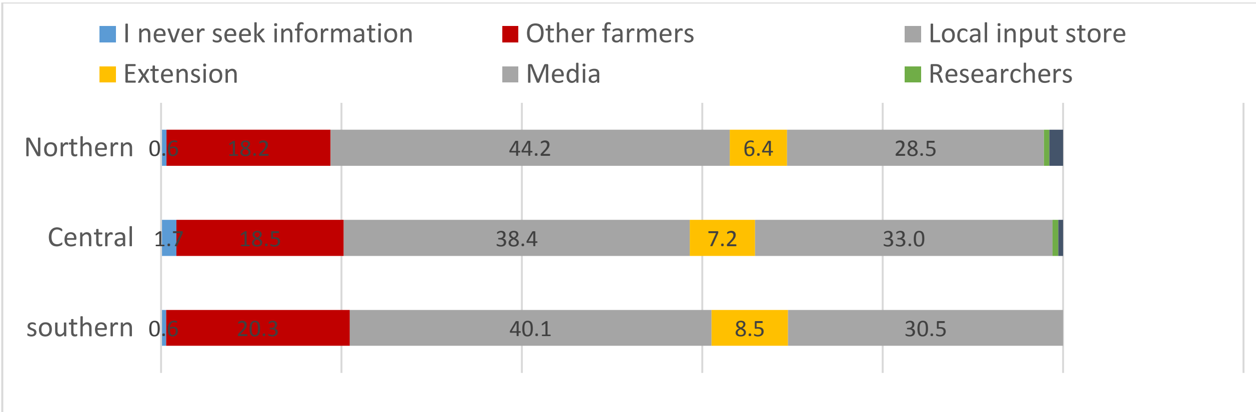

Figure 5. Sources of agriculture information in study area (%)

However, in terms of seeking advice, government extension appeared to be the major supplier of information related to the control of stresses that affect bean production in the study area. Other farmers were also useful in proving advice on stresses on bean and this was particularly important in the northern and central regions (Figure 6).

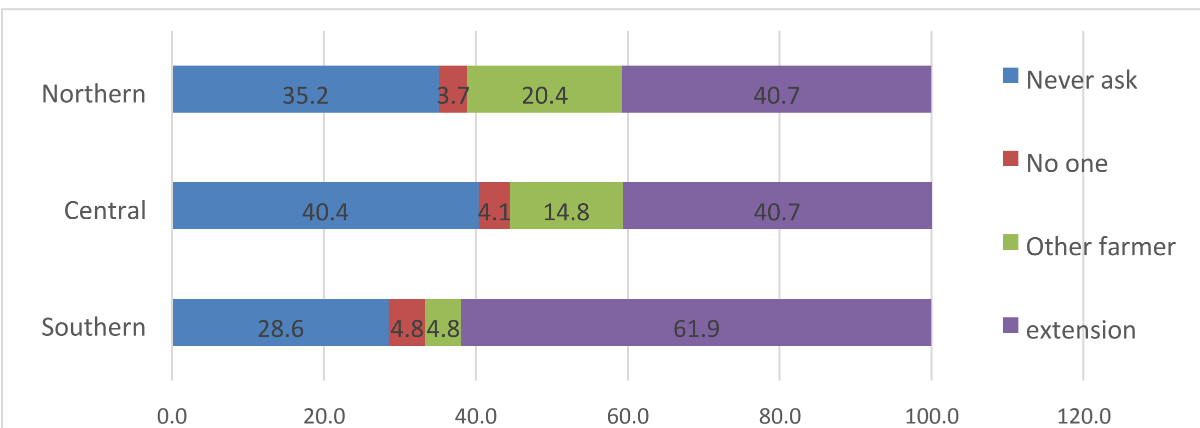

Figure 6: Sources of advice on stresses on beans by region (%)

3.1.4 Important crops

Malawian households have limited sources of income, with maize as their main source of income and food security. In terms of area, each household allocated about 0.87 ha of land to maize, which is produced under rain fed conditions using seed, fertilizers and family labour as the main inputs. In the heavily maize-based farming systems, bean ranked as second most important food security crop after maize for 50% of the households and third most important for 30% of the households (Figure 7).

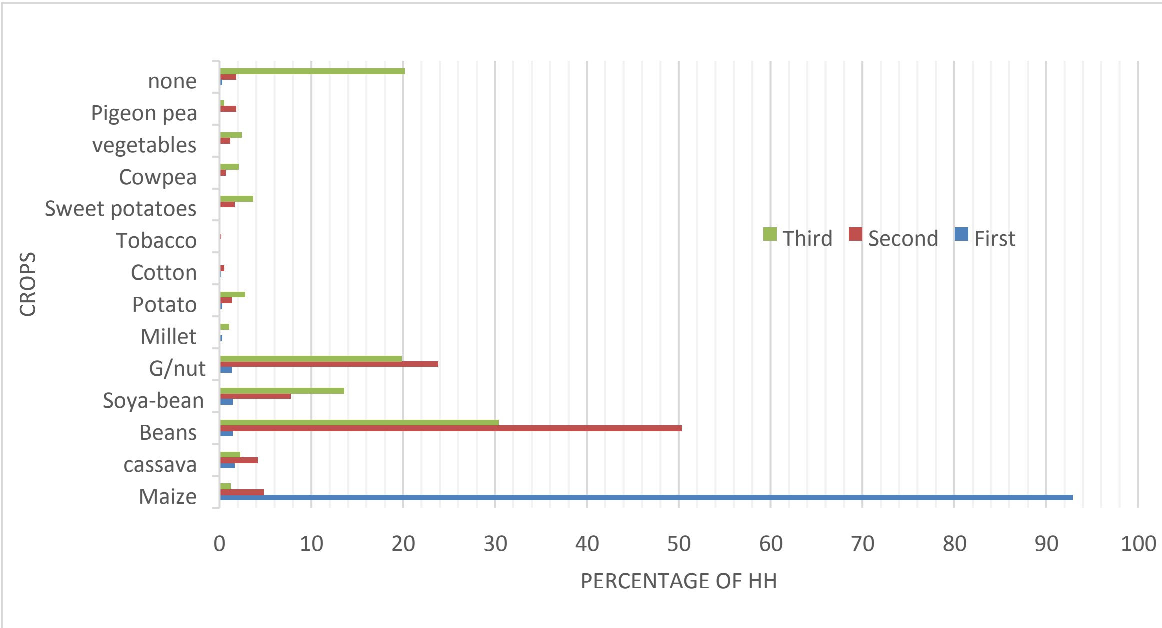

Figure 7: Important crops in the study area

Bean was also the most important grain legume produced in almost all districts in the three regions. This result demonstrates the importance of common bean to Malawian small-holder farmers as a source of food and nutrition security in a highly carbohydrates rich diets.

