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

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ABSTRACT

Common bean (*Phaseolus vulgaris* L.) is an important crop mainly for smallholder farmers in Tanzania, for home consumption and cash income. Its productivity has been low due to a number of factors, including environmental stresses and limited input use. The socio-economic environment calls for development and dissemination of improved bean varieties that are well adapted to multiple constraints, in order to improve and stabilise bean productivity on smallholder farms. The objective of this study was to assess the adoption and spatial distribution of improved common bean varieties in Southern Highlands of Tanzania. The study used a bivariate probit model to account for possible correlation between the disturbances. Results show that the improved varieties have extensively diffused in the study area, with new improved bean varieties replacing old ones. A host of factors at plot level (e.g. perceptions about soil fertility status and plot distance from residence), household level (e.g. agricultural wealth, number of dependents, access to off farm income and years of experience in bean growing), and village level (e.g. distance from the village to main road, agricultural credit), significantly influenced the adoption of the improved varieties. Farmers who adopted new improved varieties attached a higher weight to agronomic attributes. Market attributes partly explained continued cultivating of old improved bean varieties. Results support investment in market hard and soft infrastructure in form of roads, financial services, farmer cooperatives and integration of ICT in seed dissemination.

Key Words: Bivariate probit model, *Phaseolus vulgaris*

RÉSUMÉ

Le haricot commun (*Phaseolus vulgaris* L.) est une culture très importante pour les petits paysans en Tanzanie, il sert à la consommation domestique mais aussi génère des revenus. La production du haricot commun est faible en raison d'un certain nombre de facteurs dont les facteurs environnementaux et la faible utilisation d'engrais. L'environnement socio-économique appelle au développement et à la vulgarisation de variétés améliorées adaptées à des contraintes multiples, dans le but d'augmenter et de rendre stable sa production chez les petits paysans. L'objectif de la présente étude est d'évaluer le taux d'adoption, ainsi que la distribution spatiale des variétés améliorées du haricot commun dans les terres émergées au sud de la Tanzanie. Le modèle probit bivarié a été utilisé pour tester une probable corrélation entre les perturbations. Les résultats ont montré que les variétés améliorées ont été largement diffusées dans la zone d'étude et que les variétés améliorées remplacent progressivement les variétés traditionnelles. Un lot de facteurs: à l'échelle des champs (perceptions sur le niveau de fertilité des sols et distance entre champs et résidences), à l'échelle des ménages (pouvoir d'achat, nombre de personnes en charge, l'accès aux crédits et le niveau d'expérience en production du haricot commun), à l'échelle des villages (l'éloignement par rapport à la route principale, disponibilité de crédit agricole), influencent de façon significative le taux d'adoption des variétés améliorées. Les paysans qui adoptent les nouvelles variétés améliorées accordent une grande importance aux traits agronomiques. Pour une grande part, la culture continue des anciennes variétés est due aux contraintes du marché. Les résultats plaident pour des investissements en termes d'infrastructures routière, services financiers, coopératives de producteurs et l'intégration des TIC dans la dissémination des semences aux fins d'améliorer la distribution.

Mots Clés: Modèle probit bivarié, *Phaseolus vulgaris*

INTRODUCTION

Globally, researchers and policy makers are increasingly paying attention to grain legumes. This growing emphasis reflects the increased awareness of the importance of these staples to food security in many developing countries, particularly in marginal environments. Grain legumes are considered vital for achieving food and nutritional security for both producers and consumers around the world, occupying an important place as a source of protein and micronutrients in human diets (Singh and Singh 1992). Common bean (*Phaseolus vulgaris*) is the most important grain legume for direct human consumption worldwide (Wortman *et al*., 1998; Broughton *et al*., 2003). In 2013, the global bean production was approximately 22,806,139 metric tonnes, 31 and 22 percent of which came from Latin America and Caribbean (LAC), and Africa, respectively (FAO, 2015).

Tanzania is the largest common bean producer in Africa, allocating approximately 1.2 million hectares per year to this crop (FOA, 2015. Bean consumption per *capita* in Tanzania is about 19.3 kg, contributing 16.9% protein and 7.3% calorie in human nutrition (Rugambisa, 1990).

Low common bean productivity growth in Tanzania is widespread and is a result of several environmental stresses such as declined soil fertility, diseases, and drought. This is exacerbated by unfavourable socio-economic environments that limit the external input use.

To address the bean production constraints, researchers in the national agricultural systems in Sub-Saharan Africa and international organisations, notably the International Center for Tropical Agricultural (CIAT), have been developing bean varieties with improved resistance to biotic and abiotic stresses, while enhancing market traits. Agronomic practices are also evaluated on the farmers' fields and suitable ones disseminated along with improved bean varieties.

