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FARM LEVEL ADOPTION AND SPATIAL DIFFUSION OF IMPROVED COMMON BEAN VARIETIES IN SOUTHERN HIGHLANDS OF TANZANIA

E. Letaa[1], C. Kabungo[2], E. Katungi[1], M. Ojara[1] and A. Ndunguru[2]

[1] International Center for Tropical Agriculture (CIAT) and Pan Africa Bean Research Alliance - P. O. Box 6247, Kampala - Uganda

[2] Agricultural Research Institute – Uyole, P.O. Box 400, Mbeya, Tanzania

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ARI	Agricultural Research Institute
BMGF	Bill and Melinda Gates Foundation
BTC	Belgian Technical Cooperation
CIAT	International Center for Tropical Agriculture
CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Center
DAP	Diammonium Phosphate
GIS	Geographical Information System
ICT	Information and Communication Technologies
NARS	National Agricultural Research System
PABRA	Pan African Bean Research Alliance
SDA	Swedish Development Agency
SUA	Sokoine University of Agriculture
TARI	Tangeru Agricultural Research Institute
VIF	Variance Inflation Factor

1.0 INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important source of food and income for smallholder farmers in Tanzania. Per capita bean consumption is about 19.3kg, contributing 16.9% protein and 7.3% calorie in human nutrition (Rugambisa, 1990). Beans occupy approximately 800,000 million hectares, coming third largest cultivated crop after maize and cassava. Production levels have been growing gradually between 2003 and 2012, driven by population growth, increase in domestic and regional bean demand. However, due to several biotic and abiotic stresses, yields have not been able to increase consistently. Bean diseases, notably Bean Common Mosaic Necrosis Virus, Common bacterial blight (*Xanthomonas axonopodis pv. Phaseoli*), halo bacterial blight (*Pseudomonas syringae pv phaseolica)*, angular leaf spot (*Phaeoisariopsis griseola)*, anthracnose (*Colletotricum lindemuthianum)*, rust (*Uromyces phaseoli)* and nematodes present major constraints in common beans in Tanzania (Hillocks, 2006). Other challenges such as low levels of input use, use of poor quality seeds, weather dependency, limited use of mechanical inputs, limited post-harvest handling skills, inadequate storage facilities, lack of reliable market and inadequate extension services also affect bean production in Tanzania (BTC, 2012 and Birachi, 2012).

Crop breeding has been the primary strategy used to address bean production constraints in Sub-Saharan Africa and Tanzania in particular. The Tanzanian bean improvement program was initiated in 1959 at Tangeru Agricultural Research Institute (TARI). Driven by export market, the initial emphasis was directed at improving the quality and productivity of beans. By 1980, four disease resistant varieties were released (Hillocks, 2006). In 1984 CIAT introduced improved bean seeds from Tropical America for crop improvement in the mid-altitude and highland areas for central, East and Southern Highlands.

Eleven bean varieties namely EAI 2525, EG 74, Jesca, Lyamungu 85, Lyamungu 90, Selian 97, SUA 90, Sugar, UAC41, Uyole 90 and Uyole 96 were released in Tanzania between 1980 and 2000 as a result of this intervention (PABRA database, 2014). In a follow up study conducted in 2002, about 29% of the farmers in the Southern Highlands of Tanzania had adopted some of these varieties released between 1980s and 1990s (Mussei et al., 2002).

By 2012, Tanzania had also released three more varieties using CIAT parent materials (i.e CIAT lines) including Wanja, Uyole 03 and Selian 05 through the collaboration between CIAT and NARS under the umbrella of the Pan African Bean Research alliance (PABRA data base, PABRA, 2009). Uyole 03 and Selian 05 are resistant to pests and diseases and have high yielding potential; Wanja and Uyole 03 have a good taste and also cook fast. Wanja is also drought resistant and has short maturity period (PABRA database, 2014). Active participation of men and women farmers was the main approach used to ensure that varieties released meet the preferences of the targeted users.

Complementary efforts were invested in producing and disseminating seed of these varieties to support their fast adoption and diffusion. Between 2009 and 2013, about 1745.5 tons of quality bean seed were produced and distributed to farmers across the Southern Tanzania highlands through a diversity of dissemination channels (i.e. posters, radio episodes, newspapers, leaflets, mobile-based systems, agricultural shows/ field days, on farm research and community based seed production) have been used to reach farmers with information and seed of new improved varieties.

This study assesses the adoption of recently released improved bean varieties (i.e. 2000 and afterwards) and updates the information on the adoption (PABRA, 2014).

Based on the survey data from 75 villages in 20 districts across Southern highlands of Tanzania, we also map out the spatial spread of these major variety categories using GIS methods and identify the determinants of whether the farmer uses the new varieties fully or partially using an ordered probit model. Results from this analysis can be used to formulate policies aimed at improving productivity of beans in the region. Furthermore, understanding determinants of adoption of improved varieties will help address bottlenecks in the promotion of improved bean varieties in the Southern Highlands of Tanzania.

The rest of the report is organized as follows: Section 2 presents the methods. Data sources and data types then follow in section 3. In section 4 results and discussions are presented followed by the summary of key findings and policy implications in section 5.