3.2 Common Bean Area Allocation, Management Systems and Output Utilization

3.2.1 Area allocation and management system

It is observed (Table 5) that each household in the study area cultivates an average of about 0.31 ha of bean that constitutes approximately about 22.5% of the total cropped land area. The average number of bean fields per household is 2.04, with field sizes ranging from 0.36 to 0.5ha (Table 5). Households in the central and southern regions have significantly more plots under bean cultivation (average of 2.10 plots) than those in the northern region (Table 5). The scale of bean production is, however, relatively smaller in southern region (0.21ha), where population density is higher than in central and northern regions.

Table 5: Cropped area, average land allocated to bean production and cropping patterns by region

Variables	Regions			
		1	2	3
	Overall	Southern	Central	Northern
Number of observation	989	107	613	269
Total cropped area (ha)	1.71 (1.825)	1.095 (0.752	1.697 (2.041)	2.061 (1.614
Average bean field sizes (ha)[12]	0.462 (0.448)	0.359* (0.288)	0.493 (0.504)	0.434 (0.346)
Bean area (ha)[NB]	0.305 (0.274)	0.211(0.178)	0.308 (0.294)	0.330 (0.234)
Bean fields per household (No.)	2.040 (0.985)	2.10 (0.982)	2.10 (1.035)	1.593 (0.642)
Owned cropped area (%)	91.8	85.2	90.8	97.6
Cropped area under beans (%)	22.47	23.36	23.43	19.87
Cropping systems (% bean fields intercropped(13, 23)	64	65***	74***	40
Bean intercrops (%)				
Maize	93.65	98.57	92.48	95.37
Groundnuts	3.49	0.00	4.65	0.93
Sorghum	2.22	1.43	1.99	3.70
Cassava	0.63	0.00	0.88	0.00

Notes: Figures in parentheses are standard deviations; ***, **, and * imply significance levels at 1, 5 and 10% respectively. NB: Bean area after correcting for intercropping

Common bean is commonly grown in association with other crops. Overall, 64% of the bean area was under intercropping system, but this intercropping was highest in the Southern region where it accounted for 74% of the cultivated bean plots. Bean-maize intercropping was the most dominant cropping system accounting for about 94% of bean area intercropped with other crops. Other types of bean intercrops although less important are bean-groundnuts, bean-sorghum and bean-cassava (Table 5).

About 82.6% of all the recorded cropped fields during the households' survey were reported to be managed by household heads (mainly men) with spouses managing only 16.5% of the fields. Household heads were also more likely than spouses to make decisions on the inputs used in the bean fields, crop management, and use of income from sales. This pattern of decision making is practiced in relatively land constrained areas of the southern region as compared with other regions. On the other hand, women were more likely to make decisions on harvesting activities as well as post-harvest handling because of their position in the food and agriculture systems. As described in Table 6, bean is cultivated under a wide range of environments in terms of land terrain (slope) and soil types. The majority of the bean fields (75-77%) recorded in the household survey across the three regions were located on sandy-loamy soil type. With regard to the slope, bean is mainly cultivated on flat to medium slopes, with minimal risk of erosion. In more land constrained southern region, about 22% of the bean fields were cultivated on slope considered to be steep.

Table 6. Physical characteristics of the bean fields

Variables		Regions				Chi2
		Overall	Southern	Central	Northern	
Number of observations		989	107	613	269	
Soil type (%)	Sandy-loam	75.94	76.47	75.31	77.25	6.15
	Clay	17.63	19.61	16.75	18.88	
	Sand	6.43	3.92	7.94	3.86	
Plot slope (%)	Flat	53.35	46.23	59.44	42.38	33.64***
	Medium	33.64	32.08	28.74	45.35	
	Steep	13.01	21.70	11.82	12.27	
Dimba	% of farmers	33.33	29.76	32.69	36.65	

The main agricultural inputs used in bean production were found to include: labour, organic manure, chemical fertilizers, and pesticides. Overall, 61.6%[8] of the fields cultivated with bean were treated with fertilizer, perhaps because of the subsidy program during the survey period (Table 7). However, within intercropped fields, fertilizer was applied selectively to maize (36.8%), while direct application to bean crop was in 24.8 % of these fields (8.7% on beans only and 16.1% on both bean and other intercrops). This means that although farmers received subsidy, their use of chemical inputs on bean crop remains low because of the subsistence nature in the farming systems. Instead, the majority applied chemical inputs on maize, which is the staple as well as commercial crop (Table 7).

Table 7: Percentage of farmers using inputs and other management practices in bean production

Inputs application	Regions				Chi2
	Overall	Southern	Central	Northern	
Number of observations	989	107	613	269	81.80^{***}
Fertilizer use in bean fields					
1. on beans only	8.71	5.61	9.98	7.06	
2. on both bean & maize	16.11	14.95	17.68	13.01	
3. on maize only	36.78	39.25	43.70	20.07	
Fertilizer use in maize fields	52.89	54.2	61.38	33.08	

[8] Computed as a sum of (1+2+3 in Table 7)

Manure use in bean fields	21.43	19.64	23.65	17.10	
Pesticides use in bean fields	6.34	7.14	6.69	5.204	
Herbicides use in bean fields	0.91	0.00	0.816	1.487	

3.2.2 Varieties grown

During the survey, respondents were asked to list all varieties planted in each bean field cultivated in season 2012/2013. It was observed that the surveyed households grew several varieties simultaneously on their farm. The average number of varieties grown in a bean field was 1.71, with a few farmers growing up to six varieties in one bean field. On average, variety diversity per bean field is higher in central region compared with southern region but this difference was not statistically significant in case of northern region. The higher diversity of varieties in central region could imply presence of more risks of crop failure in this region, which lies at relatively low altitudes compared with the southern and northern regions.

Both local and improved varieties were grown in the study area. Approximately 15 improved bean varieties were recorded among surveyed households across the regions (Figure 8). Improved varieties grown by at least 5% of the surveyed households were: Kalima (13.5%), Kholophethe (9.2%), Napilira (5.8%), and Chimbamba (5.4%) released in 1993, 2002, 1996 and 1993 respectively.

