TECHNICAL REPORT

ASSESSSING THE IMPACT OF THE TROPICAL LEGUMES II& III PROJECT ON COMMON BEAN PRODUCTIVITY, PROFITABILITY AND MARKETED SURPLUS IN SOUTHERN HIGHLANDS OF TANZANIA

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Table of contents

List of tables

List of figures

EXECUTIVE SUMMARY

Crop improvement is an important route to improving agricultural productivity in developing countries and the heart of bean research in sub-Saharan Africa where high disease pressure and climatic variations are severe. For decades, the National Bean Research programs in sub-Saharan Africa and international Center for Tropical Agriculture (CIAT) have been promoting improved bean varieties in the region under the umbrella of the Pan Africa Bean Research Alliances (PABRA). Common bean is an important food security crop and a source of income in Tanzania with a growing importance as an export earner. Thus, higher productivity and disease resilience advantage of improved varieties relative to the traditional one can increase food security, marketable surplus and lower per unit average cost of production, which raises the incomes of producers that adopt.

In 2007, the National Bean Research Organization and CIAT intensified the efforts to improve bean productivity under the auspices of the Tropical legumes project (TL II &III) project led by ICRISAT and financially supported by the Bill and Melinda Gates foundation. Consistent with the national objective of poverty reduction, the goal of TL II & III project was to increase the productivity of legumes in Sub-Saharan African and East Asia via development and delivery of high-quality seed of higher yielding cultivars with superior tolerance to diseases. Based on monitoring reports, the project achieved high performance in terms of varietal releases and seed production. For example, the breeding program recorded 15 varietal releases, the highest ever, during the period of the project and disseminated them to farmers via integrated seed systems also supported under the project.

This report assesses the farm level utilization of improved bean seed (i.e. improved varieties) and its impacts on bean yield, incomes and marketed bean surplus. To examine the farm level utilization of varieties promoted under the Tropical legumes project, adoption data were disaggregated by varieties differentiated by year of release and measured in terms of household and area planted. Then, adoption was defined as a multivalued treatment variable to account for partial adoption while separating varieties promoted under the project from old improved varieties when comparing with landraces. Then, an inverse probability weighted regression (IPWRA) approach was used to estimate impacts of improved bean adoption while modelling the outcome and the treatment to correct for potential selection bias.

The data used came from the Southern Highland zone of Tanzania. This zone was selected because the Bean research Program, Uyole Agriculture Center, for the zone had registered the highest number of varietal releases under the project and because the budget limitations prohibited us from implementing a national-wide study. The SHZ covers the Southern and Western agro-ecological zones of Tanzania, located between 1,200–1,500m and 1,400–2,300m altitudes above sea level. The zone contains the most fertile land in Tanzania and a unimodal type of rainfall that starts from the month of October and goes on up to April, on an average of 100–200mm per month. The data were collected through a survey of 750 bean growing households that were selected based a three stage stratified and proportionate sampling method and implemented in 2012/2013 and again in 2016 by the socioeconomic team at Uyole in collaboration with CIAT. Trained enumerators collected the data using a pre-tested structured household and community questionnaires.

Results show solid performance fueled by investment in seed systems and outstanding properties of the varieties. According to farmers, new varieties released in 2003-2011, outperform old ones and local varieties in terms of yield, marketability and consumption traits. These properties together, with increased access to seed have driven the adoption of new improved varieties from 32% in 2013 to 42% of growing households in 2016, which is equivalent to 3.3% annual growth in adoption rate. In terms of area share, adoption of new varieties increased from 21% in 2013 to 25% in 2016. Adopting and non-adopting households are similar in terms of demographic characteristics such as age, household size, gender, and education but differ in endowments and physical environment. Adopters were wealthier, farming better fertile soils with optimal soil pH and were more likely to be located closer to Uyole research center compared with non-adopters. Some farmers still hold on to their landraces because these perform better on low fertile soils than new varieties. These differences in resource endowments and microenvironments may pose significant challenges that block the road to accelerated varietal turnover.

The study findings indicate that the bean improvement under the Tropical Legumes project has been successful in increasing productivity, which was the main goal of research investment. Adopters of new improved varieties produced 32% more beans for the same unit of land, compared to if they had planted landraces. However, the estimated average yield increment if adopters of old improved varieties were to move to new improved varieties was modest—perhaps explaining why some of these farmers continued to plant old improved varieties. Adopters gained productivity via: 1) the higher yielding advantage of new improved varieties, 2) upward adjustment in seeding rates even though improved seed costs more than landraces. After accounting for additional costs in production, adopters obtain additional profits, putting extra income in their pockets in line with the national objective of poverty reduction. Thus, the yield advantage offsets the higher price of improved seed and upward adjustment in seeding rate. These results demonstrate that the project did not only increase access to quality seed but also enhanced the farmers' managerial abilities.

Because of greater yield, adopters marketed surplus increased by 38%, which is remarkable and confirms that bean improvement has contributed to smallholder integration into the market. However, as new varieties gain area share, the resulting greater yields and integration in output markets is accompanied by a growing masculinization of the value chains, which could potentially discourage women from investing in bean technologies. In light of these results, there is need for follow up research to understand from women's perspectives the effect of the shift in control of marketed surplus in favour of men and the intervention to address it if negative.

1.0. INTRODUCTION

This report documents the results from a study conducted to assess the impact of the Tropical Legumes (TL) project in Tanzania. From its inception in 2007, the goal of TL project was to increase the productivity of common bean via development and delivery of high-quality seed of higher yielding cultivars with superior tolerance to diseases. This goal is in line with the national objective of reducing poverty as reflected in the country development plan of 2016-2021 (Ministry of Finance and Planning, 2016). Higher productivity and disease resilience advantage of improved varieties relative to the traditional one can increase marketable surplus and lower per unit average cost of production, which raises the incomes of producers that adopt. Besides being important sources of food security, common bean in Tanzania and in several other East African countries is traded in domestic and export markets—generating revenue for growers. Thus, it is possible that increased bean productivity may stimulate demand for inputs such as labour, fertilisers, seed-- etc; which also contributes to rural poverty reduction through multiplier effects (Becerril & Abdulai, 2010; de Janvry & Sadoulet, 2001; Minten & Barrett,2007).

The study focuses on micro-level impacts of bean improvement on selected multiple causal linkages along the impact pathway; farm level utilization of improved seed (i.e. improved varieties), change in bean yield, and marketed bean surplus using cross sectional survey data; collected from the same households that were interviewed in 2013-- thereby enabling us to estimate the changes in variety adoption. First, the study examines the farm level utilization of improved bean varieties differentiated by the year of release and measure the extent to which, varieties promoted under the project have been adopted in terms of households and area share. Secondly, the study analyses the impact of improved bean varieties adoption on yield gains based on a multivalued treatment effects framework to account for partial adoption measured at plot level. The study applies an inverse probability weighted regression (IPWRA) approach to estimate impacts of improved bean adoption while controlling for selection bias by modelling the outcome and the treatment equations (Wooldridge, 2010 962-963). The estimated yield gain is, then compared with the additional cost of production attributed to the new variety growing to get a picture of the project success in raising crop profitability and household income gains.

After estimating the effect of improved variety adoption on yield, the study examines causal relationship between improved bean variety adoption and crop commercialization, measured by marketed surplus, based on the similar analytical framework as alluded to the previous paragraph. While some evidence on the impacts of bean research on household welfare has been documented in previous studies (Larochelle et al., 2015, Katungi et al., 2018), no study, we know of, has documented the impacts of bean improvement on marketed surplus and its implications for gender equality. In our analysis, we seek to answer questions like; to what extent did the adoption of improved technologies contribute to marketed surplus and did it affect men and women differently? Our hypothesis is that as bean productivity increases, the marketed surplus increases,—but women lose control over the crop to men.

The study also contributes to the emerging literature on impact studies that have used doubly robust IPWRA approach in a multivalued framework to account for different adoption intensity of a technology or components of a technological package. For instance, Smale et al. (2018) used a multivalued treatment effects to distinguish the impacts of open pollinated and hybrid sorghum in Mali. Manda (2016) used the same to distinguish hybrid and open pollinated maize when estimating the impact of improved maize on food security in Eastern Zambia. Our study applies the IPWRA to distinguish varieties based on year of release (as old vs new) while accounting for plot level partial adoption. Previous studies conducted on improved bean varieties have either treated all improved varieties as the same (Kalyebara et al., 2008) or combined landraces and old varieties when assessing the impact (Letaa et al., 2015; Larochelle et al., 2015; Katungi et al., 2019). Over the years, there has been improvement in the bean varietal development processes of CIAT and her NARS partners that aim to generate new variety releases that are superior to old ones in terms of yields and/or market attributes (Mukankusi et al., 2018). This means that aggregating new & old improved varieties and/or old improved with landraces as was done in previous studies (e.g. Kalyebara et al., 2008; Asfaw et al., 2012, Letaa et al., 2015 and Musimu, 2018) would underestimate the impacts of new releases under the project. The superior yields of new releases is mirrored in trial data (PABRA database, 2016), but there has been no empirical evidence that adopters of new releases do indeed experience higher yields than those who grow old releases for beans. Yet, it is important to know how effective improved bean varieties from the project interventions are-- relative to local ones and, once we know that, we can evaluate the benefits of replacing old varieties with new ones. To differentiate new varieties from old ones as well as account for plot level partial adoption, the adoption of improved varieties was measured at plot level as a multinomial categorical treatment variable (identified as 1=only new varieties, 2=only old varieties, 3=only local varieties and 4=mixture varieties).

In the next sections, the report presents a summary of the bean production context, highlighting key features and milestones in the bean research of Tanzania. In section three, is a discussion on the study area, describes with some detail the methodological approach followed and the fieldwork carried out to collect data used in the analyses. After explaining how we implement the survey, we describe patterns of the adoption of the improved beans and its diffusion in section four. Then, an overview of the estimation strategy follows in section five while results appear in section six sequentially laid out to align with the study objectives. The report concluded with an extended summary and recommendations.

2.0. THE CONTEXT AND PROJECT INTERVENTION

The Tanzanian economy relies heavily on agriculture, which contributes about 30 % of the GDP and employs nearly 80% of the labour force (AFDB, 2011). Common bean (Phaseolus vulgaris) is an important food security crop grown in the country; it accounts for about 80% of total legumes produced (Rapsomanikis, 2014) and ranks third after maize[1] and cassava in terms of area cultivated. About 1,134,394 hectares of beans are cultivated per year (FAO 2014) across the country, grown mainly by smallholder farmers for home consumption and for sale. Approximately 48 percent of bean production is sold and the bean exports from Tanzania, flowing mainly to her neighbouring countries (such as Zambia, Mozambique, Rwanda and Kenya) has been growing at an average rate of 12% per year since 2005 (FAO, 2018).

Recognizing the contribution of beans as a source of food and income for the poor, the government of Tanzania has been pursuing the goal of improving its productivity. Bean research in Tanzania began in 1965 with a focus on export varieties and was expanded to subsistent varieties as well as formally institutionalized in 1977 (Hillocks et al., 2006). The primary goal of this research is to increase bean productivity through breeding and promotion of integrated crop management practices (ICM). Research is conducted in collaboration with international institutions especially the Centro International de Agricultural Tropical (CIAT) under the umbrella of the Pan Africa Bean Research Alliances (PABRA) and Southern Africa Regional Bean Research Network

[1] Maize contributes 60% of dietary calories and is an important source of income, except in areas where cash crops such as tobacco are well established (Urassa 2015).

(SABRN). In 2007, the National Bean Research Organization and CIAT intensified the efforts to improve bean productivity with financial support from Bill and Melinda Gates foundation via the TL project led by ICRISAT.