In Tanzania, research on common bean improvement started in 1959 at Tangeru Agricultural Research Institute (TARI), with the major focus on disease resistance for export canning bean varieties (Hillocks *et al*., 2006), that were being affected by the rust at that time. Elsewhere, farmers were growing local cooking bean type for their subsistence consumption and experiencing yield losses. It was not until 1971, that the national bean improvement program redirected its effort to cooking bean type and started to address diseases that were identified as the major constraint, limiting bean productivity (Karel *et al*., 1981 as cited by Hillocks *et al*., 2006). From the effort invested since 1971, 34 improved bean varieties have been released (PABRA database, 2015), 18 of which were released between 2001 and 2013. All the improved bean varieties are categorised by researchers as potentially high yielding, resistant to pests and diseases, and have acceptable consumption and market traits (PABRA Database, 2015). Compared with bean varieties released earlier, varieties released during 2002-2013 have resistance to multiple stresses and are better adapted to the physical production environment (PABRA Database, 2015).

The improved bean varieties have been disseminated to farmers through a combination of channels (e.g. posters, radio episodes, newspapers, leaflets, mobile-based systems, agricultural shows/ field days, on farm research and community based seed production) (PABRA, 2013). Between 2009 and 2013, about 1,745.5 tonnes of quality seed of improved bean varieties were produced and distributed to farmers across the Southern highlands of Tanzania. Despite the high number of improved bean varieties released, and extensive efforts to popularise them among farmers, no recent study has been conducted to evaluate their adoption and diffusion through communities. In 2002, the Uyole Agriculture Research Centre and CIAT conducted a study to assess the uptake of improved bean varieties in

Southern Highlands of Tanzania. The study found that about 29% of the bean growing households in project sites had adopted improved bean varieties (Mussei *et al*., 2002). Since the study was conducted in the project sites, results are not generalisable at the regional level. Furthermore, the study did not investigate the factors that facilitated or constrained the adoption process in the region. This paper fills this knowledge gap by assessing the adoption and spatial diffusion of improved bean varieties in the Southern highlands of Tanzania.

MATERIALS AND METHODS

Data sources. The data used in the study were collected through a survey of the bean growing households in 2012 and 2013 cropping seasons, from the four administrative regions: Mbeya, Rukwa, Ruvuma and Iringa of Southern Highlands of Tanzania. The Southern Highlands of Tanzania accounts for about 24.3 percent of the total national bean cultivated area, and lies at an altitude of 400 to 3000 metres above sea level. The highest peak lies at 2891 metres above sea level in Iringa region. Rainfall is typical of unimodal type that runs from November to May and averages between 750 to 3500 mm per year (United Republic of Tanzania, 2012).

Soils are generally leached and highly weathered, with frequent acidity and of relatively moderate fertility (United Republic of Tanzania, 2012). These conditions favour production of a diversity of crops that include common bean (Wortman *et al*., 1998). Common bean is dominant among the pulses, accounting for 38 percent of the total cropped land area in Southern Highlands (United Republic of Tanzania, 2012).

A multi-stage sampling procedure was employed to select households for the study. In the first stage, information on distribution of bean area across regions, by district, was obtained from the National Agriculture Census conducted in 2007/2008 by the National Bureau of Statistics (NBS). With the help of experienced researchers at Uyole Agriculture Research Centre, the districts in each region were listed and telephone contacts of district development officers obtained. Through these contacts, the number of villages per district was obtained and the sampling weight for each district computed using the proportional-to-size sampling method. Then, a total of 75 villages were selected from the 2,466 villages in 21 districts (after eliminating districts that were identified by key informants as urban settlements) based on probability sampling method. The actual villages were selected randomly from a list of villages in each district. For every selected village, a list of households was obtained from the village head and 10 households randomly selected using random start. A village head is a person selected by government to provide administrative leadership to the village. Consultations with the village heads confirmed that the list was based on the household geographical order and random sampling was suitable. In total, 750 households were interviewed in two rounds.

The first round of data collection was conducted in December 2012 and gathered information on socioeconomic characteristics of the decision maker and household, knowledge and use of bean varieties, plot characteristics, variety attribute demand and market access. During this period, the survey also gathered community level information on the availability of input distribution centers for improved seeds, agricultural credit/loan services, as well as the nature of roads connecting to the village all year round.

The second round of data collection was conducted in March 2013 and elicited information on varieties planted per plot during the study year, plot characteristics (such plot size as slope, perception of fertility, inputs use intensity and distance from the residence), and sources of seed. The Uyole Agricultural Research Institute of Tanzania collected the data in collaboration with the International Centre for Tropical Agriculture (CIAT).