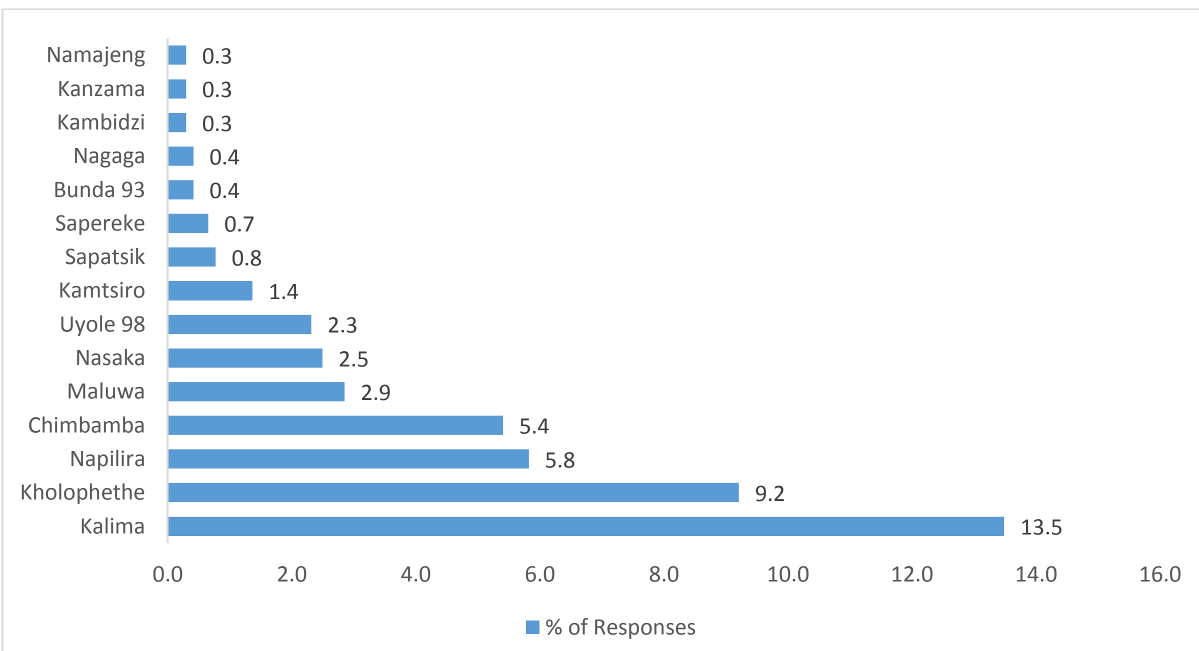

Figure 8: Frequently grown improved bean varieties (% responses) in the study area

Kholophethe and Chimbamba varieties were popular in the south, while Kalima was the most popular improved variety in both the Central and Northern regions (Figure 9). It was also observed that popular varieties were relatively used across districts (Figure 10). Overall, improved varieties were cultivated by about 63% of the surveyed households in the southern and central regions and 71% in the northern region (Table 8). Surprisingly, Uyole 98 improved variety that was released in the southern highlands of Tanzania and diffused through cross border trade into Malawi ranks second most popular in the northern region. The same variety also diffused to other parts of Malawi where about 2.6% of the sampled households in the central region grew it in 2013.

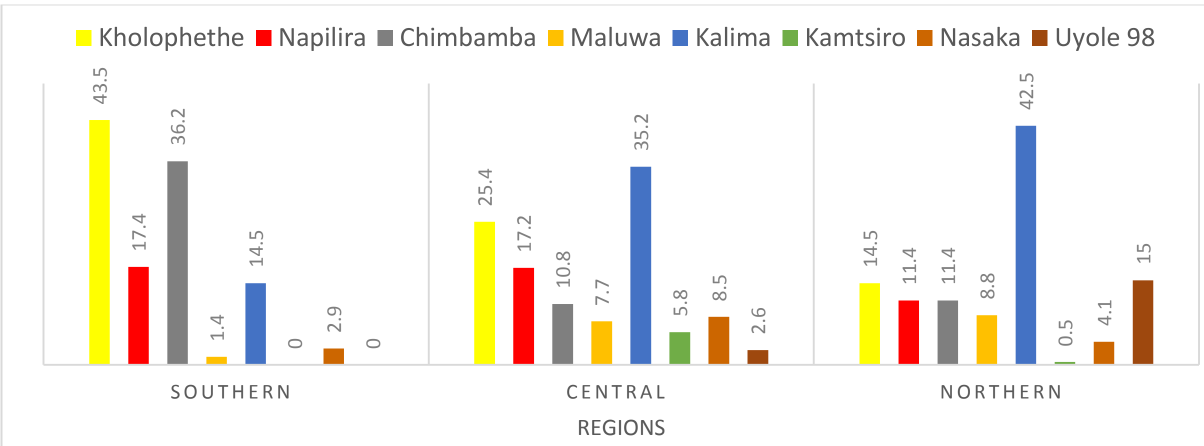

Figure 9: Improved varieties adoption patterns by region

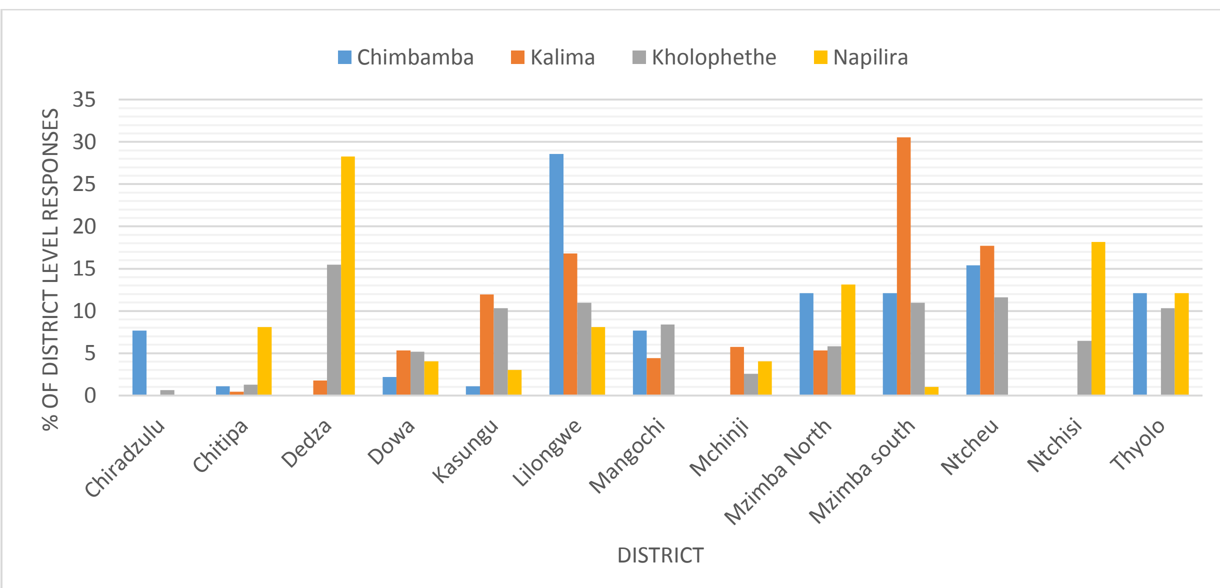

Figure 10: Average percentage of households growing popular varieties by district

In general, observed adoption results indicate that in each community where improved varieties were adopted, local varieties continued to be grown simultaneously with the improved varieties in the same field, implying that adoption of improved bean varieties has been partial. For example, of the total 990 bean fields in the study area, about 54% consisted of improved varieties released about two decades ago (before year 2000), while 15% of the bean fields had relatively new improved varieties (i.e. those released after 2000), and a whole 70% of the fields were planted with local varieties (Table 8).