The collaborative bean improvement research has resulted in about 43 varieties released since 1979, with an average of 1.1 variety releases per year (Table 1). The highest rate of variety release occurred between 2011 and 2017, an indication that the breeding program has been more productive during the last 10 years under the support of the Tropical legumes project. In terms of targeting, emphasis has been on increasing yielding potential and adapting beans in the traditional growing areas. Most of the releases are suitable for the agroecosystems of the medium and high altitude zones with rainfall above 500 mm per year and medium to high temperatures. The temporal varietal pattern indicate a growing interest in varieties with tolerance to abiotic stresses and nutritional quality. For example, two of the recently released varieties are purposely targeting drought conditions while two are for nutrition enhancement (PABRA 2016).

Table 1: Summary of varietal releases in the last 4 decades

Period of release	Number of releases	Number of lines contributed by CIAT	Rate of release/yr	Number of varieties/'million ha)	Bean Area (million ha)
1979-1990	7	5	0.7	14.6	0.478
1991-2000	9	3	0.9	15.6	0.577
2001-2010	12	4	1.2	14.3	0.842
2011-2020	15	0	2.1	13.8	1.085

Source: computed from PABRA data and FAO crop production data

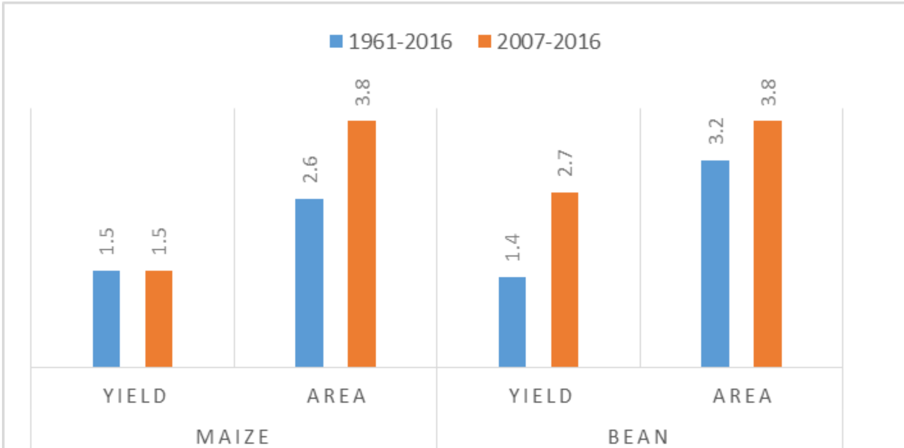
The contribution from CIAT to the bean improvement research in Tanzania over the last four decades is substantial. Although we did not carry out a full pedigree analysis due to data limitations, the available information shows that direct introductions from CIAT accounts for about 28% of the varieties released in the last 4 decades (PABRA database 2016). The average number of direct introductions has remained almost uniform at an average rate of four across decades perhaps because of slow maturity of the local breeding program in Tanzania. The National Bean Breeding programs of Tanzania has been conducting local crosses and occasionally selecting and releasing superior landraces. Between 1979 and 2000, two landraces and 3 local crosses were released while 5 local crosses were releases in the last two decades.

In the context of self-pollinated crops such as common bean, the private sector investment in seed business remains thin due to uncertain demand --requiring publically funded intervention to support adoption. Accordingly, CIAT and the National Bean Research Programs of Tanzania have been conducting action research aiming at developing integrated seed systems as an essential component of the bean improvement program. In 2003, CIAT introduced the “wider impact model” in Ethiopia (Rubyogo et al., 2010) that was later scaled out to other countries including Tanzania following its remarkable transformation of bean seed systems in Ethiopia. The model requires cultivating partnerships with major actors along the value chains, identifying partner roles in order to integrate formal and informal seed systems.

The contribution of the intensive bean improvement efforts is reflected in bean production trends. Yields reported in FAO data (2018) show an average growth rate in bean yield of about 1.3% since 1961. During 2007-2016, the period that corresponds to the intensive engagement under the TL project, bean yield grew at an average rate of 2.7%. Although still modest, this is a notable improvement especially when compared with previous bean yield growth rates of 0.8% realized between 1980 & 2006 and the yield growth rate of 1.5% experienced in the same country for maize during 2007-2016 (Figure 1).

In Tanzania, bean production mainly occurs in association with maize across different agro-ecological zones that experience climatic variability and disease pressure. Common bean is very sensitive to fluctuations in climatic conditions and highly susceptible to a range of diseases (Kweka et al., 2014). Yet, the crop production is mainly with family labour under minimal use of purchased inputs such as fertilizers, pesticides or herbicides. Earlier breeding efforts endeavored to address this challenge by including enhancement of resistance of bean to diseases as a subcomponent of the breeding goal but variety released could only address one or two constraints at a time--and farmers tended to favour local varieties that were preferred on the market (Kweka et al., 2014). Since 2000, the national programs and CIAT breeding team have pursued development of varieties with resistance to multiple constraints. In addition, farmer participatory variety selection (PVS) method based on multi-locational trials managed and monitored by farmers became a step in the breeding processes to ensure that varieties developed have traits that are important for farmers and acceptable on the market. In summary, most of the varieties released after 2000 are an improvement over old releases in terms of yield, adaptability and represent user preferences (PABRA, 2016).

Figure 1: Yield and area growth rates (%) for beans and maize in Tanzania during 1961-2016 (source: computed from FAO data, 2018)



3.0. THE STUDY AREA, SAMPLING AND DATA COLLECTION

3.1 Study area

The National Bean Research of Tanzania occurs at three agricultural research centers, each serving the needs of specific agrological conditions. They include: 1) Selian Agricultural Research Institute (SARI) focusing on the Northern zone, 2) Uyole Agricultural Research center that focuses on Southern Highland zone (SHZ) and 3) Ari-Maruku Agricultural Research Institute for parts of the Western zone and Kagera region. All the three centers participated in the TL project. However, due to limited budgets, it was not possible to conduct the impact study at national level. As such, we selected a zone that had recorded significant number of variety releases under the project, which was the Southern Highland zone (SHZ). In SHZ, the project supported development of nine varieties and their dissemination to farmers together with other five varieties, notably: Bilfa Uyole, wanja, Urafiki, Uyole03 and Uyole04[2]. Project interventions covered 18 districts, which make up 70 percent of the districts in the SHZ.

The SHZ covers the Southern and Western agro-ecological zones of Tanzania, located between 1,200–1,500m and 1,400–2,300m altitudes above sea level and made of highlands with undulating plains separated by hills and mountains (URT 2006 in Luhunga, 2017). The zone contains the most fertile land in Tanzania and a unimodal type of rainfall that starts from the month

[2] The five varieties were on the shelf at the time of project initiation in 2007

of October and goes on up to April, on an average of 100–200mm per month (Luhunga, 2017). Administratively, four regions (Mbeya, Rukwa, Iringa and Ruvuma) that form the grain basket for Tanzania and account for 24.3 percent of the total national bean area, equivalent to 194,021 ha of beans make up the zone (NBS 2013). These regions are composed of five sub agro-ecological zones that support a wide range of crops and livestock production. Bean production occurs in all the five agro ecological zones (FAO calendar:http://www.fao.org/agriculture/seed/cropcalendar); mainly planted in the months of February and March after maize has been planted in December-January.

3.2 Sampling and data collection

The study uses two main data sets collected through a survey of bean growing households implemented by the socioeconomics team of the Southern Tanzania Agricultural Research Institute (ARI) Centre at Uyole in collaboration with the International Centre for Tropical Agriculture (CIAT). The first data collection took place in 2012/2013 through a survey that covered all the four administrative regions. At the time the sampling in 2012, the project was under way in the regions, which rendered it unnecessary to stratify the study area into treated and control geographical areas before the actual survey.

The first survey used a three stage stratified and proportionate sampling method to select the households for the survey. First, a list of 20 districts that are important for bean production used as a sampling frame after removing urban districts from the 2012 National agricultural census of Tanzania report. According to the National agricultural census of Tanzania conducted in 2012, the 20 districts selected for the study consisted of approximately 2466 villages allocated in the four administrative region. Based on village population and bean area, we computed probability weights and used them to select 75 villages for the survey.

The final step was the selection of actual villages and households for the interviews. A list of wards and villages obtained from the district extension office in the selected districts formed the sampling frame for villages using random numbers. To select the households, we used a systematic random sampling procedure. The village register obtained from the local leaders served as the sampling frame and households on the list were numbered sequentially. The first household was selected at random from this list, and the remaining 9 households were chosen at fixed intervals x

= N/10 (where N = number of households on the village list) until the target number of bean farmers was reached. In total, the first survey in 2012/2013 covered 750 households in 75 villages. In the follow up survey conducted in 2016, 661 households were re-interviewed. Other households were unavailable for different random reasons.

The data were collected using a pre-tested structured household and community questionnaires. The household questionnaire elicited information on household and plot level data; mainly on socio-demographic characteristics, food consumption, social capital and networking, household characteristics and assets, sources of income as well as access to institutional services, credit and agricultural inputs and bean marketing. The plot level data was on bean production, adoption of varieties, cropping systems, plot characteristics, inputs used, other modern technologies and bean harvests. Direct interviews of household heads or spouse conducted by trained and experienced enumerators were the methods used to collect the data.

The second survey implemented between August and December 2016, on the same households surveyed in 2012/2013, used computer Assisted Personal Interviewing (CAPI) technique. Numerous quality checks were included during questionnaire programming to identify inconsistencies and prevented enumerators from moving forward with the survey before rectifying the errors. Before actual interviews with households, the survey tool was pre-tested, and adjustments made to reduce errors, interview duration, and address ambiguities.

In the two rounds of the survey, focus group discussions with key informants gathered data on community level variables that could explain varietal adoption patterns. Specifically on: availability of infrastructural services (e.g. farmer cooperatives, agricultural input distribution centers, and agriculture credit services), productive resources such as seeds and credit through extension agents, agro-input dealers and Non-Governmental Organizations, agricultural wage rates, prices of staple crops. Additional information was on village characteristics including exposure to production shocks such as drought or hailstone.

3.3 Measuring improved variety adoption

In the context of informal seed systems, as is the case of beans in Tanzania, measuring variety adoption presents different challenges. Common bean varieties differ by their genetic structure that determine their yielding potential and acceptability. Broadly speaking, landraces and improved are grown in Tanzania. Among the improved, some were released two decades ago (i.e. 1980s/1990s) and their performance in form of resistance might have been broken down due to changes in the production constraints. Moreover, new varieties released in 2002, and afterwards, are generally resistant to multiple constraints and developed in the era of participatory variety selection. In recognition of the improvements in the profile of varieties through research that was also alluded to in section 2.0, we first differentiate varieties by type (improved vs landrace) and further distinguish improved varieties into two groups based on the year of release as old (those released before 2001 and new (those released after 2000). Based on this categorization, adoption is as a multivalued categorical variable measured in an ordered manner. In reality however, crop variety adoption at farm level is often partial at either plot or household level or both.

The issue of partial adoption at household level was addressed by measuring adoption at plot level but cases of partial adoption that correspond to mixed varieties within the same plot remained. The survey data used in the study show significant number of plots that were planted with a mixture of local cultivars and improved varieties; some of the latter varieties classified as new or old—thus being partial adopters. Literature suggests different explanations for partial adoption behavior as either risk management strategy, experimentation with new technology to reduce uncertainty about the performance of new varieties (Smale et al, 1991) or gain skills (Leathers and Smale, 1991). In other context, partial adoption portray behaviours driven by the need to match varieties with microenvironments such as soil attributes (Bellon an Taylor, 1993[3]). Thus ignoring this category will miss out important information in the analysis. Thus, plots planted with mixed varieties were differentiated as a distinct level of adoption now defined as a multivalued nominal variable that can potentially be observed at four levels: 1) for plots planted with new improved varieties, 2= of varieties are old releases, 3= improved and local mixed and 0= for local varieties only.

[3] Bellon, M and Taylor, JE (1993) "Folk" Soil Taxonomy and the Partial Adoption of New Seed Varieties. Economic Development and Cultural Change. DOI: 10.1086/452047.