2.0 METHODS

2. 1 Econometric approach

Several econometric models have been developed for explaining adoption behavior of farmers. Probit and logit models are commonly used in the adoption analysis when the dependent variable takes two discrete values of 0 and 1. However, these only investigate the probability of adoption and how the likelihood of adoption changes when certain policy variables change. When the dependent variable is ordered and categorical, ordered logit and probit models are preferred. On the other hand, multinomial logit model is used with multiple unordered discrete dependent variables-- therefore considered unsuitable for the analysis in this study.

Adoption of improved bean varieties involves two decisions: the decision on whether or not to plant new varieties and the extent/ degree of use. Adoption decision is a behavioral response that arises from a need to maximize expected benefits given the constraints (costs) faced by the decision maker.

Bean producers operate under environment characterized by uncertain climatic conditions, dynamic market prices and poor access to information. Therefore, when faced with the decision to choose between a new and old variety, the farmer makes his decision based on the information about the variety with regard to its relative advantage on the farm, in the market and suitability to meet consumption preferences. Adoption decision is taken only when incentives outweigh disincentives, but the continued use of a technology depends on farmers' perception on incentives and disincentives. The new bean varieties exhibit enhanced resistance to multiple constraints integrated with farmer preferences since they were selected with their active participation. The farmer has the option of adopting the varieties fully to replace existing ones or adopt partially if it is the optimal solution. Partial adoption can also result if the farmer is uncertain of the performance of the variety and decide to experiment with the technology for own learning or increase on-farm variety diversity to guard against risk of crop failure. Furthermore, partial adoption can be a result of seed accessibility constraints as was reported in the groundnuts study in Tanzania (Katundu et al., 2014).

The data used in the paper reveals households that have fully adopted the new varieties and others that have adopted partially. Yet another group of households have not adopted at all. Based on this data, households can be characterized into three ordered groups with respect to use of new improved varieties: 1) no adoption, 2) partial and 3) full adoption. An ordered probit model that allows for multiple ordered values for the dependent variable was therefore preferred over Tobit which is based on the assumption that adoption is driven by demand (Greene, 2003). An ordered probit model measures the probability that the dependent variable (Y_i, for the ith household) falls in one of the discrete categories conditioned on levels of the independent variables (X_i).

Denote y^* the unobservable expected utility from the improved variety derived by any farmer *i*. Following Greene (2000), expected utility y_i^* is a function of observable variables, x_i representing farm and farmer specific characteristics, and unobserved variables, ε_i as follows:

$$y_i^* = \beta x_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

In an ordered probit framework, the decision to adopt improved bean varieties is given by: $y_i = 1 \quad if y_i^* < \gamma_1$ for households that did not adopt; $y_i = 2 \quad if \gamma_1 < y_i^* \leq \gamma_2$ if the improved varieties are adopted partially and $Y_i = 3 \quad if y_i^* > \gamma_2$ if varieties are adopted on the entire land pre allocated to bean production. The γ's are cut off points to be estimated jointly with β which is a vector of coefficients. The implied probabilities that the ordered adoption decision y takes the different values are given as in equations 2-4:

$$P(y_i = 1 \mid x_i) = \Pr(y_i^* \leq \gamma_1 \mid x_i) = P(\beta x_i + \varepsilon \leq \gamma_1) = \phi(\gamma_1 - \beta x_i) \qquad (2)$$

$$P(y_i = 2 \mid x_i) = \phi(\gamma_2 - \beta x_i) - \phi(\gamma_1 - \beta x_i) \qquad (3)$$

$$P(y_i = 3 \mid x_i) = P(y_i^* > \gamma_2 \mid x_i) = 1 - \phi(\gamma_2 - \beta x_i) \qquad (4)$$

Where, ϕ is the cumulative probability function of a standard normal distribution, and X is a vector of variables to be discussed later on hypothesized to explain the probability that a randomly selected bean producer falls in either of the categories in eqns: 2-4.

The marginal effects are calculated using the linear probability index and they show the effect on the probability of adopting in a particular category for changes in the independent variables, expressed as: $dP(y=1,2,3)/dx_i)$.

2.2 Explanatory variables in the model

The empirical evidence on agricultural technology adoption in Tanzania (Katinila et al., 1998; Bisanda et al., 1998; Kaliba et al., 2000; Asfaw et al., 2010; Sitomwe, 2011; Kassie, 2012; Gregory and Sewando., 2013; Shifera w et al., 2005) and that from elsewhere (Katungi et al., 2011; Bamuller, 2012; Ramakers et al., 2013and Feder et al., 1985) have shown several specific household, farm as well as village related factors that influence agricultural technology adoption. We follow this literature and the theory of expected utility in selecting factors included in the analysis of improved bean varieties in Southern Tanzania Highlands.

Household characteristics: Household demographic and social factors commonly included in the adoption models are: household size, wealth assets, education, age and gender of the primary decision maker. Household size is a proxy for labor endowments but can also influence adoption through consumption demand. Since improved varieties are not necessarily labor increasing, we expect household size to influence adoption through its effect on household consumption demand. Large households might be more likely to adopt new varieties that are risk reducing if they face a higher risk of starvation. Gender of the household head captures the differences between household typology with regard to access and control over productive resource. Women have been argued to be generally more constrained in terms of access to external inputs and information (Dey, 1981).

Thus male headed households are expected to positively be more likely to access and utilization improved bean varieties. Education enhances ability to obtain, use and process information relevant to a technology (Schultz, 1975).