Table 8. Plot level use of improved and local varieties

	Regions							
	Central (n=607)		Northern (n=269)		Southern (n=112)		All (N=990)	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Plot level use of varieties (1=yes, 0=no)								
Varieties released after 2000	0.15	0.36	0.10	0.31	0.27	0.44	0.15	0.36
Varieties released before 2000	0.52	0.50	0.65	0.48	0.40	0.49	0.54	0.50
Locals	0.75	0.44	0.63	0.48	0.60	0.49	0.70	0.46
Area share occupied by each variety (0-1)								
Varieties released after 2000	0.09	0.24	0.05	0.19	0.19	0.36	0.09	0.25
Varieties released before 2000	0.34	0.38	0.48	0.42	0.31	0.41	0.37	0.40
Locals	0.56	0.40	0.46	0.42	0.45	0.44	0.52	0.41

In terms of area share occupied by each variety, all improved bean varieties occupied about 46% of area cultivated with beans, while local varieties dominated with an average area share of 52% (Table 8). The local varieties as described in Kananji (2007) were well adapted to the local environment, tolerant to drought and have good flavour/ taste that consumers like. For farmers who rely on rain-fed agriculture but with uncertain weather conditions, landraces that have been selected over generations offer a good strategy for managing risks of crop failures. This perhaps explains the continued popularity of local varieties as compared with the various varieties developed and introduced to farmers two decades ago. Of the area occupied by improved varieties, a bigger proportion is accounted for by varieties released before 2000. These varieties developed before the introduction of the modern breeding technologies are only able to resist one constraint at a time. Although varieties developed after 2000 can resist several constraints simultaneously, they accounted for only 9% of the bean area. Low use intensity of the relatively newer improved bean varieties can be attributed to perhaps limited access to seed especially when farmers face liquidity constraints or due to experimentation when the technology is still new (Smale et al., 1995).

As described in Table 9, farmers who grew new improved varieties released in year 2000 and after can be distinguished from the rest of the bean growers by the level of formal education of the decision maker, household asset endowments and access to market. Adopters were significantly more educated, wealthier and located closer to the main towns (markets) as compared with the non-adopting farmers. Further, a significantly larger proportion of adopters had participated in off-farm activities (43.9%), were members of farmer associations (62%), had mobile phones (79.5%) and were resident in villages where markets for agricultural produce were accessible (54.5%) as compared with the non-adopters (Table 9).

Based on household asset index, which was computed as a combination of livestock, agriculture equipment and household durable good using a principle component method, the sample was ranked and stratified into 5 quintiles, where the bottom quintile 1 represents the poorest households and the topmost quintile 5 representing the wealthiest population segment. Figure 11 shows that the percentage of households that cultivated varieties released in 2000 and afterwards in 2013 was highest in the middle quintile (3) and dropped slightly as one moves to the top quintiles (4 & 5).

Table 9: Selected socio-economic characteristics of adopters and non-adopters

Characteristics	Sample (N=593)	Adopters (n=132)	Non-adopters n=461
Household head gender (1=male)	0.838 (0.015)	0.864 (0.300)	0.831 (0.017)
Dependency ratio	0.517 (0.009)	0.509 (0.019)	0.519 (0.010)
Organization membership (1=yes)	0.504 (0.021)	0.621 (0.042)**	0.471 (0.023)
Phone availability (1=yes)	0.595 (0.020)	0.795 (0.020)***	0.540 (0.023)
Household head age (years)	44.944 (0.530)	44.75 (1.149)	45.000 (0.598)
Village market availability (1=yes)	0.400 (0.020)	0.545 (0.044)***	0.360 (0.022)
Distance to nearest town (km)	73.735 (1.625)	66.644 (3.353)**	75.766 (1.848)
Off-farm activity (1=yes)	0.371 (0.020)	0.439 (0.043)*	0.351 (0.222)
Wealth index	-0.067 (0.039)	0.214 (0.077)***	-0.148 (0.044)
Tropical Livestock Units (TLU)	0.905 (0.059)	1.248 (0.122)***	0.807 (0.067)
HH head formal education (years)	6.999 (0.154)	8.011 (0.296)***	6.719 (0.176)

Farm size per capita (ac)	0.888 (0.029)	1.013 (0.070)**	0.852 (0.031)
Access to extension advice (1=yes)	0.400 (0.020)	0.439 (0.043)	0.388 (0.023)
Access to agricultural credit (1=yes)	0.084 (0.011)	0.114 (0.028)	0.076 (0.012)

Notes: *, ** and *** indicate significance levels at 10%, 5% and 1% respectively

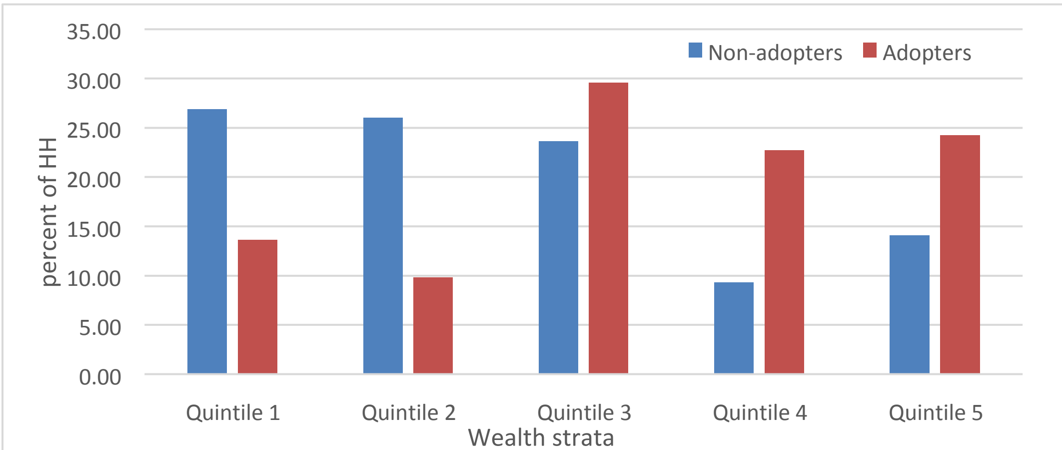

Figure 11: Adoption rate of improved bean varieties across wealth quintiles

A similar trend is observed in figure 12 for the proportion of bean area allocated to varieties (perhaps proxy measure of popularity of the varieties). Combined, improved bean varieties occupy nearly 50 percent of bean area for all wealthy groups except for the households in third wealthy quintile, who seem to allocate more share to local varieties than improved bean varieties. However, the bottom poorer households allocated 4.0 percent of their bean area to improved varieties released after 2000, which is about 6 times lower than that allocated by the households in 4th and 5th quintiles (Figure 12). These households instead allocate more of their bean area old improved varieties as the wealthier households seem to be replacing old varieties with new ones.