4.0 DESCRIPTIVE STATISTICS ON ADOPTION AND DIFFUSION OF VARIETIES

In this section, we provide an overview of variety diffusion across farms and compare attributes of varieties that have diffused faster with those they are replacing to begin to identify variety traits that may be driving adoption. Then we describe farm-level adoption patterns that informed our choice of adoption measure for multivariate analysis of adoption.

4.1 Improved variety adoption rates and diffusion patterns

This section examines the extent of variety diffusion in terms of the percentage share of growers and land share planted in 2013 and 2016. Before embarking on describing varieties that have diffused faster, it is better to provide an overview of improved variety adoption and spatial diffusion patterns.

Half of the bean growing households have adopted improved varieties cultivated by 50% in 2016; 42% of the household are growing improved varieties released after 2001 and 18% of the households grow improved varieties released before 2001 (old releases). The adoption rate for new varieties raised from 32% in 2013 to 42% in 2016, which is equivalent to 3.3% annual growth in adoption rate (Table 2). Table 2 also shows that the adoption rate of the same varieties in terms of area share increased from 21% in 2013 to 25% in 2016. This is evident that farmers are shifting from old to new varieties.

Table 2. Cultivar specific adoption levels in 2013 and 2016, Southern Highlands of Tanzania

Variety category	Variety	Year of release	% of households		Area share (%)	
			2013	2016	2013	2016
Improved varieties released before 2002	Kabanima	1979	**4.80**	7.51	5.31	8.93
	Uyole 84	1984	4.20	2.56	3.22	2.38
	Lyamungo 90	1990	0.00	0.17	0.00	0.01
	Uyole 90	1990	0.15	0.00	0.03	0.00
	Uyole 94	1994	2.85	2.73	0.78	0.93
	Uyole 96	1996	**11.86**	3.75	5.45	1.57
	Uyole 98	1998	0.30	1.02	0.07	0.50
	Sub total[NB]		**23.12**	**17.07**	14.86	**14.32**
Improved varieties releases in 2002 and	Wanja	2002	**6.31**	8.53	4.04	4.23
	Bilfa Uyole	2002	0.30	0.00	0.11	0.00
	Urafiki	2003	0.00	0.68	0	0.40

afterwards (i.e. developed and/or disseminated under the Tropical legumes project)	Uyole 03	2003	**6.16**	8.70	3.56	3.97
	Uyole 04	2004	2.10	3.58	1.66	1.15
	Njano_Uyole	2008	**14.11**	16.04	7.87	10.61
	Roba1	2010	0.45	0.17	0.49	0.04
	Calima Uyole	2011	3.00	3.92	2.66	2.65
	Rosenda	2012	0.00	0.34	0.00	0.52
	Fibea	2012	0.00	0.17	0.00	0.10
	Subtotal[NB]		**30.63**	**37.89**	**20.39**	**23.67**
	Overall adoption			**50.00**	**35.24**	**38**

Source: survey data, 2013 & 2016. NB: subtotal are computed based on % of households that cultivated the category of varieties rather than total of individual variety adoption rate, thus is not equivalent to individual variety sum.

The proportion of households growing old releases decreased from 23% in 2013 to 15%, whereas the share cultivated with the same varieties dropped from 15 to 14%. These trends are also notable in the geographical spread of new improved varieties in the study area. By 2013, new varieties were mostly cultivated in the Northern and Central parts of Southern Tanzania, with the highest adoption rates reported in Kilolo and Mbeya rural districts. On the other hand, old releases were concentrated in the two districts of Namtumbo and Songea districts (figure 2b.) Between 2013 and 2016, there was a significant increase in the diffusion of new improved varieties within and across districts between 2013 and 2016. Most districts observed more than 20% of their bean-growing households that planted new varieties in 2016. Additionally, varieties released after 2001 spread further to new households, including those in districts of Songea, Ludewa, Mbarali, Mufindi and Mbozi, where adoption rates recorded in 2013 were low. During the same period, the proportion of households growing old releases decreased in their stronghold districts of Namtumbo and Songea districts of Ruvuma region, where they have been replaced by varieties released after 2001 (Figure 2c).

Figure 1.a ***District profile for adoption of*** **improved varieties released before 2001 in 2013**

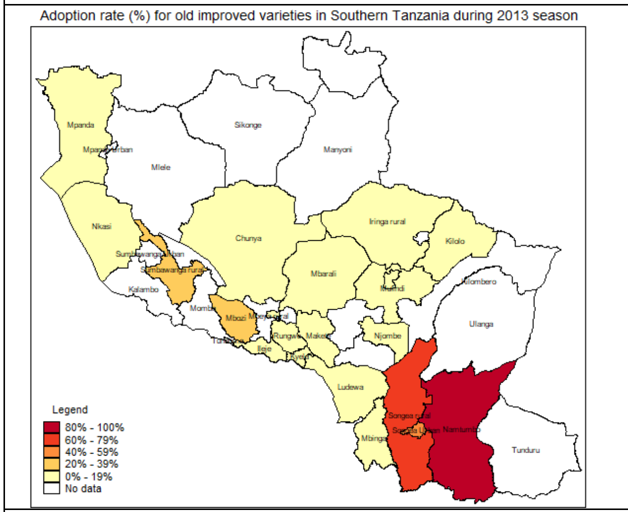


Figure 1.b ***District profile for adoption of*** **improved varieties released in 2002 & afterwards in 2013**

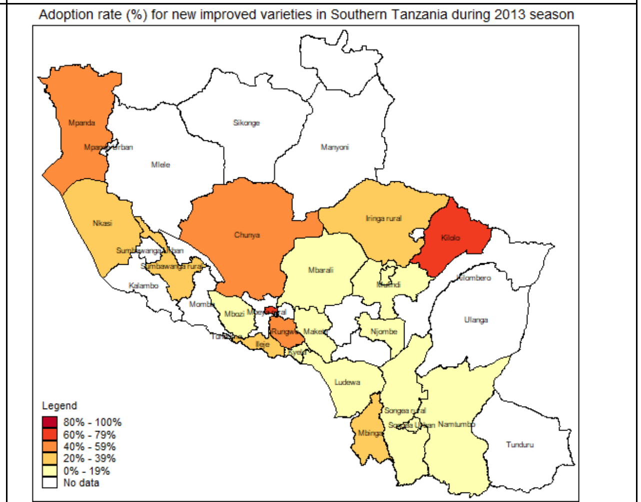


Figure 1.c ***District profile for adoption of*** **improved varieties released before 2001 in 2016**

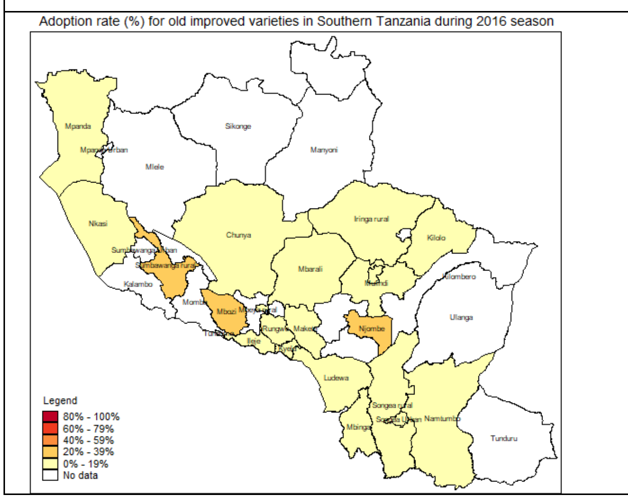
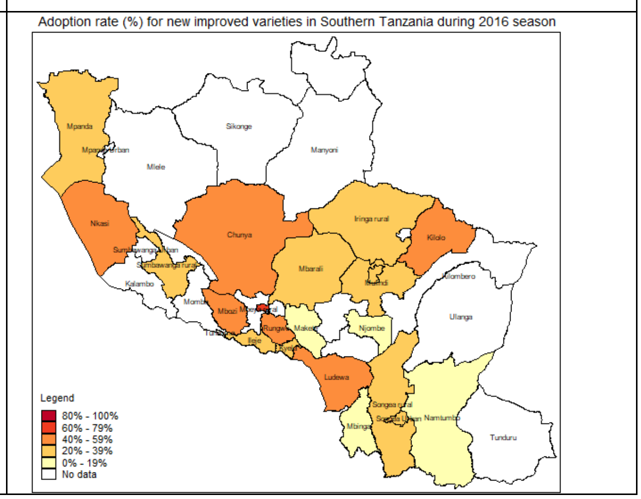


Figure 1.d ***District profile for adoption of*** **improved varieties released in 2002 & afterwards in 2016**



The adoption rates for improved varieties released after 2001 is higher in districts that are located in the borders with countries that import beans from Tanzania (Figure 2.d). More specifically, these are the districts (Namtumbo, Songea & Mbozi) that border with Mozambique, Malawi and Zambia. This perhaps reflects the high demand of these varieties in the export markets and information flow facilitated by the power of weak ties that provide micro-macro bridges (Granovatter, 1973).

4.2. Fast diffusing improved varieties and their relative importance

Overall, farmers reported 17 improved varieties that were cultivated on 38% of the bean area in 2016. Four of the improved varieties (i.e Njano Uyole, Wanja and Uyole 03 and Kabanima) occupied 28% of the total bean area and account for 70% of the area under improved varieties, --thus being the most popular improved varieties grown[4]. The four popular improved varieties have spread to nearly all districts but they vary in patterns of districts where they are concentrated. Wanja was concentrated in Chunya 60-79% of the households cultivate it and fairly diffused in three districts of Iringa rural, Mlindi and Ludewa. On the other hand, Njano-Uyole variety is concentrated in five districts of Nkasi, Songea rural, Kilolo, Mbozi, Mpanda and Nkasi. In Songea rural, Njano Uyole has dislodged Uyole96 that was popular and traded across borders to Mozambique. While the adoption of Kabanima variety is highest in Sambawanga rural, where 20-39% of the households cultivate it, geographical adoption patterns for this variety are not as clustered as for the Wanja and Njano-Uyole (Figure 3d). The varietal clustering may suggest presence of contextual factors linked to agro ecological systems or socioeconomic factors that influence users' preferences. The seed dissemination strategies used to promote the varieties could also biased the adoption into selected districts resulting in adoption clusters.

[4] Wanja was grown by 8.5% of the households; Njano-Uyole, by 16%; Uyole03 by 8.7% and Kabanima by 7.5 % of the sampled households