However, higher educated individuals are also more likely to earn higher wages from off-farm than on-farm given the same proportion of off-farm and on-farm time. Thus the expected sign of education on the adoption of new improved bean is indeterminate. Likewise, the effect of age cannot be determined a priori. For instance Adesina and Baidu (1995) found out that age was positively related to adoption of sorghum in Bukina Faso and Guinea whereas Asiedu-Darko (2014) found out that age had a negative influence on the adoption of agricultural technologies in three farming areas in Ghana. Older farmers may have more experience in bean production and may also have witnessed some of the benefits associated with improved varieties. On the other hand, older people tend to be more familiar with old ways of doing things and less eager to change.

Household wealth in terms of physical assets (livestock, landholding and household consumer goods) has been associated with access to information and risk preference behavior (CIMMYT, 1993). Thus, we expected wealthier households to be more likely to adopt. However, the poorer might derive more utility from new varieties because of their risk reducing properties and wealth could instead be negatively related with adoption if the wealthier households have alternative ways of addressing biotic and abiotic stresses. Furthermore, information communication devices (ICTs) such as radio and Mobile phones are increasingly becoming useful for dissemination of information on new agricultural technologies. Possession of ICT device such as mobile phones help overcome some of the obstacles to technology adoption by facilitating access to information knowledge sharing and learning, financial services and input and output markets (Bamuller, 2012).

Thus the availability of ICT device in the household is expected to have positive influence on adoption of improved bean varieties.

Farm characteristics: The farm characteristics include farm size, farm altitude, land tenure, perception about soil fertility and plot distance from dwelling. Farm size is an indicator of wealth in the household that is often correlated with the ability to acquire information from sources outside the farm (Feder et al., 1985). Large farm size also reduces the opportunity cost of experimentation, thus the probability to adopt (Sitomwe et al., 2009). On the other hand, land constraint may increase the relative advantage of new high yielding varieties because of the desire to increase productivity per unit area. The effect of farm size on new improved bean adoption is expected to be indeterminate. Furthermore, because different varieties adapt to different elevations, farm altitudes was also added to assess its influence on the adoption of improved bean varieties. Security of land ownership has also demonstrated to affect agricultural technology adoption decisions (Kassie et al., (2012) and Sserunkuma (2005). Better tenure security gives farmers ability and incentive to invest in productivity enhancing technologies. Furthermore, adoption of technologies has been observed to be lower in soils with average fertility and higher for good soils in Malawi (Chirwa, 2005). Therefore, if the farmers do not think that soil fertility is a problem, it is more likely that they will invest in the improved bean varieties. This is because perhaps they perceive a higher pay off from inherently fertile soils than less fertile soil. Distance to the plot is also an important determinant of adoption because of increased costs of monitoring the technology performance when plot is farther away from the residence. Distant plots have been reported to receive less attention and less frequent monitoring, particularly for maize and legumes which are edible at green stage (Teklewood et al., 2013). Hence, farmers are less likely to adopt the improved bean varieties on such distant plots.

However, only farm size and farm altitude were used in the analysis due to data limitation on the other farm related variables.

Location and contextual factors: Location and contextual factors such as agricultural extension services distance to market and availability of input distribution centers for improved seeds or agricultural loan schemes may affect adoption of new improved varieties. Regular contact with extension staff increases farmers' awareness on availability of new technologies as well as how they can be applied. Positive influence of extension contact has been reported in several adoption studies including Kaliba et al. 2000; Akudugu et al., (2012). Thus it is expected to positively influence the adoption of new improved bean varieties. Rural markets in developing countries are generally poorly developed and characterized by high transaction costs arising from high search costs, transportation costs, monitoring costs and limited access to information (Soudulet et al., 1996). Longer distances to markets, typical of the situation in the study area further contribute to market imperfections and are expected to exhibit a negative effect on adoption of new technologies. Input distribution centers for an improved seed in the villages enhances not only the accessibility of seeds and credit but also provide platforms for information access and markets. Thus it is expected to have positive influence on adoption of new improved bean varieties. Similarly, agricultural credit/ loan services in the villages enhance credit access and hence it is also expected to have a positive influence on adoption.

3.0 DATA SOURCES AND TYPE

3.1 The study area

The study was conducted in Southern Highlands, one of the three major bean growing regions in Tanzania. The other two are the Northern Zone (Arusha, Kilimanzaro and Manyara region) and the Great Lakes region in the West and Southern region (BTC, 2012). The zone accounts for about 24.3 percent of the total national beans area, equivalent to 194,021 ha of beans (Agricultural census and FAOSTAT, 2013) and more than 80 percent of the households derive their livelihood from agriculture and related activities (Mbululo and Nyihirani, 2012). Administratively, the zone has four regions, namely Mbeya, Rukwa, Ruvuma and Iringa. According to their order of importance, the major bean producing regions in the zone are Mbeya (12.4 percent of the total land area), Iringa (10.2 percent), Ruvuma (7.8percent) and Rukwa (7.6 percent) (United Republic of Tanzania, 2012).

Southern highland region of Tanzania is diverse in terms of altitude, climatic conditions and farming systems. The climate varies from sub humid and tropical to temperate in higher altitudes. The zone lies at an altitude of 400 to 3000 meters above sea level, with the highest peak of 2891 meters above sea level in Iringa. The rainfall is typical of unimodal type with a single rainy season from November through May, and dry conditions during the rest of the year. The amount of rainfall ranges from 750 to 3500 mm per year. Soils in the zone are generally leached and highly weathered with frequent acidity and relatively moderate fertility (Republic of Tanzania, 2012). Common bean requires moderate amounts of rainfall (300 – 600mm), although adequate amounts are essential during and immediately after flowering. The crop is also not very sensitive to soil type as long as the soil is reasonably fertile and well drained (Wortman et al., 1998).