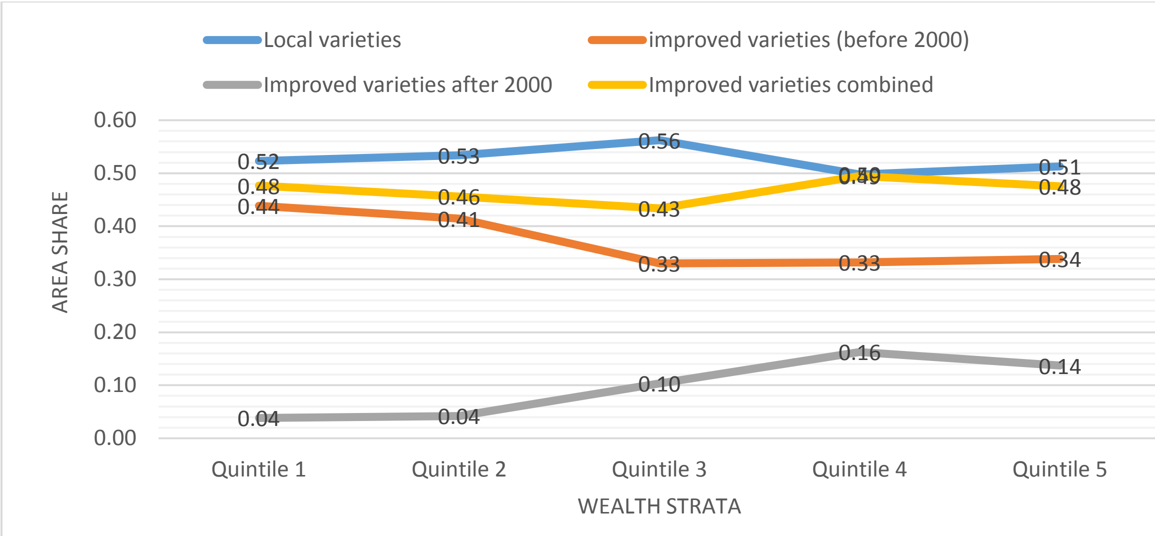

Figure 12: Share of bean area allocated to bean production by variety category

3.2.3 Non-adoption of improved varieties: is it rejection or lack of access?

The sampled farmers were asked to list all improved bean varieties they knew but not grown in the study season. For the varieties known but not grown, each farmer was asked whether the variety was ever grown or not and reasons for not growing it. Varieties known to some farmers, but not grown are reported in Figure 13. It is observed that most of these varieties were also those commonly grown by other bean farmers and these include: Kholophethe, Napilira, Kalima and Chimbamba. In particular, Kholophethe, a variety released in 2002 was reported by the highest number of households across the study area. Approximately 20% of the households knew about this rapidly diffusing variety but were not growing it. Next were Napilira and Kalima varieties with 11.6% and 8.9% of farmers respectively who knew about them but did not grow them.

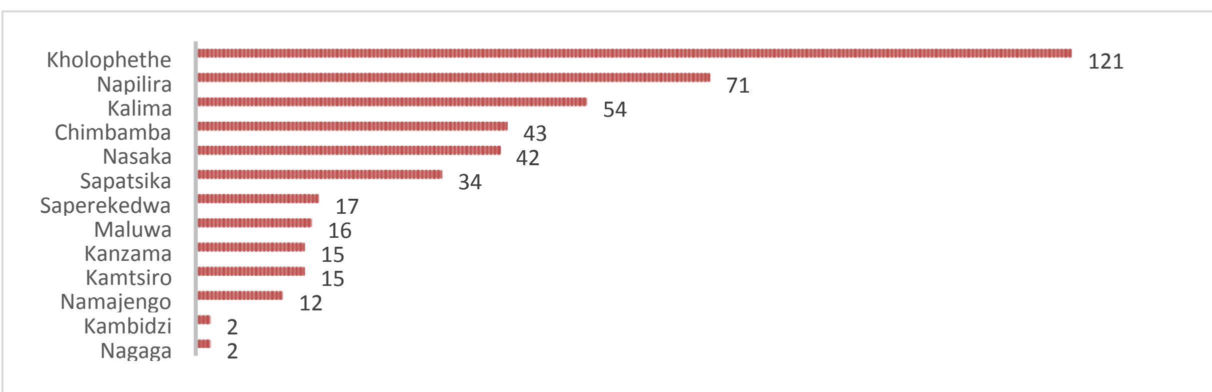

Figure 13: Number of households not growing certain bean varieties

It was investigated further into why the popular varieties in the same communities were not grown by some farmers. Table 10 shows that factors (classified into two broad groups) hindering the adoption of improved bean varieties were: (a) seed related factors encompassing un-availability of seeds and limited cash to buy seeds of the improved varieties), and (b) technological characteristics, where farmers prefer a different variety over the known improved variety.

Table 10: Factors and reasons why known varieties by households were not grown, 2012/13

	Reasons why known variety was not grown			
	Never grown		Grown & abandoned	
Factors	Frequency	%	Frequency	%
Seed access factors				
Seed not available	306	53.7	109	26.8
Limited cash to buy seed	42	7.4	22	5.4
Perceived technological characteristics				
Variety was susceptible to disease/pest	16	2.8	56	13.8
Low yielding variety	17	3.0	77	18.9
Variety matures late	2	0.4	10	2.5
Variety had poor taste	3	0.5	9	2.2
Low price received for this variety	14	2.5	12	3.0
No market	9	1.6	21	5.2
Demand side barriers				
Lack of land to experiment	14	2.5	3	0.7
Requires high skills	5	0.9	7	1.7
Prefer other varieties	142	24.9	81	19.9
Total	570	100.0	407	100.0

Problems of access to seed of improved varieties was the most important reason given by the households for not growing bean varieties farmers are aware of. Of the farmers who knew about some improved varieties, but had never grown them, the majority (54%) indicated that seed for the variety was not available, whereas about 7% indicated they had limited cash to buy the seed. Low yielding varieties and susceptibility to pests and diseases were also provided as reasons for abandoning some of the known improved varieties. This may not be surprising since some of the listed improved varieties are old and could have lost their resistance as pests and diseases evolve in the wake of climate change, implying that there is need to push for dissemination of recently released varieties.