Fig 3 a. District profile of adoption of Njano-Uyole, 2016

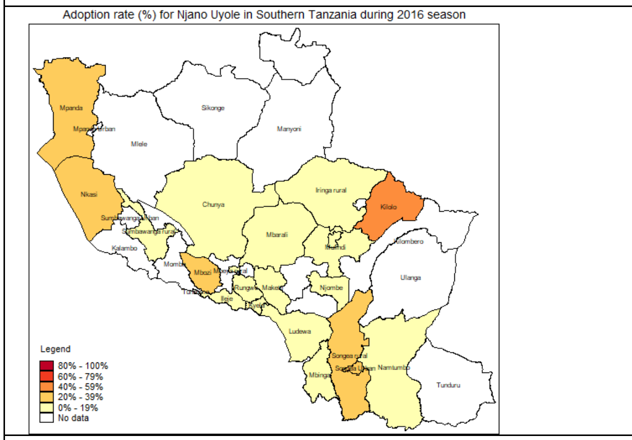


Fig 3.b; District profile of adoption of wanja, 2016

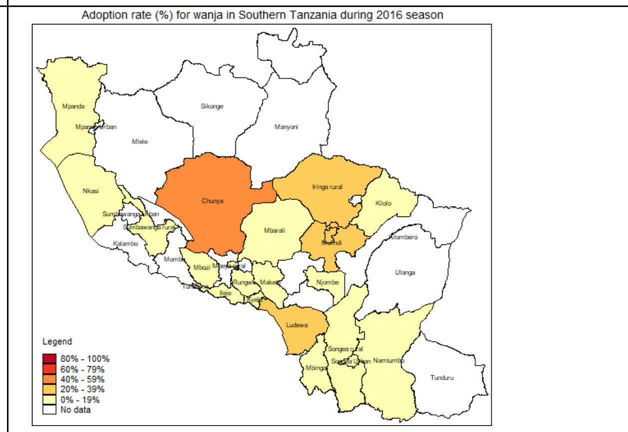


Fig 3.c District profile of adoption of Uyole 03 in 2016

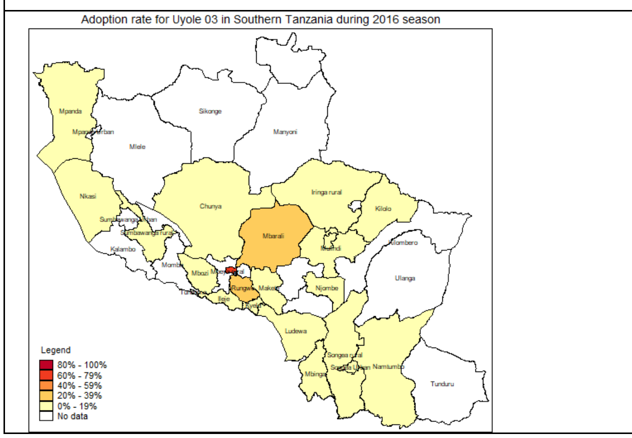
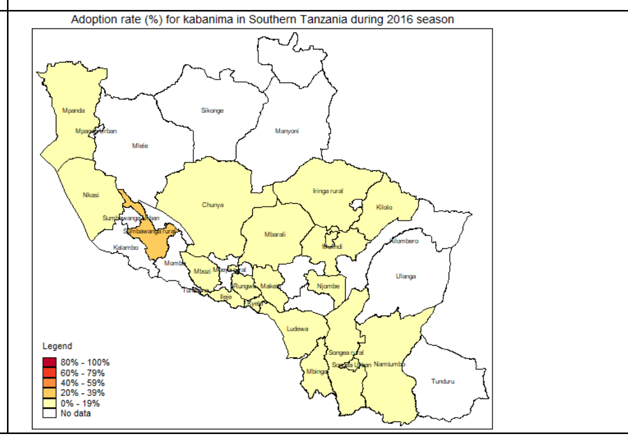


Fig 3.d District profile of adoption of Kabanima, 2016



4.3. The Performance of popular varieties as compared with Uyole96

With the exception of Kabanima released four decades ago, the three popular varieties were released between 2001 and 2009—thus diffusing rapidly. The fast diffusion of new varieties may reflect an improvement in the trait levels of that makes them more attractive to farmers or possible biases in seed marketing toward the varieties[5]. During the survey, each farmer was asked to rate each variety performance on a five point scale; where 1=very poor, 5 excellent and the score of 3 depicts an average rating. Then using an equality score test, each of the four popular varieties (i.e.

[5] We are unable to test the l biases in seed marketing as possible explanation for faster diffusion of these varieties due to lack of variety disaggregated data on seed multiplication and dissemination.

Njano Uyole, Wanja, Uyole 03 and Kabanima) was compared with Uyole 1996 in terms of attribute rating. The average score ratings for each attribute is shown in table 3 and reveal that Njano-Uyole, the most popular improved variety, performs statistically better than Uyole1996 in most attributes. It was scored higher than Uyole96 in terms of market demand, price of grain, short cooking time, colour (yellow), taste of grain/leaves, storability and enhanced resilience to drought. Farmers also perceive the three popular varieties to perform better than Uyole96 under low fertilizer treatment, thus more suitable for their farming conditions that are characteristics by low use of purchased inputs.

Table 3. Variety attribute performance as stated by farmers for popular varieties compared to Uyole96[NB]

Attributes	Njano Uyole	Wanja	Uyole 03	Kabanima	Uyole 96
Production					
Yield	4.32	3.89	4.15	4.51**	4
Maturity period-early	4.17**	3.58	3.40*	3.6	3.71
Ability to withstand excess rainfall	3.44**	2.74	3.00	3.54***	2.86
Drought tolerance	3.49***	2.76	2.7	3.22**	2.67
Fertilizer requirement	3.07***	2.71**	2.75***	3.05***	2.05
Pest tolerance	3.29	3	2.95	3.3	3.05
Disease tolerance	3.24	3.24	3.1	3.27	3.29
Processing and marketing					
Ease of shelling	3.90***	3.26**	2.95*	3.81***	2.57
Storability	3.73***	3.37**	3.19*	3.47*	2.71
Market demand	4.4***	3.83	3.91	4.11*	3.52
Price the grain fetches	4.44***	3.6	3.81	3.78	3.43
Cooking time	4.30***	3.77	3.52	3.73	3.48
Color	3.86***	3.26	3	3.3	2.95
Size of beans	3.49	3.6	3.29	3.38	3.43
Consumption traits					
Taste of beans	4.07**	3.87	3.24	3.22	3.48
Taste of leaves	3.95***	3.34*	2.71	3.14	2.76
Overnight keeping quality	3.74***	3	2.91	3.24	2.95
Nutritional value	3.74***	3	2.91	3.24	2.95

4.3. Household level adoption patterns and access to seed

Adopting and non-adopting households are similar in terms of demographic characteristics such as age, household size, gender, and education but differ in livestock endowments, social networks and farm location with respect to elevation and soil pH. A typical household consists of 5.1 people, with each active member (15-64 years of age) working for 1.5 consumers in the household[6]. On average, households are headed by individuals aged about 50 years, with an average of 7 years of schooling and 83% of them are males (Table 4). For livestock ownership, adopters of old variety releases fare better. This group of households tend to have more livestock units and live at higher elevation than households that grow local or new improved varieties (0 & 1). Adopters and non-adopters have similar amount of land allocated to bean cultivation and land holding, which is about 4 Ha per households.

Access to a technology such as seed of improved varieties is a precondition for adoption. The survey, included questions on sources of seed and means of access, i.e. whether purchased, exchanged or free. As indicated in figure 4, majority of the farmers rely on their own saved seed, seed obtained from other farmers within the village or on seed purchased from the nearby rural grain market.

Table 4. Selected characteristics of the sample by adoption status

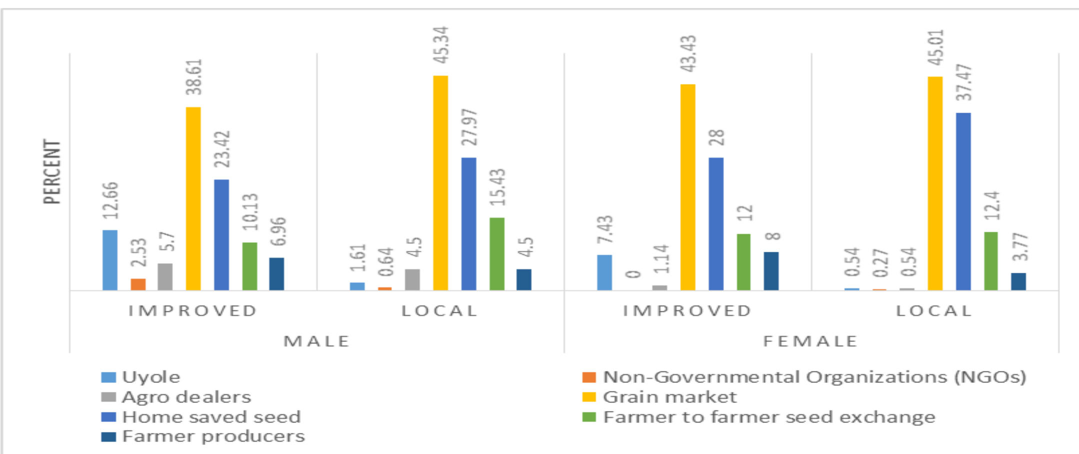
Variable	**Total Sample**	**Non-adopters (only local)**	**Adopters of IV new releases**	**Adopters of IV old releases**	**Partial adopters (variety mixtures**
Age HH head	49.57	49.39	49.48	48.72	50.01
	11.85	11.98	11.39	10.17	12.59
Sex of HH head (1=male	0.83	0.83	0.86	0.76	0.84
	0.37	0.38	0.35	0.43	0.37
HH head years of schooling	6.96	6.79	7.4	7.27	6.88
	2.72	2.15	4.02	1.9	2.98
Household size	5.11	5.00	5.30	5.25	5.22
	1.92	1.95	1.63	2.34	1.88
Ratio of dependents to	0.56	0.57	0.54	0.60	0.54
active HH members	0.22	0.22	0.20	0.20	0.21
Tropical livestock units	1.91	1.64	1.92	**3.14**	2.08
	2.92	2.41	3.28	3.97	2.6
Land holding (ha)	3.82	3.56	3.62	**5.56**	4.1

[6] There are 0.55 dependents (those that are either aged below 15 or above 64years) per one active member.

	6.14	5.01	6.07	11.59	5.83
Wealth index	0.75	0.75	0.75	0.77	0.74
	0.37	0.37	0.38	0.38	0.36
Distance from village to	85.38	**90.31**	**91.68**	49.4	86.6
good road(min)	91.84	92.75	96.99	71.1	92.96
Distance from residence to	8.89	7.28	**12.22**	9.44	9.48
cooperative (km)	15.80	13.38	17.68	17.12	18.41
Distance from village to	12.62	12.37	**13.93**	11.90	11.83
input distribution (km)	18.57	17.74	19.43	19.10	19.57
Village elevation	1470.59	1444.26	1440.05	**1657.29**	1502.49
	395.65	420.18	368.1	307.01	337.38
Distance to seed centre (min)	85.38	53.13	59.58	33.24	45.22
	91.84	72.16	85.43	44.27	63.38
Distance from Mbeya town	257.23	270.43	**216.25**	273.67	255.24
(km)	201.08	215.38	187.35	162.65	188.31
Soil Ph. (%)	58.97	58.61	59.33	**59.85**	59.07
	2.41	2.43	2.58	2.02	2.13

NB: Bold depict statistically higher than other figures; **,* denote significant 1 & 5 % levels respectively. SD are standard deviations and IV=improved variety

Figure 4: sources of seed by bean type used by farmers in 2016



Actors in seed supply chain such as Uyole Research center, NGOs and agro dealers represent formal seed systems and reflect multiple strategies to strengthen the formal and informal linkages. Besides being suppliers of early generation seed to private seed companies and specialized farmer seed producers, Uyole Research Center proactively engaged in direct seed distribution in villages as a strategy to create awareness, stimulate seed demand and catalyze the seed access in the informal seed systems. Community level data revealed that direct seed distribution covered 17% of the sampled villages and was mainly carried out by the government extension agents and Research Program at Uyole (85%), whereas NGO's and Rafael group[7] operated on a small geographical scale (15%) of the sampled villages. Overall, villages that received direct seed distribution tended to be closer (about 171km) to Mbeya town, where the Uyole Agriculture Research Center is located, than those that were excluded from seed distribution (about 279km from the same town)[8]. This suggests that the interventions by public institutes to create awareness about the new technology may not have been random, which perhaps explains higher adoption rates in communities closer to the research station (Table 4).

Farmers in villages without seed distribution program can possibly obtain improved seed from inputs market centers or seed distribution centers, which are respectively available within in a distance of 12 km from the villages and approximately 85 minutes walking time (Table 4). Long distance to seed sources can potentially constrain adoption of improved bean varieties in early stages of technology diffusion as has been reported in case of fertilizers in Ethiopia (Minten et al., 2013).

4.4 Plot characteristics and adoption patterns

Plot level analysis reveals more complex adoption patterns. It is evident that partial adoption of improved bean varieties is common in Southern highlands of Tanzania. Out of the 776 bean plots in the data, 153 were cultivated with only improved varieties released after 2001 and 63 plots were solely under old releases, whereas 444 plots were solely planted with local varieties—suggesting that farmers tend to hold on to their local varieties. The remaining plots were cultivated with a mixture of local and improved varieties. From bivariate analysis, we see that plots cultivated with variety mixtures contain, on average, 2.6 varieties. Households who mix improved varieties with local ones also tend to allocate smaller area to bean production (0.49Ha). On average, households cultivate 0.6 ha of beans, which constitutes 23-27 percent of the total land owned. Bean area is

[7] In about 54% of the sampled villages it was reported that beneficiaries pay some amount of money for the seeds they receive.