The prevailing rainfall regime and soil conditions in the zone are thus favorable for common bean cultivation.

Due to the diverse climatic conditions across the regions, several different crops are cultivated in the Southern Tanzania Highlands. However, the major crops grown in the zone include maize, sorghum, sweet potatoes, millet, ground nuts, Bambara nuts, paddy, bananas, pulses (beans, chick peas, cowpeas, pigeon peas and green gram), bananas, cardamom, coffee, cotton and tobacco (Lazaro and Bisanda, 2004). Among the pulses, dry beans are the most dominant in terms of area planted, accounting for about 38 percent of the total land area in Southern Highlands (United Republic of Tanzania, 2012). In addition to agriculture, the main source of livelihood, households in the zone also obtain income from Forest resources; livestock/ herding; fishing and off-farm activities (Lazaro and Bisanda, 2004). Several roads (trunk, district and feeder roads) also connect to the different parts of the zone, but the most of the feeder roads are less accessible during rainy seasons. Common bean market structure in Southern Tanzania is a multi-tier one consisting of village markets, distant markets in urban centers and the external markets across country borders, each providing different opportunities to sellers and buyers (Mussei et al., 2005). The key players are farmers, traders and consumers. Different types of beans distinguished by color, shape, size and other attributes like cooking time and palatability are sold in Tanzanian bean markets

3.2 Sampling and data collection

A multi-stage sampling procedure was employed to select the households for the study. In the first stage, the available secondary information on bean production distribution and population was used to determine the distribution of the sample fixed at 750 households due to budget limitation. Using probability sampling, a total of 75 villages were then selected for the survey.

The actual villages were selected randomly from a list of villages in each district selected based on random numbers. The lists of villages were obtained from district agriculture office. For every selected village, a list of households resident in the village was obtained from the village head.

In Tanzania, the village administration is well organized with a village office managed by government representative. Based on the village list, 10 households were randomly selected using a random start. Consultations with the village head confirmed that the list was based on the household geographical order and random sampling was suitable. The data was collected by the socioeconomics department team from Uyole Agricultural Research Institute of Tanzania in collaboration with the International Centre for Tropical Agriculture (CIAT) between December 2012 and March 2013.

To ensure quality of data gathered, enumerators were trained on the questionnaire and field data management. Then the questionnaire pretested before the actual start of the interview. The survey elicited households, plot and village information. A wide range of household's demographic; production activities, plot specific characteristics as well as infrastructure and services for each household and village were collected. Key household socio economic elements collected were age, sex and education level of household head, family size, asset ownership, participation in agricultural extension and training services, distance from the market center and size of land owned by the household. For each plot, information was collected on plot size, bean varieties cultivated during the study year, inputs use intensity, seed types and seed sources. At each village, information was gathered on the availability of input distribution centers for improved seeds and agricultural credit/ loan services.

About 48 percent of the households had at least one member involved in a farmer organization during 12 months prior to the survey whereas only 5 percent of the households obtained credit for buying seed, fertilizer, pesticides, agricultural equipment's or invest in transport. Access to off-farm income is also limited (about 10 percent) in the study area (table 1).

Table 1: Descriptive statistics for selected sample characteristics

Variable	Mean	SD	Minimum	Maximum
Access to off-farm income (1=yes)	0.10	0.31	0	1
Accessed credit (1=yes)	0.05	0.21	0	1
Membership to farmer associations (1=yes)	0.48	0.50	0	1

Source: Field Survey, 2012

4.0 RESULTS

4.1 Bean production management systems

A typical bean farmer cultivates about 2.03 ha of land, of which about 26.75 percent (0.54 ha) is allocated to common bean production. Farming is organized around the homestead, perhaps to minimize on the costs of transportation and application of inputs. The family is the main source of labor used in bean production as only 10 percent of the households reported use of any hired labor. Each household owns about four hand hoes and one plough for performing various farm operations, with tractors owned by only 0.1 percent of households.

Farmers employ several crop husbandry practices: land preparation (ploughing), planting, weeding, crop protection from pests and diseases, harvesting, threshing and postharvest handling in bean production with varying intensities across farms. For example, about 21% of the farmers do not seem to weed their beans while only 24% reported having monitored their plots for any disease occurrence and intensity in the bean fields.

Proper storage is also necessary to protect the grains from pests and microorganisms (aflatoxins), but the majority of the households do not have proper storage facilities. Only 44% of the households reported keeping the beans either in bags or stores.

In addition to land and labour, farmers in southern highlands of Tanzania apply fertilizers and pesticides in bean production. Fertilizer and pesticides use rate were 47 percent and 33 percent respectively. This is an improvement from 1.4 percent of fertilizer use rate reported in earlier study by Mussei et al., (2002) and relatively higher than SSA average. The rise in use of fertilizers in bean production can be attributed to the fact that beans are increasingly becoming a commercial crop rather than only food crop. In the last five years, the bean interventions under PABRA also promoted use of integrated soil fertility and disease management approaches that contributed to observed increased use.