3.2.4 Sources of seed for improved varieties

Seed of improved bean varieties diffuses through various channels including informal ones such as own saved seed, farmer to farmer and grain markets. Seed recycling is a common practice in the study area, where each farmer allocated about 8-11% of the harvest to use as seed for next planting. The use of home saved seed in

Malawi has been attributed to limited cash to purchase seed and scarcity of seed at planting time (Scott et al., 2003). In approximately 69% of the surveyed villages, there were no agricultural markets where farmers could buy seed at planting times (table 11). The majority of the farmers travelled an average distance of about 3.3 km (or 48 minutes) to access the nearest market, but this distance is much longer for farmers in northern region than those in the southern and central regions (Table 11). It is further revealed that the nearest village was located at an average distance of 11.25 and 28 km from tarmac road and district town, respectively.

Table 11: Market access in the study area by region

Variables	Overall (N=610)	Southern (n=84)	Central (n=364)	Northern (n=162)
Village market availability [13, 23]	0.42 (0.49)	0.54 (0.50)	0.49 (0.50)	0.19 (0.39)***
Distance(km) to village market [13, 23]	3.34 (4.87)	2.23 (2.14)	3.05 (3.43)	6.71 (10.67)***
Distance to village market (min) [13, 23]	47.84 (48.18)	34.13 (32.28)	46.65 (48.89)	75.53 (53.91)***
Transport cost to village market (MK) [12]	143.23 (159.85)	63.90 (98.33)	163.67 (161.47)***	128.33 (185.08)
Distance (km) from village to tarmac road [13, 23]	11.25 (15.80)	5.93 (7.74)	8.25 (16.19)	20.73 (14.03)***
Distance (km)to main district town [13, 23]	28.76 (22.51)	25.02 (19.65)	26.80 (25.00)	35.10 (15.88)***
Main transportation means	Percentages			
Back / head load / walking	79.46	80.00	79.78	76.67
Bicycle	15.89	17.78	16.39	10.00
Motor bike	0.39	0.00	0.55	0.00
Mini bus	4.26	2.22	3.28	13.33

Notes: Figures in brackets are standard deviations; ***, **, and * imply significant at 1, 5 and 10% respectively

3.3 Bean Yields and Food Security

Bean yield in Malawi is low, about 570 kg/ha as reported in FAO data (2014) and far below the potential yield of 2000 kg/ha (Chirwa *et al*., 2007). Due to intercropping, quantity of seed was used as a proxy for area in computing yield. Table 12 reports the estimates of bean yields based on the quantity of grain per one kg of seed planted by households in 2013/2014 cropping season. In assessing the yield differences between adopters and non-adopters of new varieties, varieties released before 2001 are combined with local varieties.

Table 12: Average bean yield and use of produce by adoption status

	All		Adopters		Non-adopters		Significance levels
Variables	Mean	SD	Mean	SD	Mean	SD	
Yield (kg harvested/kg of seed planted)	8.12	7.62	9.53	8.52	7.77	7.36	***
Seed planted (kg)	19.91	27.79	25.09	40.18	18.63	23.63	**
Value of seed	3265.00	4537.70	3860.50	6644.10	3074.10	3598.10	**
Cost of fertilizer/kg of seed planted	1707.42	3414.52	2038.44	3377.36	1624.15	3422.25	ns
Seed lost to pests per kg planted (Kg)	0.53	0.38	0.36	0.30	0.57	0.39	***

Notes: *, **, and *** significance levels at 10, 5 and 1% respectively

On average, a household obtained yield of 8.12 kg of grain for one kg of seed planted, which translates into 568 kg of harvest per hectare, assuming a seeding rate of 70 kg/ha. This is consistent with the estimates of 570 kg/ha reported by FAO (2014). Adopters of bean varieties released in 2001 and afterwards obtain about 9.53 kg per one kg of seed planted that is significantly higher than average harvested (7.8kg of grain obtained per one kg of seed) by non-adopters (Table 12). Table 12 further shows that farmers lost significant amounts of harvest due to production constraints. For example, for every kg of seed planted, households lost an average of about 0.53 kg to pests and the loss was more severe among non-adopters of new varieties (0.57 kg/kg of seed) relative to adopters (about 0.36 kg/kg of seed). The lesser seed loss among adopters is perhaps because the newer varieties have traits that are resistant to several constraints (Table 12).

3.3.1 Food security and household dietary diversity

Food insecurity is a pressing issue affecting the well-being and health of many Malawians. Figure 14 indicates that about 46.5% of the households experience some food shortage in the course of the year. Food insecurity is most prevalent during the months of January, February and March, when a respective 16%, 25% and 12% of the households experience food shortage. These are the months when the crops are growing. The food insecurity, however, reaches its lowest rates of 0.34-1.2% of the households during and immediately after harvest that occurs in the months of April, May, June and July (Figure 14).

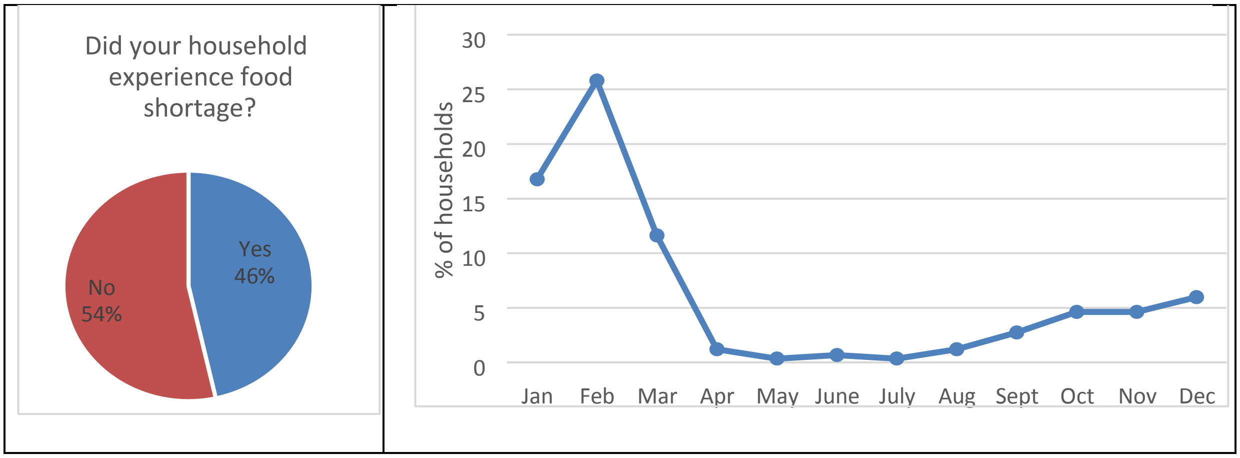

Figure 14: Percent of households experiencing monthly food insecurity in the study areas

Compared with the food secure households, most of the food insecure households were likely to be asset poor and relied on informal strategies to cope with food stress, notably: relying on less preferred foods (37.1%), limiting portion sizes at meal times (23.27%) and limiting variety of foods consumed (20.24%) (Figure 15). The asset poor households were thus compelled to either compromise on food quality or quantity to manage the stress.