[8] Comparisons of mean distance from Mbeya town by seed distribution was done using T-Test statistic

significantly smaller among growers of mixed varieties and larger for household that grow old improved varieties (Table 5).

Farmers tend to adopt improved varieties on plots that are of relatively higher soil pH and are located at the bottom or valley of the gradient, whereas local varieties are cultivated on plots whose soils tend to be of lower pH and on steep slopes (Table 5). Majority of the farmers cultivate new improved varieties within their existing plots, by either displacing an old improved variety, local variety or another crop—which in most cases is maize[9].

Table 5: Plot characteristics and crop management systems by adoption status

	Local varieties		New improved varieties		Old improved varieties		Mixture (IV+loc	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number observations	444		153		63		100	
Cultivated bean area (ha)	0.564	0.44	0.537	0.444	0.83	0.752	**0.494**	0.4
% land occupied by bean	0.264	0.237	0.251	0.234	0.332	0.236	0.234	0.211
Number of bean plots	1.70	0.86	1.71	0.80	1.52	0.72	1.17	0.43
Bean plot size (ha)	0.344	0.266	0.345	0.307	0.545	0.490	0.479	0.444
Number of varieties	1.92	0.99	1.86	0.89	1.65	0.83	2.56	0.87
distance to plot (min)	42.4	70.9	37.7	43.2	41.7	30.5	42.5	41.4
Altitude	1436.6	421	1433.2	365.8	1659.6	310	1498.2	340.9
Soil pH (%)	58.6	2.4	59.3	2.6	**59.9**	2	59.1	2.1
Plot manager(counts)								
Female	241		74		28		56	
Male	203		79		35		44	
Plot slope (1=yes, 0=no)								
bottom/valley	0.45		0.58		0.46		0.45	
Moderate/gentle	0.48		0.38		0.51		0.46	
Steep	0.06		0.04		0.03		0.09	
Soil fertility (1=yes, 0=no)								
Good	0.45		0.52		0.3		0.35	

[9] In about 62% of the plots, farmers indicated that they reduced on maize population (usually intercropped with beans) when adopting improved bean varieties. This is not surprising given the yield trends in figure 1, which shows that in the last decade, bean yields have been growing faster than those of maize.

Medium	0.52	0.44	0.68	0.62
Poor	0.03	0.04	0.02	0.03

4.5. Bean crop management, per hectare output and utilization

Table 6 summarizes the mean values of variables that determine the productivity of one bean production cycle. Inputs commonly used in bean production are family labor and seed whereas use of purchased inputs such as fertilizers, herbicides and pesticide is generally low. The average amount of labour (84 man-days), herbicides (0.49 Lt/ha) and fertilizer used (23kg/ha) do not vary significantly between plots distinguished by adoption status. Plots cultivated with improved bean varieties received significantly more kgs of seed per hectare (70kg/ha) than those planted with local varieties (59kg/ha).

Table 6. Descriptive statistics of bean production inputs, prices and yield

	Total sample	Local varieties	New improved varieties	Old improved varieties	Improved and local mixed
Number of plots	773	444	153	63	100
Yield (kg/ha)	745.06	654.2	**871.6**	778.2	719.7
	534.57	396.8	513.7	527.3	617.0
labour m-days/ha	83.90	83.1	94.4	73.7	83.5
	66.99	65.1	78.4	58.2	60.8
Quantity of seed (kg/ha)	63.23	**58.93**	70.43	70.81	69.07
	42.19	39.45	46.77	51.37	42.05
Amount of Fertilizer (kg/ha)	23.09	21.7	22.0	24.4	32.3
	42.38	42.0	42.1	41.7	46.3
Herbicide kg/ha	0.49	0.32	0.83	0.79	0.67
	1.19	0.92	1.51	1.39	1.45
	652.68	680.07	621.60	692.7	653.30
Unit cost of seed (Tsh/kg)	1457.04	1538.15	1506.24	1346.09	**1204.32**
	693.71	686.55	760.75	685.01	599.91
Unit price of bean grain Tsh/kg	1141.80	1157.62	1123.28	1096.67	1108.79
	544.18	558.01	520.27	439.84	568.70
Average wage rate (Tsh/day	5050.51	5109.23	5071.90	4825.40	4900.00
	1706.86	1772.92	2000.00	1819.50	1478.81
Manure use (%)	10.70	11.5	9.2	11.1	11.0

Pesticide used (%)	31.83	**25.5**	38.6	46.0	40.0

NB: Bold imply significantly different. Unit cost of seed is computed based on subsample of HH that bought seed and is averaged across sources.

The higher yielding properties of improved bean seed is evident. The average yield on plots that were cultivated with bean varieties released after 2001 in 2016 season was 890kg/ha, which is about 220kg/ha higher than the yield from local varieties. Bivariate analysis also suggest that new releases perform better than old releases (890kg/ha vs 816kg/ha). On the other hand, plots cultivated with variety mixtures (i.e. local + improved) tend to have low yields but slightly perform better than local varieties.

Table 6 also shows that the adopters fare better than non-adopters in terms of the total bean sales. By comparison, adopters sell a bigger proportion of their production (52%) than non-adopters (41%), thus implying that use of improved bean varieties may increase marketed surplus. On the other hand, households that mix improved and local in the same plot tend to market a small proportion of their production (38%) than full adopters, which implies that partial adoption is motivated by the food security objectives. Adopters and non-adopters do not systematically differ by the price of bean grain prevailing in the community to suspect that differences in market incentives could have motivated by adopters to sale more of their production.

5.0 IMPACT OF IMPROVED VARIETY ADOPTION: ECONOMETRIC ESTIMATION.

5.1. Impact on bean yield

The impacts of Tropical Legumes project on the economic wellbeing of smallholder bean growing households in Southern highlands of Tanzania is estimated in two stage process. In the first stage, we estimate the adoption of improved bean promoted under the project and derive the latent propensity to adopt. We measure adoption as a choice of a bean variety to plant in a plot pre allocated to bean production and conceptualize it within an agriculture household model (Singh et al., 1986), in which a household's production and consumption decisions are non-separable. In this framework, farming families maximise utility they derived from an agricultural good, leisure and purchased good given a set of constraints. Common constraints faced by bean growers in Tanzania include those on the budget, access to information, credit and the availability of improved seed and other inputs. In view of these constraints, farmers can choose to adopt fully by replacing local or old variety with a new variety. Alternatively, the farmers have the option of growing new variety alongside old variety, in which case the new varieties would compete for limited land with existing bean varieties.

If adopted, improved variety should provide increment on the total harvested bean per unit area, but the level of yield gain would depend on the newness of the variety. Therefore, it is important to understand how variety age influences yield in order to draw lessons and inform decisions on resource allocation. The study uses a multinomial logit model since plot level variety use is a categorical multivalued variable defined as 1= only improved seed promoted under the project, 2= improved seed developed and disseminated before the project, 3= a mixture of local and improved varieties & 4= local varieties only. On-farm trial data provide evidence that improved varieties promoted under the TL project, i.e. released after 2001, are higher yielding and can tolerate multiple constraints—thus an improvement on the varieties released earlier ((i.e. before 2000). Moreover, older improved varieties have been re used several times, which could have reduced their efficacy. While there are three categories of varieties that portray an ordered improvement, some plots combine the three categories--thus creating partial adoption as alternative treatment level.

In the second stage of our analysis, we identify the causal effects of improved bean variety adoption on outcome variables: yield, crop income and bean sales. The fundamental challenge, however is that we only observe outcomes of beneficiaries, but we do not observe the outcomes of the same beneficiaries if they did not adopt the variety—thus, we face a problem of missing data (Imbens and Angrist 1997; heckman, Ichimura and Todd, 1997). Randomised experimental designs are the “gold standard” for addressing this challenge given that individuals in treated and those in the control groups are selected randomly to be identical except that one of them receives the treatment. In the context of this study, (i.e.Tropical Legumes), randomized experiment approach was less likely to succeed given that the interest of the project implementers was to reach a wide population, which they pursued via multiple public-private partnerships. In the absence of randomization, which is common with cross sectional survey data used in this study, matching techniques restore randomness by mimicking experiment ex-post. According to Rosenbaum and Rubin (1983), conditioning on the propensity score –the probability of receiving the treatment given the covariates, rather than on the full set of covariates, is sufficient to balance treatment and comparison groups. This literature was extended to multivalued treatment by Imbens (2000).

As in the binary case, multivalued treatment effects are conditional on observable characteristics. We apply inverse probability weighted regression adjustment (IPWRA) method developed by Robins and Rotnitzky (1995) and van der Laan & Robins (2003). IPWRA combines Propensity score matching and regression adjustment technique to ensure consistent estimates of the treatment effects parameters.

Outcome model: $Y_{ijk}; f(\beta_i, X_i) + \varepsilon_i$ (1)

Treatment model: $pr(T = 1,2,-- j) = h(\alpha\ Z_i) + \omega_i$ (2)

Where T is the indicator for adoption status, measured as a multivalued treatment in which, each subject could receive one of the several different treatments or else not receive treatment at all. Y_{ijk} is the potential outcome k of a household i that receives treatment level j, i.e. adopter category j. Then X is a vector of covariates that influence the outcome Y_{ik}, whereas Z is a vector of covariates that explain treatment assignment, T; Vectors X and Z may overlap. Vectors ε, ω consist of random components of respective equations and are assumed to be correlated.

Now, let Y_{i0k} denote the potential outcome of a household i that did not receive any treatment (i.e. grew local varieties). In the context of a multivalued treatment, the individual plot/household treatment effects can be expressed as: $Y_{ijk} - Y_{i0k}$ for $t \in (1,......j)$. Then the average treatment on the treated is estimated as:

$$ATET_{ipwra} = N_j^{-1} \sum_{i=1}^{N^j} (\hat{Y}_{ijk} - Y_{i0k}) \qquad (3)$$

According to Woodridge (2010), IPWRA can achieve some robustness to misspecification in the parametric models (i.e. propensity score or regression adjustment model) as long as one of them is correctly specified. Because of this property, IPWRA is called is a double robust estimator. The IPWRA technique has been applied in estimating impacts of variety adoption by Smale et al., 2018; Bonilla et al., 2018). IPWRA is implemented as a three steps estimation procedure. In the first step, the probability that the individual is treated (i.e. belong to adoption level j) is estimated and the propensity scores predicted. The inverse of the probability that each observation is in the treatment or control group is used to re-weight the sample in the second step. This creates a sample in which the distribution of covariates is independent of the treatment—thereby ensuring that the requirement of weak confoundedness is satisfied. In the third step, the expected outcome is estimated for each observation using a weighted outcome model that includes some of the observable characteristics used to estimate the treatment model and additional information. In our case, we use linear outcome functions and estimate using inverse probability weighted least squares.

The IPWRA, however can only address self-selection that is based on observables, but does not control for biases that may stem from unobservable heterogeneity between the treated (adopters) and untreated individual (non-adopters). For example, if farmers who choose to adopt are systematically different from those who do not in a way that is unobserved to the research, our estimates from IPWRA will be biased. In order to ensure the robustness of our results, we include in the treatment model, variables that control for intrinsic unobservable factors related with plot characteristics and plot management. A similar strategy was used by Smale et al., 2018 in their estimation of sorghum variety adoption impacts on household welfare in Sudan. The application of the inverse propensity scores also requires that the propensity score is non-zero and less than one for all observations (i.e. this is a condition for common support). To assess for this property in our data, propensity scores for treated and control observations were plotted on graphs to examine the overlap of the distributions. Figure 5.4 shows that these distributions do, in fact, overlap.