Inorganic fertilizers are the most popular, with DAP and UREA being the most important, used by about 40 percent and 15 percent of the households respectively. Organic manure was also used by up to 16 percent of the households in bean production. On the other hand, the important pesticides were Thionex insecticides (31percent) and selectron (16 percent). Other pesticides were dursban, and Smition (Table 2).

Table 2: Descriptive statistics of households growing beans

Variable	Mean	SD
Number of hand hoes owned	4.22	2.06
Number of ploughs owned	0.51	1.60
Ownership of tractor	0.001	0.04
Hired labor use (1=yes)	0.099	0.30
Land cropped (ha)	2.03	2.04
Land allocated to beans (ha)	0.54	0.71
Plot distance from homestead (walking minutes)	42.26	42.94
Yield (kg/ ha)	794.10	506.11
Seed used (kg/ha)	81.34	17.43
Fertilizer use intensity (kg/ha)	53.65	14.14
Pesticide/fungicide/herbicide use intensity (liters/ha)	2.01	1.22

Source: Field Survey, 2012

Among the users of fertilizers and pesticide/ herbicide, application intensity is about 53.65kg of fertilizer and 2.01 liters of herbicides per hectare. The study findings also indicate that farmers used 81.34kg of seed per hectare. The average yield of beans amongst the sampled households was 794kg/ ha, which is slightly more than average yield of 700 kg/ha in the whole of Tanzania (FAOstat, 2014). However, this is lower than yield potential of over 1500kg/ha for the recently released varieties (Tryphone, 2013).

4.2 Varieties grown

A diversity of bean seed types distinguished by color, growth habit, seed size and genetic enhancement (improved or landraces) were grown. Bush seed types are the most popular amongst the households in the study area (89.4 percent) whereas only 10.62 percent of the varieties planted were of the climbing type. Beans are mostly planted as single variety, with only 15.8 percent of the plots cultivated as mixed varieties, which could be a result of research that introduced improved resistant varieties or market production orientation. In terms of color, no seed color emerged dominant. The red seed types are grown on 33.23 percent of the plots; yellow type on 24.57 percent while purple and beige types occupy 8.66 percent of the plots. Red seed types are highly marketable and have export potential (Wortman et al., 1989). The availability of potential market for beans within and outside Tanzania perhaps explains the relative abundance of red seed types which are highly marketable and have high export potential. However, the red seed types are more important in Ruvuma, Rukwa and Mbeya regions (57.3 percent, 32.68 percent and 27.21percent). On the other hand in Iringa, the most important seed was the yellow type (31.72 percent).

In terms of genetic improvement and year of release, three major bean categories are grown: 1) new improved varieties released in 2000 and afterwards, 2) Old improved varieties released between 1980s and 1990s and 3) Land races.

The land races occupy 43 percent of total cultivated bean area and are more important in Iringa (54 percent), followed by Rukwa (27 percent) and least important in Rukwa (Table 3). In the semi-arid areas of the northern parts of Iringa region located between 1000-1500masl with mean annual rainfall of 500-800mm, landraces are the dominant varieties accounting for 58 percent of bean area followed by old improved varieties (34 percent) while new improved varieties occupy 7.6 percent of the bean area (Table 3).

Elsewhere in other subzones, with mean rainfall of 800-1400mm, all variety categories are grown with variations more important at village level. Figure 2 also shows that land races occupied more than 26% of the cultivated bean area in 72% of the sampled villages.

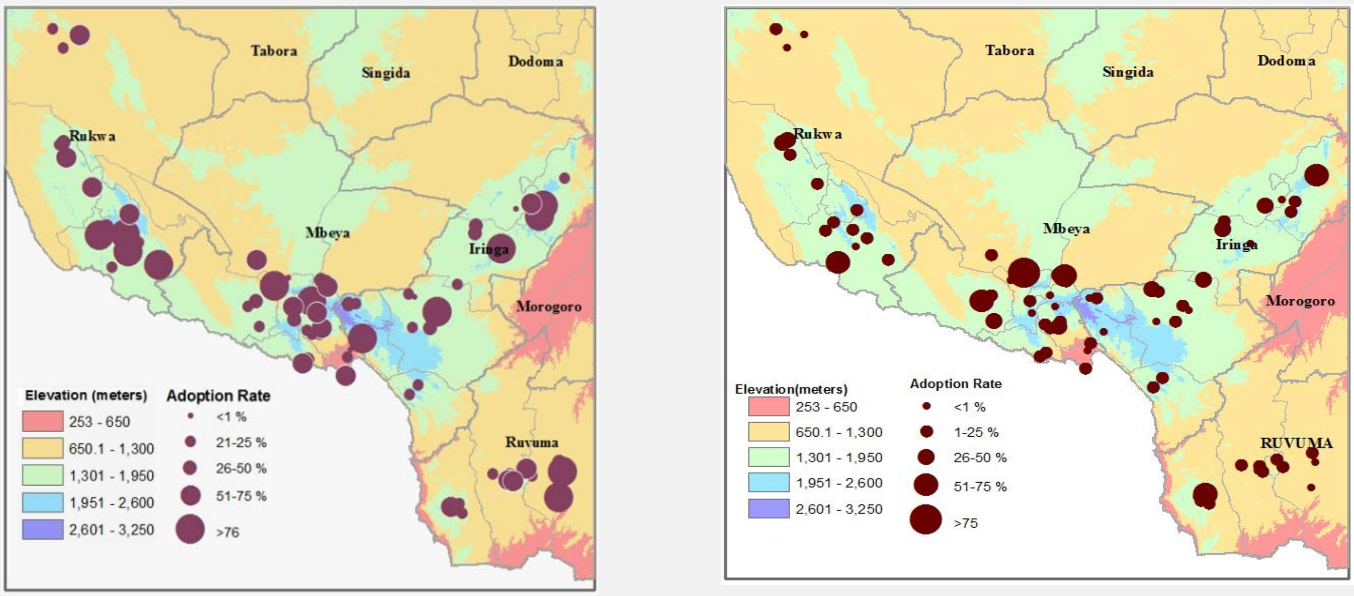
Table 3: Common bean varieties cultivated in 2011 - 2012 season, Southern Tanzania Highlands