Figure 15: Coping strategies used by households to withstand food shortages

Table 13 lists 12 different food groups consumed in Malawi and their respective frequency of consumption. Cereals were consumed by almost 98% of the households, and are the most frequent and available food group. Thus the national food security is defined in terms of having access to maize (MOAFS, 2011).

Table 13 Types of food groups and items consumed and household dietary diversity

Food group	Food groups	% of households			
		All sample (N=593)	Adopters (n=132)	Non-adopters (n=461)	p-value
1.	Cereal grains (maize, wheat, rice, sorghum, millet	98.82	99.17	98.73	0.694
2.	Vegetables	81.96	66.25	86.15	0.0001
3.	Legumes (cowpeas, beans, peas/nuts)	62.39	75.42	59.20	0.001
4.	Sugar or honey	60.54	57.08	48.63	0.098
5.	Oil, fat or butter	56.83	68.33	58.56	0.0506
6.	Fruits	50.25	69.58	53.70	0.0016
7.	Other foods (tea, coffee)	41.32	45.00	23.26	0.0001
8.	Roots or tubers (cassava, yam, sweet potatoes etc.)	27.66	56.67	37.63	0.0001
9.	Fish (dried, fresh or shellfish)	22.6	34.17	19.66	0.0007
10.	Meat, beef	17.37	28.33	14.59	0.0004
11.	Milk or milk products	12.82	21.67	10.57	0.0011
12.	Eggs	10.62	10.00	10.78	0.8043
13.	Number of food groups (Dietary Diversity Score)	5.438 (0.065)	6.348 (0.140)	5.177 (0.685)	0.0001

The other frequently consumed foods are vegetables and legumes as reported consumed by about 82% and 62% of the sampled households, respectively. Milk products or milk and beef were the least popular, consumed by less than 20% of the sampled households. In all, except for cereals and eggs, the frequency of consumption of the food groups was higher among adopters than non-adopters of improved bean technologies.

Each household consumed about 5.4 food groups; but adopters had a higher dietary diversity score (6.3) than non-adopters (5.2). The difference in the dietary diversity score between the households that had adopted improved bean varieties and those that had not adopted was statistically significant at 1% level (Table 13). This means that compared with non-adopters, adopters were more food secure households.

3.4 Propensity Score Analysis Results

Results for the adoption of improved technology (the first stage in propensity score estimation) and food security outcomes are reported in Tables 14 and 15. We begin by discussing briefly the results for the adoption model estimated in stage one based on a probit model.

3.4.1 Improved bean variety adoption

The results presented in Table 14, column 3 are the average marginal effects of the factors hypothesized to influence adoption of improved bean varieties. The test for the model's goodness of fit, using a likelihood ratio statistic showed to be statistically significant at 1% level, indicating that the variables jointly explained much of the variation in probability that a household adopts improved bean varieties.

Table 14: Estimates of the probability that household adopts new improved bean varieties in Malawi, 2013/2014

Variables	Coefficient	ME	SE	P>z
Household head gender (1=male)	-0.067	-0.175	0.048	0.709
Household head age (years)	0.004	0.001	0.001	0.466
Asset index	0.057	0.015	0.019	0.427
Village market availability (1=yes)	0.497	0.134	0.035	**0.001**
Phone availability (1=yes)	0.501	0.123	0.035	**0.001**
HH head education (years)	0.041	0.011	0.005	**0.026**
Dependency ratio	0.071	0.183	0.080	0.818
Member in farmer organization (1=yes)	0.192	0.0495	0.032	0.132
Distance to nearest town (km)	-0.002	-0.001	0.0004	0.135
Farm size per capita (acres)	0.173	0.045	0.022	**0.045**
Engaged in off-farm activity (1=yes)	0.058	0.015	0.034	0.659
Subsidy for bean inputs (1=yes)	0.226	0.06	0.036	**0.085**
Constant Observed	-2.029		0.413	**0.001**
Predicted probability				

The results indicate that adoption of improved bean varieties in Malawi is influenced by a host of factors. In this study, mobile phone ownership increased the likelihood of adopting improved common bean varieties by 12.3%. Mobile phones are increasingly being used as channels for communicating agricultural-related information to farmers because they facilitate access to information about agricultural technologies (Adong et al., 2013; Mwaura, 2014). Similarly, one additional year of formal education increased the likelihood of adoption by 1.1%. Farmers that are educated are more efficient in interpreting and evaluating information on new technologies than those that are not, thereby facilitating their adoption. Beyond information, farmers who obtained subsidy on bean seed were 0.6% more likely to adopt improved bean varieties because under subsidy program, improved seeds are often distributed.

Market access is another factor that emerged from the analysis as important for adoption of improved bean varieties. Results showed that farmers in villages with markets were 13.4% more likely to adopt improved beans than those who were not. Existence of a village market might facilitate fast diffusion of varieties from early adopters to the potential adopters given that grain markets are important sources of seed. On the other hand, the negative effect of distance to the nearest town on the probability of adopting improved bean varieties reflects the fact that technology dissemination in the context of poor road networks might be biased against remote rural areas.

3.4.2 Common support and covariate balancing

The predicted propensity scores for the adopters ranged from 0.0332 - 1 while that for non-adopters ranged between 0.006 - 0.991; thus the condition of non-zero probability of all households in the sample for the treated households was met. In other words, there were sufficient observations among the non-adopters with a high propensity to adopt and thus constitute the control group. Results as reported in Table 15 indicated that after stratification on propensity score into five quintiles of equal size, adopters and non-adopters have nearly the same propensity scores. In order to check whether the distribution of measured covariates is similar between adopters (the treated) and non-adopters (untreated) households within each propensity score stratum, a T-test statistic was performed for equality of means for continuous variables and binary dummies. Results in appendix 1 show that the difference in means of all covariates between adopters and non-adopters in the 4th and 5th propensity score quintiles are not statistically significantly different at 5% or 10 level (appendix 1). For the 1st, 2nd and 3rd quintiles, only two covariates in each were statistically significantly different at 5 and 10% level (appendix 1) between treated and control groups, which is further evidence that the estimation of the propensity score was properly specified. This implies that the covariate balancing condition for the application of PSA was met and hence it was okay to use it.

3.4.3 Effect of improved bean varieties on household food security

Results in Table 16 are estimates of the effect of adoption on household dietary diversity, derived by comparing the household dietary diversity score (HDDS) directly between treated (adopters) and untreated (non-adopters) households. The statistical significance test of mean difference was done based on the T-test statistic. Results represent estimation of average treatment effect on households having similar observable characteristics. For improved bean varieties released after 2000, the average effect of adoption on the household dietary diversity score was about 0.765 (14.7%) for the adopters – meaning that the HDDS would have been 14.7% lower had they not adopted.