5.2. Effect on income from beans

While producing improved bean varieties is expected to yield greater output per unit area, its adoption may be accompanied by changes in input usage that engender greater production costs. Thus, the effect of improved bean variety adoption on crop income obtained by the adopting household depends on the change in private profits. Following Larochelle et al., 2015, the change in the private profitability of shifting from local to improved bean is estimated as the difference between observed and counterfactual profits:

$$\Delta\pi_{ij} = (R_{ij} - C_{ij}) - (R^{*}{}_{ij} - C^{*}_{ij}) = \Delta R_{ij} - \Delta C_{ij} \quad (4)$$

Where, (R_{ij}, C_{ij}) and (R^*_{ij}, C^*_{ij}) are the observed and counterfactual revenue and cost pairs per hectare of variety category j cultivated by household i. If we assume a fixed village bean grain price (P_k) during the cropping season of the study[10], the per hectare change in revenue (ΔR_{ij}) obtained by adopters varies as a function of only change in value of yield given by (ATET) for a shift from local to improved bean varieties i.e. $\Delta R_{ij} = ATET_{ij} * P_k$. Similarly, the change in production cost (ΔC_{ij}) due to adoption of improved varieties is calculated as the difference between the observed cost (C_{ij}) and counterfactual cost (C^*_{ij}). The counterfactual input usage depends on observed input level and average percentage changes in input use intensity resulting from adoption of improved varieties plus the cost of technology (i.e. seed). Comparisons of means of quantities used on hectare basis across adoption status[11] based on ANOVA show that adoption of improved bean results in upward adjustment in quantity of seed, while the usage of labour, herbicides and fertilizer is not affected by adoption of new varieties (Table 6). Therefore, the change in production cost is expressed as a function of input k for which adjustment occurs and the cost of technology.

$$\Delta C_{ij} = \sum (x^1_{ijk} - \frac{x_{ijk}{}^1}{1 + \Delta x}) n_k \qquad 5$$

Where $x^1{}_{ijk}$ represents the observed use intensity of input k in plot j cultivated by household i .

To estimate the cost of improved seed, each farmer was asked his/her source of seed that was planted in 2016 cropping season, the quantity planted and its cost by variety. For farmers that planted seed from their previous harvest or farmer-to-farmer seed exchange, an imputed value was attached on the assumption that they bought seed during the season when adoption occurred. As the data shows, the unit value of seed varies by seed type (i.e. local vs improved) at each source (i.e. grain market, farmer seed producers and agro dealers)[12]. For farmers who planted own saved improved seed in 2016.

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[10] The price information was gathered from the community survey

[11] The comparison of means was performed based on a matched subsample using weights computed from propensity score.

[12] Price of seed from own savings and farmer to farmer exchange does not vary by type.

5.3. Effect of IV adoption on market participation intensity

Smallholder bean producers participate in the market as sellers or buyers. In this study, we focus on the participation in market as sellers, measured as the quantity of bean sold. There are households who decided to sell part or all their bean harvest and a few who did not sell any part of their harvest. If we assume that the amount of bean sold is a linear function of the bean variety type cultivated and other explanatory factors, then a bean marketed surplus model can be expressed as:

$$M_i^* = \lambda H_i + \pi T + \mu_i$$
$$M_i = \begin{cases} M_i = M_i^* > 0 \\ 0 \quad M_i^* \le 0 \end{cases} \tag{6}$$

Where M_i^* is the latent unobserved variable denoting the total volume of bean farmer i supplies to the market. The variable M is the observed amount of bean sales and equal to the latent variable when the household decides to sell and observed as zero for non-market participation. Then, *H* is a vector of variables that explain the variations in the amount of observed bean sales. The variable T_{ij} denotes the adoption decisions expressed as a function of explanatory factors in vectors $Z_i \,\&\, \omega_i$ (eq.2), some of which also influence market participation.

To account for potential censoring bias, a selection model characterizing the decision on whether or not to sell beans in equation 4 is estimated first using a probit model

$$\Pr obit(dsale = 1) \quad if = \Pr ob(\text{M>0})$$
$$= d(s_i \eta_i) + v_i,\ v_i \text{ N(0,1)} \tag{7}$$

The variable "dsale" is a qualitative indicator of whether a household sold any beans in the study season, s is a vector of variables that explain the decision on whether or not a household sells bean, η_i is a vector of parameters to be estimated. The mills ratio (λ) is then calculated as $\phi(\eta_i K_i) / \Phi(\eta_i K_i)$ [13] and included in the main model of market participation intensity alongside other potential explanatory variables in vector (H) of the quantity of bean sold (M) in order to correct for selection bias.

[13] ϕ, Φ are the respective probability density and cumulative density functions.

$$M_i = \psi_j H + \iota\lambda_i + \pi_j T_j + \mu \qquad (8)$$

Equation 8 is then estimated with Inverse weighted probability regression to account for potential endogeneity of adoption in market participation intensity as specified in equation 2.

6.0 RESULTS FROM ESTIMATION

In this section, we present results from econometric estimation, beginning with the determinants of bean variety choice.

6.1 Determinants of IV adoption

Results from the multinomial logit (MNL) estimated in the first stage of IPWRA reveal the determinants of the variety choice (i.e. adoption of improved bean variety outcome). Taking local varieties as the baseline adoption, results in table 7 reports the coefficients as well as the marginal effects from MNL. The likelihood ratio test statistic from MNL as shown by the chi-square value (157.7) was highly significant ($p < 0.001$), which suggests that the model adequately explains the variation in the adoption data. The results interpreted are the marginal effects and appear in column of table 7.

Table 7. Determinants of improved variety adoption

	New improved varieties			Old improved varieties			Improved mixed with local varieties		
	me	Std. Err.	P>z	Me	Std. Err.	P>z	Me	Std. Err.	P>z
Age	0.067	0.076	0.378	0.045	0.052	0.386	0.0451	0.0646	0.485
Years of schooling	0.017	0.006	0.006	0.005	0.005	0.354	-0.002	0.0061	0.762
dependency ratio	-0.105	0.08158	0.198	0.06499	0.0507	0.2	-0.076	0.0687	0.268
Elevation (masl)	0.004	0.059	0.94	0.133	0.066	0.043	0.0477	0.0625	0.446
Soil fertility moderate	-0.068	0.035	0.049	0.025	0.024	0.286	0.0598	0.0316	0.058

_Poor	0.054	0.088	0.537	-0.029	0.074	0.696	-0.021	0.0938	0.822
Slope									
moderate	0.002	0.036	0.956	-0.014	0.024	0.549	-0.017	0.0319	0.585
Bottom/valley	-0.026	0.076	0.727	0.002	0.055	0.967	0.0554	0.0585	0.344
Distance to cooperative (km)									
1	0.0266	0.04153	0.522	0.02983	0.0271	0.271	0.0161	0.035	0.645
2	0.0395	0.04064	0.331	0.03087	0.0279	0.268	-0.023	0.037	0.527
Iringa	-0.190	0.050	0.000	-0.008	0.036	0.817	0.0056	0.0441	0.9
Rukwa	-0.137	0.055	0.013	0.145	0.042	0.001	-0.015	0.0517	0.771
Ruvuma	-0.266	0.065	0.000	0.046	0.048	0.337	0.0295	0.0495	0.551
Intercropping (%)	-0.001	0.00055	0.031	0.0006	0.0004	0.174	2E-05	0.0005	0.969
time (hrs) to paved road	-0.011	0.01067	0.307	-0.0219	0.0093	0.018	-0.008	0.0103	0.447
wealth index	0.0569	0.0451	0.207	0.0292	0.0313	0.352	-0.034	0.0406	0.402
Land size (ha)	0.0142	0.02024	0.484	-0.0305	0.0141	0.03	0.007	0.0182	0.7
Soil_PH	0.0137	0.00696	0.049	0.01026	0.0058	0.078	0.0031	0.0065	0.635
dist_adopt_new	0.0028	0.00089	0.001	-0.0012	0.0009	0.155	0.0018	0.0008	0.02
Likelihood ratio Chi2 (57)	157.97	Prob > chi2		0.0001					
Log likelihood	-602.1								
Number of obs	600								

The results indicate that the adoption of improved varieties is influenced by the access to the technology, characteristics of the physical production environment and market conditions. Being located in a district with a higher percentage of adopters in 2013 significantly and positively increased the likelihood of cultivating new varieties while negatively associated with planting old improved varieties. More specifically, a one unit increase in the district level percentage of new bean variety adopters above the average of 27% in 2013 (three years prior to the survey) was found to increase the probability of growing new varieties in 2016 by 0.03% and by 0.02% for mixed varieties while that of old varieties reduced by 0.02% (Table 7). However, the magnitude of the coefficients are smaller, which could probably be attributed to the fact that different supplementary channels of seed delivery were pursued under the project over the last 10 years—thereby reducing the partial influence of each in the adoption process. Since, district level adoption rates of 2013 was included as instruments to control for possible endogeneity of new improved variety adoption in yield function, these results lend credence to the validity of our instruments. Distance from the village in hours walking to the nearest paved road (Asphalt) has significant negative influence on the probability that a bean field is planted with new improved varieties. Controlling for the two proxies for technology supply, we see that regional variations in the new variety adoption remains. Compared with Mbeya region, the probability of growing new improved bean varieties or old releases is respectively lower in Iringa, Rukwa and Ruvuma by 16.4%, 11.2% and 25.1% (Table 7). On the contrary, the adoption rate for old variety releases is higher in Rukwa than in Mbeya. Overall, the regional variation in the adoption of improved bean types suggests that the dissemination of new varieties to support adoption has been relatively more intense in Mbeya region that is in close proximity of research station—culminating in spatial diffusion bias against other regions.

The demand side factors linked to information access re-enforce the technology access constraints. The education level of the household head and distance from cooperative, included as proxy for access to information have the expected signs but only education is statistically significant. The education of the household has a positive effect on the likelihood of allocating land to new improved varieties. The size of landholding, that is well recognized in the agricultural development literature as important determinant of new agricultural technology adoption (Feder et al., 1985), does not seem to influence the adoption of new improved bean varieties but was negatively correlated with cultivation of old improved varieties. We interpret this result as a reflection of the declining performance of old varieties. With regard to the importance of plot level specific characteristics in determining adoption, results show that farmers are less likely to plant new varieties on plots they perceive as of low soil fertility. Instead, farmers tend to allocate mixtures of local and improved varieties to plots of low fertility, which means that farmers match varieties with soil quality and are likely to select fertile plots for new improved varieties, which could easily bias yield estimates if not controlled for it.

The attributes of physical environment represented by soil pH and elevation influence variety choice. Results reveal that the probability of planting improved bean varieties is slightly higher in areas where soil PH is within 6 to 7 range, i.e, the optimal pH for bean production, and lower below pH of 6. On the other hand, soil PH does not seem to matter much when it comes to decisions related to mixing varieties in a plot, probably because variety diversity enables farmers to minimize expected yield loses emanating from unfavourable soil conditions. Also important in variety choice is elevation, although the effect was significant only for old improved variety choice decisions. A one-percent increase in average village level elevation measured in meters above sea level is associated with 17% increase in the probability that old improved varieties are chosen over local ones(Table 7).

6.2 Effects on yield and income from beans

The estimates from IPWRA, which show the average effect of improved variety adoption on yield are reported in table 8. Before we embark on discussing the findings, we show that there was no density distribution of the estimated probabilities around zero or one, which confirms that overlap assumption for the validity of IPWRA was upheld (figure 3). The results of the falsification test provide evidence that the instrumental variable, i.e., district level percentage of adopters in 2013, meets exclusion restriction as it has no statistical significant power in the yield function for local varieties (p-value=560).