Variety	Year of release	% bean area occupied				
		Total	**Mbeya**	**Rukwa**	**Ruvuma**	**Iringa**
Old improved	**1980s/1990s**	**41.5**	**31.42**	**59.94**	**37.63**	**31.3**
U84	1984	20.64	6.08	37	21.94	14.83
Kabanima	1979	12.85	14.59	19.01	0.59	10.7
U94	1994	2.89	3.58	2.47	0	4.64
U96	1996	4.69	5.84	1.46	15.1	0.88
U98	1998	0.43	1.33	0	0	0.25
New improved	**2002-2011**	**15.9**	**20.77**	**13.45**	**11.63**	**14.99**
Wanja	2002	3.46	3.73	3.75	0.29	3.31
Njano	2009	6.68	8	3.74	7.8	8.47
U03	2003	2.93	6.1	2.99	0	1.12
U04	2004	1.49	1.65	1.98	2.44	0
Calma-Uyole	2011	1.17	1.29	0.99	0	2.09
Bilfa-Uyole	2002	0.05	0	0	0.32	0
Urafiki	2003	0.12	0	0	0.78	0
All improved	**1984-2011**	**57.4**	**52.19**	**73.39**	**49.26**	**46.29**
Land races		**42.61**	**47.81**	**26.61**	**50.74**	**53.73**

Source: Field Survey, 2012

As expected, old improved varieties are more frequently cultivated compared to varieties released recently and account for 42 percent of the total cultivated bean area.

However, they are cultivated in the same altitude zones as new ones (ranging between 650.1-2160 masl), but with relatively high levels of diffusion in 40 of the sampled villages where they occupy over 51 percent of the bean plots (Figure 1a). The most popular of the old improved varieties is Uyole 84, released in 1984 (Table 3). Uyole 84 is high yielding relative to the other varieties, with a potential of up to 4000 kg/ha and has excellent leaves for eating (Hillocks, 2006). Other popular old varieties are kabanima and Uyole 96.



a) Old improved varieties (1980-1999) b) New improved varieties (2002-2011)

Figure 1: Distribution of common bean improved varieties released in Southern Tanzania Highlands 1980-2011

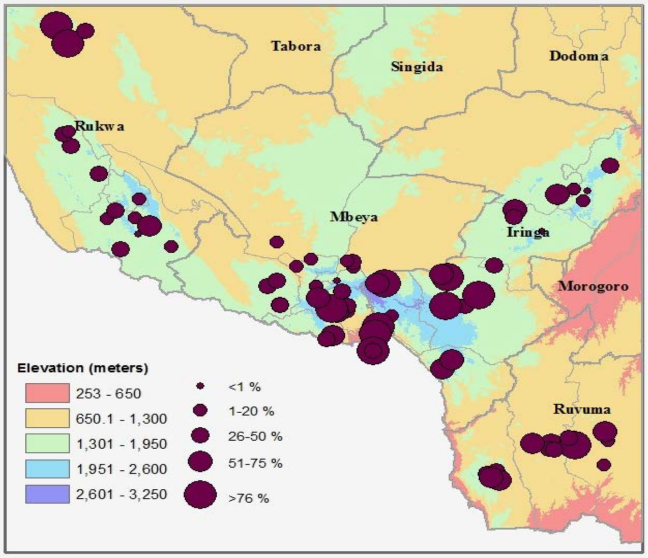


Figure 2: Distribution of land races of common beans in Southern Tanzania Highlands

On average, varieties released since 2000 occupy 16 percent of the cultivated bean area (Table 16). They are however more important in Mbeya, where the bean program at Ari-Uyole operates from. This perhaps gives farmers in Mbeya region more access to the seeds of new improved varieties (all bred from ARI-Uyole) than those in distant places from the center. Figure 1b shows that improved varieties released since 2002 are grown in almost every sampled village but account for a small proportion of area planted in the whole village because they are still diffusing. For example, new improved varieties occupy between 1-25 percent of the cultivated bean plots in 53.3 percent of the sampled villages while it is between 26-50 percent of the plots in 12 percent of the villages. The varieties are grown in a wide range of elevation but more concentrated at altitude 1301-1950 masl.

Njano, released in 2009 is the most important of the new improved bean varieties in the study area, occupying about seven percent of the cultivated bean areas. It is high yielding, drought tolerant and a bio-fortified variety (PABRA database, 2014). The other improved bean varieties released recently that are diffusing rapidly are Wanja and Uyole 03 (Table 3).