Table 16. The effect of household dietary diversity score

Strata	Dietary diversity score (HDDS)							
	1		2		3		2-3	
	Combined		Adopters (1)		Non-adopters (0)		Weighted difference of means	P-value
	Mean	SD	Mean	SD	Mean	SD		
Quintile 1	4.71	1.56	5.69	0.88	4.64	1.58	0.071	**0.066**
Quintile 2	5.06	1.56	5.96	1.46	4.95	2.11	0.111	**0.027**
Quintile 3	5.47	1.44	6.18	1.33	5.35	1.43	0.118	**0.028**
Quintile 4	5.77	1.42	6.39	1.34	5.58	1.4	0.195	**0.008**
Quintile 5	6.18	1.51	6.5	1.72	5.91	1.24	0.270	**0.032**
Pooled ATT							0.765 (14.7%)	

4. SUMMARY AND CONCLUSIONS

Malawi is one of the countries in sub-Saharan Africa that are frequently hit by food shortage. Addressing the severe biophysical constraints that contribute to this challenges in Malawi has been a major thrust for the bean improvement programme in the country. The contribution of this study was to document the adoption of improved bean varieties released over the last three decades and test the effect of growing new improved varieties on household food security. This study used farm level data collected from small-scale producers, to analyse the adoption of improved bean varieties and its effect on food security in Malawi. The study gathered data through a nation-wide survey of a sample of households that was representative of bean growers. Adoption determinants were estimated using a probit model while the food security effects were computed using a propensity score analysis with stratification method.

Results reveal high utilisation levels of improved variety, although the level of adoption of newly released varieties (i.e. varieties released after 2000) is still modest. Several factors influence the adoption of new improved bean varieties in Malawi but most important ones according to the study are related to access to the technology, proxied by: mobile phone ownership, existence of village markets, household asset index, and household head education level. These results provide useful lessons for seed system and variety dissemination initiatives in the country. To sum up, the presence of extension services in a village and possession of mobile phones are found to be important determinants for adoption of improved bean varieties. These two can be integrated into seed delivery programs to re-enforce each in the systems. Extension workers can be supported to keep in touch with the farmers through mobile phones. For the farmers without mobile phones, community radios and group learning can be encouraged and integrated into seed delivery initiatives. This may necessitate a study to understand the relationship between extension and ICT based communication channels and assess how to best redesign extension services to effectively complement the farmers' socio networks. Existence of a grain markets also increases the likelihood of adopting improved varieties. Although grain markets are important sources of seed for new varieties, researchers or development practitioners have little influence in having them established. The researcher can use exhibitions of new varieties within villages that lack grain market outlets to expose new varieties to potential adopters. In doing this, villages that lack markets should be given priority. At the same time, results highlight the important role played by education in adoption of new improved varieties. Although the new improved varieties demonstrate superiority over old improved and landraces in terms of yield as well as curbing yield loss emanating from biophysical constraints, it may not be easily learnt from a word of mouth. Hence use of variety demonstrations in villages that have low adoption rates should be considered to promote the varieties.

The results further show that adoption of improved bean varieties is associated with increased household diet diversity, which means that promoting the use of new improved common bean varieties to replace old ones and land races has the potential to increase the household food security. On average, adopters were found to be 14.7% more food secure than they would have been if they had not adopted new improved varieties. Therefore, policies aimed at enhancing bean productivity and promoting adoption of new improved technologies by providing information, strengthening seed systems and seed marketing should be central to the food security strategies in Malawi.

Finally, future investigations based on methods that test and control for selection on unobserved characteristics are needed in order to validate these results and provide robust checks on the estimates of the impact of improved bean varieties on food security. Such methods include use of panel data to support analysis of the dynamics of adoption and test whether impacts persist over time.

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Appendices:

Appendix 1: Balancing property of covariates

Variables	Adoption status	Propensity score strata				
		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Sex household head	Adopters	0.875	1	0.824	0.857	0.815
	Non-adopter	0.7838	0.819	0.851	0.856	0.891
	p-value	0.545	0.096	0.769	0.984	0.246
Dependency ratio	Adopters	0.533	0.523	0.443	0.505	0.521
	Non-adopter	0.54	0.515	0.539	0.499	0.479
	p-value	0.925	0.898	**0.050**	0.896	0.313
Farmer organization	Adopters	0.125	0.461	0.588	0.607	0.741
	Non-adopter	0.261	0.371	0.584	0.578	0.719
	p-value	0.396	0.532	0.975	0.785	0.791
Phone availability	Adopters	0.001	0.538	0.765	0.857	0.944
	Non-adopter	0.0128	0.39	0.733	0.889	0.938
	p-value	0.705	0.31	0.784	0.653	0.875
Age household head	Adopters	35.125	46.85	51.529	42.000	46.278
	Non-adopter	45.234	43.82	45.059	45.000	45.391
	p-value	**0.0303**	0.462	**0.042**	0.273	0.719
Market availability	Adopters	0.375	0.077	0.176	0.464	0.889
	Non-adopter	0.05	0.323	0.297	0.489	0.844
	p-value	**0.001**	**0.067**	0.310	0.822	0.480
Distance to town	Adopters	88.75	79	84.235	65.036	56.741
	Non-adopter	87.14	72	80.584	68.606	61.430
	p-value	0.862	0.522	0.773	0.664	0.539
Off-farm employment	Adopters	0.25	0.308	0.235	0.500	0.519
	Non-adopter	0.189	0.4	0.327	0.467	0.469
	p-value	0.677	0.524	0.456	0.760	0.594
Asset index	Adopters	0.587	-0.092	0.069	0.043	0.559
	Non-adopter	0.716	-0.371	-0.137	0.292	0.612
	p-value	0.308	0.103	0.290	0.208	0.821
TLU	Adopters	0.259	1.255	1.191	1.021	1.581
	Non-adopter	0.66	0.667	0.815	0.905	1.187
	p-value	0.511	0.113	0.260	0.654	0.195
Education (years)	adopters	3.875	5.231	8.294	8.321	9.222
	Non-adopter	4.306	5.942	7.787	8.000	8.781
	p-value	0.728	0.492	0.560	0.664	0.444
Per capita land size	Adopters	0.662	1.031	0.966	1.203	1.019
	Non-adopter	0.652	0.673	0.841	1.022	1.285
	p-value	0.946	**0.028**	0.349	0.247	0.168
Inputs in beans	Adopters	0.125	0.308	0.235	0.393	0.519
	Non-adopter	0.288	0.2385	0.267	0.311	0.5
	p-value	0.323	0.586	0.784	0.426	0.843