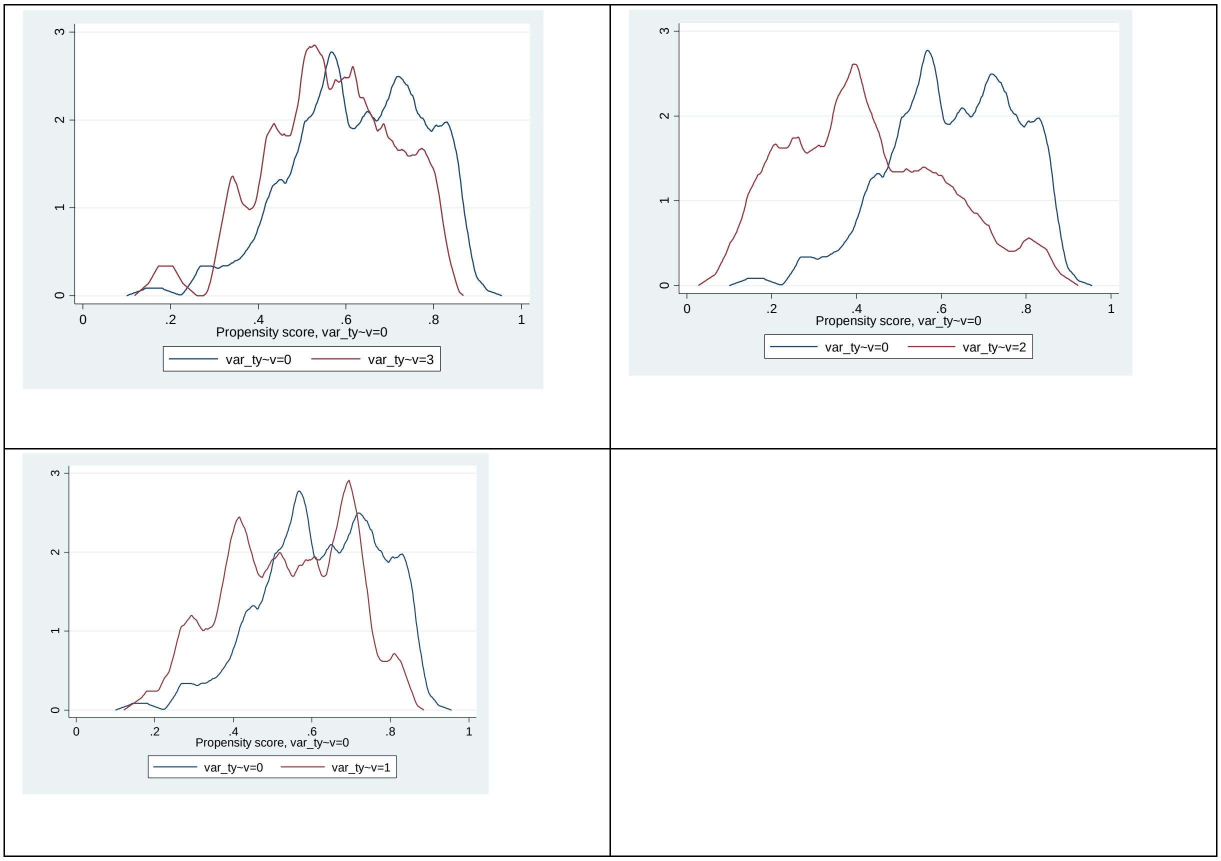
Table 8: The Impact of improved variety adoption on bean productivity

	Coef.	Std. Err.	P>z	Effect (%)	Effect in kg /ha
ATET					
Potential mean local varieties	6.397	0.055	0.000		
New improved varieties	0.325	0.091	0.001	32.5	223.00
Old improved varieties	0.225	0.111	0.043	22.5	179.00
improved mixed with local	-0.080	0.108	0.458	-8.0	0.00
ATE					
Potential mean local varieties	6.356	0.037	0.000		
New improved varieties	0.346	0.110	0.002	34.6	302.00
Old improved varieties	0.262	0.080	0.001	26.2	224.50
improved mixed with local	-0.087	0.069	0.212	-8.7	0.00

The treatment effects estimation with IPWRA indicate significant and notable yield improvement from adoption of improved varieties. On average, bean yield is 32% higher for the households that grow new improved varieties than it would have been if they grew local varieties. This is an equivalent of about 223 kg of additional bean harvested per hectare from plots planted with new improved varieties (Table 8). The average yield on farms that plant old varieties is also higher by 27% than it would have been had these farmers grown local varieties. The yield gained by the adopters of new and old improved varieties is significant at 1% and 5% levels respectively.

It is good that we decided to separate the two categories of varieties, i.e. new and old releases, as combining them would have resulted in under estimation of yield gains from new varieties, leading to inaccurate conclusions on the impact of the project.

Figure 3. Test results for common support



While new improved beans are, on average, higher yielding than local beans, adopters tend to spend more on seed than non-adopters through two mechanisms that re-enforce each other. The first mechanism relates to difference in seeding rates between adopters and non-adopters. From the comparisons of improved and the local varieties, we can see that adopters of new improved varieties (i.e. those released after 2000) planted 12.8 kg/ha more seed than growers of local varieties (Table 9). Table 9 also shows that the amount of seed planted by growers of varieties released in 1990s or earlier (i.e. therefore classified as old improved) was 14.05kg/Ha higher than the quantity planted for local varieties. The difference in seeding rates between adopters and non-adopters might be due to heightened capacity of farmers in crop management through training during seed dissemination under seed system initiatives. Alternately, the higher productivity of new varieties could have enabled adopters to embrace good crop management practices such as following recommended seeding rates that may provide additional productivity enhancing benefits.

Table 9: Effect of improved variety adoption on income from beans

Item	**Unit**	**New varieties released after 2000**	**Old varieties released before 2000**
$(PP) for Tanzania in 2016	$(PPP)[NB]	654.8	654.8
Price of seed	Tsh/Kg	1218.7	1218.7
Price of grain	TSh/kg	1141.8	1141.8
Average plot size	Ha	0.4	0.7
Number of plots		1.7	1.5
additional output per ha	Kg	203.0	161.0
Additional revenue per Ha	Tsh	231785.6	183830.0
Additional revenue per Ha	**$(PPP)**	**354.0**	**280.7**
Additional seed Per Ha	Kg	12.8	14.1
Additional expenditure on seed per ha	TSH	15599.4	17122.7
Additional expenditure on seed per ha	$(PPP)	23.8	26.1
Per kg price top up for improved varieties	Tsh	100.0	100.0
Seeding rate per ha	Kg	70.0	70.0
expenditure on improved varieties per ha	$PPP	10.7	10.7
Total additional production costs per Ha		**34.5**	**36.8**
Change in profits per Ha	**$(PPP)**	**319.5**	**243.9**
Change in bean income	**$ (PPP)**	**201.7**	**257.4**

NB: Purchasing power parity conversion factor is the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as U.S. dollar would buy in the United States. This conversion factor is for GDP.

Based on the average price of Tsh.1219 per kg of seed across various commercial seed sources, the respective cost of additional seed planted by adopters is Tsh 15599 or $24 in PP for new varieties and Tsh 17123 (or $26 at PPP) for improved varieties of old releases (Table 9). The data from various seed sources gathered during the survey also indicate that the price for improved variety seed is higher relative to the price of local seed perhaps because the former is relatively in scarce supply[14]. When we compare the average price of improved varieties with that of local varieties averaged across seed sources, we see that seed of an improved variety costs an additional TSh. 100 per kg, which means that adopters of improved varieties spent an extra Tsh7000 per hectare (or $11 in PPP) on improved seed due to price differences. Overall, the total additional cost of seed that results from adoption of new improved varieties is about $34.5 in PPP per hectare and $36.8 in PPP per hectare for growers of old improved varieties (Table 9)[15].

Net profits obtained from adoption of new improved varieties per hectare calculated by subtracting additional expenditure on seed from the value of additional output is $320.4(PP) per agricultural season. Actual earnings from improved varieties depend on the crop acreage under production. By multiplying the computed per hectare profit increments by plot size and aggregate across plots, we see that a household earns additional income from bean production of about $202 in PPP from adoption from new varieties. These results are generally in line with the bean research goal, which is to increase bean productivity and contribute to household incomes. The higher yields of improved seed compensates for upward adjustment in seed expenditure, though contribution to poverty reduction is still modest due to smaller area allocated to beans in general.

Additionally, our analysis shows that variation in bean yield in Southern Highlands of Tanzania is partly due to differences in the seeding rate and labour input intensity among farmers. On average, an increase in the seeding rate from its average by 10% would grow yield of local varieties by 1.6% and that of new improved varieties by 2.2% (Table 10); whereas yield on plots cultivated with variety mixture would grow by 3.4%. One way to interpret these findings is that since most farmers are using seeding rates that are below the optimal, marginal returns to seeding rates are significant and the same goes for labour input intensity. A ten percent increase in labour input intensity is associated with a 2.0% increment in bean yield of local varieties and that from a mixture of improved & local varieties (Table 10). Lack of statistically significant association between yield and labour in case of improved varieties could perhaps mean that farmers tend to supply adequate labour in plots allocated to improved varieties—causing low variation in the data. In case of fertilizer use however, there is no correlation with type of variety planted as majority of

[14] Price data of improved seed and local seed was gathered from each source (agro-dealers shops, grain market and farmer producers) where farmers obtain seed.

[15] Exchange rate of power purchasing parity in 2015 $ 654.8 at PPP accessed from World data atlas

the farmers either do not apply fertilizer to beans or use very low quantities, which do not show significant difference.

Table 10: Factors affecting bean yield variation in Southern Tanzania

	Local		New improved		Old improved		Mixture	
	Coef.	Se.	Coef.	Se	Coef.	Se	Coef.	Se
Herbicide	0.182	0.145	-0.178	0.293	-0.312	0.286	-0.144	0.291
Log of labour	0.223***	0.079	0.182	0.193	0.125	0.149	0.214***	0.086
Use fertiliser								
_Id_fert2_1	0.090	0.087	-0.251	0.319	-0.311	0.368	-0.206	0.231
_Id_fert2_2	-0.120	0.092	-0.431	0.276	-0.675**	0.335	-0.156	0.165
Dummy pesticide use	0.030	0.129	0.149	0.282	0.253	0.292	0.405	0.272
Communal labor	0.059	0.097	-0.715	0.619	-0.905***	0.291	0.732***	0.261
Dummy use manure	0.116	0.122	-0.038	0.343	-0.162	0.227	0.282	0.278
Log of seeding rate kg ha	0.157***	0.047	0.223***	0.078	0.028	0.125	0.348***	0.114
Log of elevation	0.360***	0.122	0.630***	0.202	0.226	0.597	0.675**	0.349
Dummy soil fertility	0.079	0.082	-0.289	0.244	0.110	0.258	0.115	0.162
Intercropping (%)	0.000	0.008	0.014	0.024	-0.078**	0.033	-0.011	0.009
Square intercropping	0.000	0.000	0.000	0.000	0.001***	0.000	0.000	0.000
Dummy if climbing bean	-0.064	0.123	-0.007	0.313	0.184	0.268	-0.023	0.152
Log age HH head	-0.091	0.151	0.603	0.574	-0.027	0.587	0.393	0.296
Years of schooling	-0.014	0.022	0.003	0.024	-0.022	0.087	-0.037	0.021
Plot slope								
Medium	0.073	0.076	-0.328	0.188	0.053	0.275	-0.134	0.175
Bottom	0.014	0.119	0.046	0.226	0.736	0.567	0.274	0.168
Plot distance	0.000	0.000	-0.009***	0.003	-0.002	0.003	0.001	0.001
Regional dummies (baseline=Mbeya)								
Iringa	-0.080	0.107	0.257	0.232	-0.890***	0.315	0.111	0.263
Rukwa	-0.168	0.132	0.118	0.241	-0.210	0.240	0.053	0.204
Ruvuma	-0.017	0.097	1.119*	0.631	-0.887*	0.509	0.375	0.239
Sex plot manager	0.018	0.100	-0.077	0.192	1.352***	0.285	0.351	0.205
_constant	2.569***	1.046	-1.163	3.120	5.073	5.791	-2.655	2.971

The bean yield also varies with elevation, which indicates the importance of physical environmental constraints. This was particularly important in the productivity of local varieties and those that are new improved. Results suggest that these varieties perform better at higher elevation, with a 0.4-0.7% increase in productivity for a 1% increase in village level elevation, being higher for variety mixtures and lower for purely local varieties. The productivity of new varieties is negatively associated with distance from residence, which affects the efficiency of inputs use since farmers are still learning about the new varieties. Household characteristics such as the age and sex of the plot manager exert a significant but weak influence on bean yield depending on management system. We found that male managers are likely to generate higher yields from old improved varieties compared with their female counterparts, but the two groups obtain same average yield for new improved varieties. This perhaps reflects the emphasis put on integrating women in dissemination of new varieties and the associated capacity building of farmers during the project.