Overall, about 16.44 percent of the households have adopted new improved varieties on all their bean plots, replacing their varieties fully while 7.04 percent have adopted partially (Table 4). Next we describe the characteristics of the sample by adoption status comparing full adopters, partial adopters and non- adopters based on simple statistics tests.

Table 4: Extent of adoption of improved varieties released in 2000 and afterwards

Adoption status	**Plots (N=940)**	**% Household (N=725)**
Full adoption	12.01	16.44
Partial adoption	10.56	7.04
Non-adoption	77.43	76.52

Source: Field Survey, 2012

4.3 Selected characteristics of the farmers by adoption status

Table 5 presents the descriptive statistics of the selected sample characteristics by the adoption status. The results show that about 10 percent of the household heads attained at least primary level of education. Education level of household head however did not vary significantly by adoption status and so is gender of the household, majority being males (96 percent). The average age of the household head was 45 years, but the full adopters were significantly older than none-adopting household heads. Similarly, household size which averaged 5 family members was significantly higher among the partial adopters than none-adopter households. The average farm size is 9.65 acres, with partial and full adopters owning significantly bigger landholding compared to non-adopters. Adopters of the new improved bean varieties (partial and full) also have significantly higher wealth index than non –adopters, indicating that asset wealth might have a role in the adoption of improved bean varieties.

Distance to the market which averaged about 9 km in the study area was significantly shorter for full adopters (6.58km) than non-adopters (10km).

This indicates that full adopters have better access to market, which is important for reducing market transaction costs. Extension service is known to catalyze awareness and exchange of information on the new improved varieties but does not seem to vary among households categorized by adoption status. About 90 percent of the sampled households also reported possession of modern information and communication devices such as Television sets, mobile phones or radio, but the difference was not significant across household adoption categories (i.e full, partial and none-adopters).

Close to half of the sampled households (49 percent) owned post-harvest handling facilities such as grain stores, with significantly more full adopters owning them than none-adopters. The new improved bean varieties are high yielding and availability of storage structures could enhance their adoption. Adoption could also cause household to invest in storage structures implying that the variable might be endogenous and including it directly could have biased estimates. Additionally, few villages, 28 percent had agricultural credit/ loan services and 27 percent had input distribution centers for improved seeds, but availability of these services did not differ significantly by adoption status.

Table 5: Characteristics of households by adoption status of new improved bean varieties

	1	2	3	4
Variable	**Total (N= 750)**	**None adopters (N= 554)**	**Partial adopters (N= 51)**	**Full adopters (N= 119)**
Education of household head (1= if above primary)[234]	0.10 (0.30)	0.103 (0.30)	0.04 (0.20)	0.12 (0.32)
Education of household head (1= if none)[234]	0.11 (0.31)	0.097 (0.297)	0.08 (0.27)	0.14 (0.35)
Wealth index[2]	-2.06e11 (0.44)	-0.031 (0.37)	0.14** (0.64)	0.10** (0.63)
ICT ownership (1= yes)[234]	0.92 (0.27)	0.90 (0.30)	0.94 (0.24)	0.96 (0.20)
Distance to market (km)[24]	9.17 (16.74)	10.26 (18.31)	6.05 (10.73)	6.58* (11.28)
Household size[23]	5.61 (2.14)	5.46 (2.03)	6.14* (2.37)	5.88 (2.36)
Household head gender (1= male)[234]	0.96 (0.20)	0.95 (0.21)	1.00 (0.00)	0.95 (0.22)
Household head age (years)[24]	45.76 (12.06)	45.31 (11.86)	44.69 (11.76)	48.12* (12.75)
Farm size (acres)[234]	9.65 (16.13)	8.85 (14.54)	16.77 (25.06)	10.66 (18.71)
Number of extension contacts[234]	1.51 (5.70)	1.65 (5.97)	2.16 (8.06)	0.72 (2.56)
Grain store (1 = if available)[24]	0.49 (0.50)	0.45 (0.50)	0.47 (0.50)	0.60*** (0.49)
Village characteristics				
Agricultural credit services in the village (1= available)[234]	0.28 (0.45)	0.26 (0.44)	0.37 (0.49)	0.31 (0.46)
Village input distribution center (1= available)[234]	0.27 (0.44)	0.25 (0.43)	0.35 (0.48)	0.32 (0.46)

Source: Field Survey, 2012

*Superscripts 234 denote that the variable is statistically different between the categories; Figures in bracket are standard deviations; asterisk *, **, *** denote significance 10%, 5% and 1% levels respectively*

4.4 Econometric results: Determinants of new improved bean varieties adoption

Ordered probit model was used to assess the determinants of adoption (full, partial and none) of the new improved bean varieties. Model diagnostic test results show that the model was significant at 1%, with R^2 of 0.044. A test of missing variables in the model using Ramsey test showed that the model does not have omitted variable bias (p - value of 0.3092, greater than 0.05 at 95 percent confidence interval). Test for multicollinearity using Variance Inflation factor (VIF) also shows that all the variables had VIF of less than 10 with mean VIF of 1.11, indicating no multicollinearity in the model.

Results on the determinants of adoption of new improved bean varieties for the ordered probit model presented in Table 6, show that factors that influence access to the technology and markets explain much of the variation in the observed adoption patterns. Wealth index as expected had a positive and significant influence on adoption (partial and full) of new improved. This suggests that the likelihood of adoption of new improved varieties is higher among wealthier households, perhaps because they have better access to seed and/or more willing to take risks. There is also a higher probability that wealthier households will adopt fully than partially, 6.2 percent and 1.1 percent respectively. This finding is in agreement with results reported in Awotide et al. (2012) who also found a positive and significant relationship between wealth status and adoption of improved rice varieties in Nigeria.

Possession of modern Information and Communication devices (ICTs) such as mobile phones, Television sets and radio also had positive and significant influence on new improved bean variety adoption. Possession of ICT devices increases the likelihood of full adoption of new improved varieties by 8.5 percent and that of partial adoption by 2.5 percent.

ICT facilitates access to information and learning; financial services and input and output markets hence overcoming obstacles to uncertainty that tend to slow down technology adoption (Bamuller, 2012). Furuholt and Matotay (2011) also found out that mobile phones affected all stages in the farming cycle including preparations, farming, harvesting and post-harvesting. It helped farmers raise their incomes by improving their ability to deal with risks and take advantage of income opportunities.

As expected, distance to market had a negative influence on the adoption of new improved bean varieties. Results suggest that farmers further away from the markets have a lower probability of adopting new improved bean varieties. Long distance to the market reduces returns to farmers because of high transaction costs in both input and out markets. As discussed earlier, farmers in the study area travel long distances (9 km) to access markets and this coupled with poor infrastructure especially roads in rural areas increases the transaction costs associated with accessing inputs and output market. Poorly functioning input and output markets erode the profitability of a technology to the farmer and hence demotivates technology uptake (Jack, 2011). An increase in distance to market from the farm by 1 km reduces the likelihood of partial and full adoption by 0.06 percent and 0.27 percent respectively. This finding is supported by the study of Asfaw et al., (2010).

The coefficient of grain storage was also found to have positive and significant influence on adoption of new improved varieties. This suggests that possession of post-harvest facilities such as storage structures tend to increase the likelihood of adoption of new improved bean varieties. The new improved varieties have the ability to withstand abiotic and biotic stresses more than the land races or old improved varieties.

Lack of storage facilities can easily result into losses thereby discouraging farmers from using the varieties, especially after investing in the technology.

Thus availability of a grain storage facility in the household increases the likelihood of full and adoption by 6.5 percent and 1.5 percent respectively. As already noted, it is possible that possession of adoption could be endogenous in the improved new varieties However, we do not control for this possibility in the analysis due to lack of instrumental variables.

Table 6: Marginal effects of the ordered probit model on the probability of adoption of new improved bean varieties

Dependent variable = New improved variety adoption (3 categories of adoption)

	None-adopters		**Partial adopters**		**Full adopters**	
Variable	**dY/dX**	**Std. Err**	**dY/dX**	**Std. Err**	**dY/dX**	**Std. Err**
Household characteristics and endowments						
Education of household head (1= primary	-0.005	0.052	0.001	0.001	0.004	0.042
Education for household head (1= >primary)	-0.043	0.054	0.008	0.009	0.035	0.045
Wealth index	-0.077**	0.033	0.015**	0.007	0.062**	0.026
ICT ownership	-0.111**	0.046	0.025**	0.012	0.086**	0.034
Distance to market (km)	0.003***	0.001	-0.001***	0.000	-0.003***	0.001
Household size	-0.012*	0.008	0.002	0.001	0.010	0.006
Gender household head	0.05	0.088	-0.009	0.014	-0.044	0.074
Age household head	-0.086	0.061	0.017	0.012	0.070	0.050
Farm size (acres)	-0.009	0.017	0.002	0.003	0.007	0.014
Extension contacts	0.003	0.003	-0.001	0.001	-0.002	0.002
Availability of grain store	-0.077**	0.031	0.015**	0.006	0.062**	0.025
Agricultural credit/ loan services in the village	-0.036	0.036	0.007	0.007	0.029	0.030
Village input distribution center for improved seeds	-0.054	0.038	0.010	0.007	0.044	0.031

Source: Field Survey, 2012

*; ** and *** denote 10%, 5% and 1% significance levels respectively

5.0 SUMMARY AND CONCLUSIONS

The paper empirically examined the diffusion and farm level adoption of improved bean varieties released from 2000 after wards in Southern Tanzania Highlands. The study categorized adopters as full or partial depending on the extent of adoption. Using ordered probit model, factors influencing adoption of the improved bean varieties were also examined. The results show that adoption of new improved varieties in the study area was 16 percent.

The study established the status of utilization and diffusion of improved bean varieties. New varieties have diffused widely into the communities and social networks—hence can be easily accessible by late adopters. The study also found a high diversity of varieties in terms of seed colour and genetic improvement within a village. It is common for new and old improved varieties as well as landraces to be grown in the same villages, suggestive of high diversity in soil characteristics within small geographical areas. However, there was limited diversity at household level with each farmer cultivating one or two varieties. This is partly attributed to increase in the number of improved varieties that increases the likelihood of finding a variety that matches farm conditions, which could have reduced the demand for diversity as a risk management strategy.

The study found out that poor market access as well as household specific characteristics hinders adoption of new improved varieties. Currently, farmers in the study area travel long distances to access markets and thus efforts to enhance markets access will help encourage adoption. The significant positive effect of ICT in the adoption of new improved varieties confirms the currently thinking and increasing interest in introducing ICT in agriculture interventions. Hence future campaigns on new improved varieties should employ ICTs especially mobile phones to deliver the information to farmers.

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