Compared to Mbeya region the productivity of local varieties and that of old improved varieties seems to be lower in Iringa and Rukwa while that of new varieties is higher in Ruvuma region (Table 10).

6.3 Effect on bean marketed surplus

In this section, we look at the contribution of improved bean variety adoption on bean commercialization, measured as the quantity of marketed surplus. Before we discuss the effects of adopting improved varieties on market participation intensity, it is important to highlight the status of bean commercialization in the study area. Approximately 65% of the households sell part of their bean production, and among those who participate, the marketed surplus is about 67% of the harvest, which is equivalent to 305 kg of bean per household per cropping season. From the average of 305kg sold per household, men transacted 254 kg while women transacted 35kg equivalent to 11% (Table 11) of the total marketed surplus. Women tend to grow beans for food and their participation in the market is often unplanned at the planting time while men grow bean for sale. Consistent with this point, plots managed by men were, on average, significantly larger (0.45Ha) than those managed by women (0.35Ha).

Since market participation is measured at household level, we collapsed the multinomial valued adoption into a binary treatment variable by focusing on adoption of new improved seed and comparing with only local seed. Plots that were planted with old improved varieties and variety mixture were excluded as the interest was to estimate the effect of a move from local to new improved seed on marketed surplus. The exploratory analysis with switch-probit full information maximum estimation[16] did not suggest that the decision to adopt new varieties and that of market participation were interdependent or made simultaneously. This result is not surprising given that bean is in transition from being pure subsistence to semi-subsistence and some households might decide to sell after production exceeds their consumption demand or in case of an emergence for cash needs. In situations where market participation is unplanned and unintentional, production decisions do affect market participation. Conditional on adoption of new varieties, the probability that a household will sell part of the harvest was 69.3% and predicted to be 66.8% for non-adopters. This means that adoption of new improved bean varieties increased the probability of bean commercialization by 2.5%.

When estimating the impact of improved seed adoption on the quantity of bean sold, marketed surplus, we account for possible interdependence of the decisions on the quantity and participation in the market as sellers of beans--although the results from likelihood ratio test did not suggest that this would be a concern[17]. Results from the Inverse weighted Probability Regression adjustment (IPWRA) of the marketed surplus on a subsample of those who participate in bean market are reported in table 11. The coefficients on the mills ratio (IMR) in both outcome equations (i.e. marketed surplus for local and improved seed) were not significant, which is consistent with the earlier results from diagnostic test after the Heckman two-step estimation. This shows that estimation of the improved bean variety on a subsample of those who participate in the market is appropriate.

Table 11: Effect of improved seed adoption on bean marketed surplus in southern Highlands of Tanzania

	Coef.	Se	P>z	Effect in volumes marketed
potential mean non-adopters	5.015	0.135	0.000	150

[16] likelihood ratio test of the interdependent decisions (p-value of chi2 value= 0.385)

[17] The independence of the quantity sold and the decision on whether or not to participation in the market was tested using likelihood ratio test as part of diagnostic results after two-step Heckman estimation. The chi2 p-value= 0.305.

ATET				
marketed surplus for adopters	0.377	0.117	0.000	56.7
share marketed by women	-0.175	0.058	0.003	
share marketed by men	0.1364213	0.068	0.046	
ATE				
potential mean (non-adopters	4.983	0.079	0.000	
marketed surplus for adopters	0.291	0.097	0.003	43.8

Results reported in Table 11 show that varietal improvement has contributed to commercialization of bean production in southern highlands of Tanzania in a substantial way. The quantity of bean sold rose by 38% among producers that shifted their bean area from local to new improved bean varieties and this effect is significant at 1%. This means that the marketed surplus among adopters would be 38% lower, or 57 kg less if they had not planted improved seed. If all households were to shift to such improved variety seed, the average effect of this adoption would be 29% increment in bean marketed surplus, equivalent of 44kg per household. Although the overall unconditional effect is positive and remarkable, results implies that the adoption of improved new varieties is likely to generate heterogeneous effects on bean commercialization with some households benefiting more than others. Overall, the results reflect largely the success of the bean improvement research in the region and underscores the importance of bean productivity growth in its commercialization drive. Majority of the net selling households reported having used revenue from bean to purchase non-food household items (e.g. clothing, school fees, appliances, kitchenware, furniture and radios). This reaffirms that the project has had important indirect benefits, as reflected in crop income gains.

Now we examine the implications of the increased commercialization on the share of marketed surplus by women. Using the bean sales data disaggregated by the sex of key principal decision makers within households, we compute the share of marketed surplus transacted by men and the share transacted by women. Then we regress this variable on the same explanatory varieties in the main model using IPWRA approach form men and women separately. Results show that within households that adopt new varieties, the share of marketed surplus transacted by men increased by 13.6% while that controlled by women decreased by 17.5%--implying that commercialization of bean tend to shift the control of bean from women to men. Results further indicate that women control over bean marketing is constrained by long distance from cooperatives, remoteness and demographics. As a household advances in age, women are likely to control less of the marketed surplus. On the other hand, factors like household wealth, access to inputs markets, off farm income and education increase the share under women's control.

The highlights of the results also show that household wealth, scale of production, productivity potential and favorable market conditions increase the probability that a household participates in market as a seller. The scale of bean production is positive and significant in all models, as expected since expansion of area is supposed to enable higher production. The findings also revealed that bean farmer integration into markets increases when farmers obtain better access to cooperatives or associations within their communities as this helps them build social networks that facilitate information acquisition. Consistent with this finding, the probability that a bean farmer sells any beans and the volume of market surplus reduces with distance from Mbeya, the regional town of Southern Highlands of Tanzania. Although, off farm employment exhibits a negative sign in selection model, its coefficient in the market surplus model for local varieties is positive and of larger magnitude (26%).

Table 12. Determinants of bean marketed surplus in Southern Highlands of Tanzania

	Market participation		Local seed Robust		Improved seed	
	dy/dx	Se	Coef.	Se	Coef.	Se
Log age HH head	-0.155**	0.078	-0.360	0.382	-0.572	0.364
sex_ HH head	0.052	0.050	0.272	0.175	0.590**	0.261
Years of schooling	0.013*	0.008	0.023	0.041	0.016	0.026
Dependency ratio	0.050	0.085	0.291	0.308	0.117	0.351
Distance from cooperative						
_Id_coop_km_2	-0.062	0.043	-0.582***	0.198	-0.375	0.235
_Id_coop_km_3	-0.168***	0.055	-0.311*	0.187	-0.484	0.347
HH wealth index	0.104**	0.053	0.559**	0.235	0.034	0.290
Log village wage rate	0.100*	0.060	0.748***	0.235	-0.477**	0.239
Soil pH	0.007	0.008	0.085***	0.033	0.162***	0.043
Regional dummies (base=Mbeya)						
_Ihh_region_2	0.029	0.057	0.164	0.237	-0.226	0.226
_Ihh_region_3	0.439***	0.080	1.360**	0.589	-0.204	0.655
_Ihh_region_4	0.186***	0.074	1.047***	0.364	-0.394	0.386
Distance to input shop (km)	0.004***	0.001	0.019***	0.006	0.006	0.008
log distance from Mbeya km	-0.077***	0.029	-0.354**	0.148	0.107	0.163
Exp. hired services	0.000	0.000	0.000**	0.000	0.0001***	0.000

Off-farm income	-0.022	0.036	0.265**	0.128	-0.028	0.200
Bean area	0.171***	0.049	1.323***	0.167	0.745***	0.160
Sex plot manager	-0.044	0.044	0.064	0.157	-0.282	0.194
Mills ratio			0.864	0.796	-0.056	0.880
_constant			-6.274**	3.011	0.612	3.587
LR chi2(18)	94.84					
Log likelihood	-338					
Prob > chi2	(101.32)	0				
Pseudo	R2	0.1303				
Number	617		277			

7.0 CONCLUSION

Crop improvement is an important route to improving agricultural productivity in developing countries. Motivated by this notion and the fact that many households depend on bean for food and income, researchers, under TL, have invested substantial efforts in bean improvement research in Tanzania in the last ten years, with a goal of increasing bean productivity. Using survey data from 661 bean-growing households in southern highlands of the country, this study employed econometric approaches and evaluated the impacts of this investment on development outcomes using four performance indicators: utilization of the research derived varieties, plot level bean productivity gains, market participation intensity and contribution to income.

The analysis indicates that overall, nearly half of the bean growing households in Southern Highlands of Tanzania are currently planting improved bean varieties, and new varieties are steadily replacing old one, i.e. those released 15 years before the time of the survey in 2016. For example, between 2013 and 2016, newer varieties penetrated further reaching 10% of the additional households and gained 3% of area share while old varieties dropped in popularity by 5.1% of households and 0.5% of area share. This means that new varieties are not only replacing old improved varieties but also local ones. The superior properties of new varieties combined with investments in developing seed systems as part of the project and variety promotional efforts have enabled the diffusion of these varieties. While the varieties are well appreciated by intended users, which is a sign of the success of variety improvement, results reveal that households with higher dependency ratio (i.e. number of children less than 15 years of age and elders aged above 64 years) and those located in remote area are less likely to adopt them. This implies that access to information that would enable farmers reduce the uncertainty about the performance of these varieties is still limited for some farmers.

The study findings support the conclusion that the bean improvement has been successful in increasing productivity, which was the main goal for investment. Results provide evidence that replacement of local varieties with improved bean varieties increase bean productivity in Southern Highlands of Tanzania with other inputs held equal, thus improved varieties have a larger yield advantage over landraces. However, we also observed that the estimated average yield increment if adopters of old improved were to move to new improved varieties would be modest and not statistically significant. The finding that there is small increment in yield between new varieties and old varieties is important for accelerating varietal turnover. Thus, it is important that during variety design, target trait levels be defined and prioritized aiming to make observable distinction between new varieties and those they are supposed to replace. For now, this understanding can inform the design seed marketing strategies that contribute to better target dissemination of varieties and facilitate adoption of new varieties in an efficient way.

Conditional on having adopted new varieties, we found that planting new varieties is more profitable than local varieties. This is so, even when adoption of new varieties lead to a slight increase in seed expenditure, since the yield advantage offsets the higher price of improved seed and upward adjustment in seeding rate. However, due to smaller area allocated to bean by adopters of new varieties and the fact that bean in Southern highlands is produced in one season per year, we concluded that poverty reduction effects of improved variety adoption are positive but modest.

On the impact of improved variety adoption on marketed surplus, results showed a positive and remarkable increase in the volumes sold. Thus, it is necessary to increase the intensity of improved variety adoption to generate an increase in yield as the excess output above the consumption level of the households will generate marketable surplus, which encourages farmers to participate in the output market. In light of these results, increasing the variables that lead to adoption of improved varieties and market participation intensity should be the focus for bean research that seeks to enhance welfare. Specifically, we recommend promotion of farmer membership in cooperatives should be encouraged. Access to seed and road infrastructure are also essential in order to increase the intensity of its adoption.

Finally, the study findings support the conclusion that crop improvement contributes to household income via two complementary pathways, i.e. profit effect and market participation intensity. As farmers sell surplus production, they expand they revenue from beans, which they can reinvest into adoption of bean productivity enhancing technologies such as fertilisers, better quality seed and management practices. The long-term outcome is that adopting households will accumulate wealth and use it to improve their livelihoods.

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