Econometric framework. In Tanzania; common bean is produced under an environment characterised by uncertain climatic conditions (Komba, 2005), high disease pressure (Wortmann *et al*., 1998; Hillocks *et al*., 2006), dynamic market prices and poor access to information services (BTC, 2012). Under such conditions, household preferences and market imperfections are not independent; and lead to non-separable household models, where production decisions are affected by the consumption decisions of the household (Singh *et al.*, 1986; de Janvry *et al.*, 1991; Sadoulet *et al.*, 1996). In the paradigm of non-separable household model, farmers' decisions over a given period of time are assumed to be derived from the maximisation of expected utility, subject to resource constraints. The underlying expected utility generated from each variety choice is assumed to be a function of farmer and farm specific characteristics, variety attributes or a combination of both; expressed in vector X and an error term ε. The decision on whether or not to adopt can be modelled as the difference between the benefit and cost of adoption or continuation of the cultivation of the bean variety option *j* by household *i* as latent unobservable variable U_{ij}* such that:

$$U_{ij}^* = \lambda_j X_i + \varepsilon_{ij} \quad \text{.................................. Equation 1}$$

Where: $j = N$ for the adoption decision of any new improved variety; and $j = O$ for the adoption of any of old improved bean varieties; $P = 1$ for adoption and $P = 0$ for non-adoption. Under the assumption of revealed preference that a farmer will adopt a technology if the net expected utility of doing so is positive and does not adopt if otherwise, we can relate the observed discrete variety adoption decision to the unobserved latent expected utility of adopting variety *j* as:

$$U_{1ij}(X) = \lambda_{1j} X_i + \varepsilon_{ij} \quad \textit{for adoption}$$

$$U_{0ij}(X) = \lambda_{0j} X_i + \varepsilon_{ij} \quad \textit{for non-adoption}$$

.... Equation 2

The expected utility, U_{1ij}, household *i* derives from an improved variety *j* is latent and unobserved to the researcher. It is observed that when the decision to adopt an improved variety is positive, implies that the expected utility from the improved variety exceeds the expected utility derived from cultivating the traditional bean varieties ($U_{1ij} > U_{0ij}$). Thus, following Nkamleu and Adesina (2000), the probability that household *i* adopts variety *j* is given by:

$$P(1) = P\left(\left(U_{1ij} > U_{0ij}\right)\right)$$

$$P(1) = p\left(\lambda_{1j} X_i + \varepsilon_{1ij} > \lambda_{0j} X_i + \varepsilon_{0ij}\right)$$

$$P(1) = p\left(\varepsilon_{1ij} - \varepsilon_{0ij} < \lambda_{1j} X_i - \lambda_{0j} X_i\right)$$

$$P(1) = p\left(\varepsilon_{ij} < \lambda_j X_i \right)$$

$$P(1) = \Phi\left(\lambda_j X_i \right)$$

Where Φ is the cumulative distribution function of ε_{ij}. The functional form of Φ depends on the assumption made about ε_{ij}, which is assumed to be normally distributed in a probit model. For a farmer i, the probability of adopting new or old improved bean varieties, respectively is given by:

$$\Phi_N \left(\lambda_N X_i\right) = \int_{-\infty}^{\lambda X_i} \frac{1}{\sqrt{2\pi}} exp\left(\frac{-t^2}{2}\right) dt$$

.... Equation 3

$$\Phi_O \left(\lambda_O X_i\right) = \int_{-\infty}^{\lambda X_i} \frac{1}{\sqrt{2\pi}} exp\left(\frac{-t^2}{2}\right) dt$$

.... Equation 4

Since new and old improved common bean varieties are adopted by farmers as crop improvement technologies, although with slightly different characteristics, their adoption decisions may be related, implying that vector ε_N and ε_O may be correlated. Therefore, estimation of Equations 3 and 4 based on a single-equation probit method may be consistent but inefficient. To derive efficient estimates, a biprobit model that accommodates non-independence of the error terms in Equations 3 and 4 was used (Greene, 2013). The bivariate probit model is based on the joint distribution of two normally distributed variables specified in Brorsen *et al.* (1996) as:

$$f(N,O) = \frac{1}{2\pi\sigma_N\sigma_O\sqrt{1-\rho^2}} e^{\left((\varepsilon_N^2+\varepsilon_O^2-\rho\sigma_N\sigma_O)/(2(1-\rho^2))\right)}$$

$$\varepsilon_N = \frac{N-\mu_N}{\sigma_N} \text{ and } \varepsilon_O = \frac{O-\mu_O}{\sigma_O}$$

.... Equation 5

Where: ρ is the correlation between N and O, the covariance is $\sigma_{N,O} = \rho\sigma_N \sigma_O$; μ_N, μ_O, σ_N and σ_O are the means and standard deviations of the marginal distributions of N and O, respectively. The distributions of N and O are independent if and only if $\rho = 0$. The biprobit model is estimated using a full maximum likelihood estimation method.

Empirical model specification. Bean varieties grown in the Southern Highlands of Tanzania were categorised into three major groups according to their origin and period of release as: (a) improved new if they were derived from research and released in 2002 and afterwards; (b) improved old if they are derived from research and released before 2002; and (c) local for landraces. To assess the spatial spread of improved bean varieties across the region, the household level adoption rates of respective variety groups were summarised at sector level and mapped using GIS tools (Fig. 1).

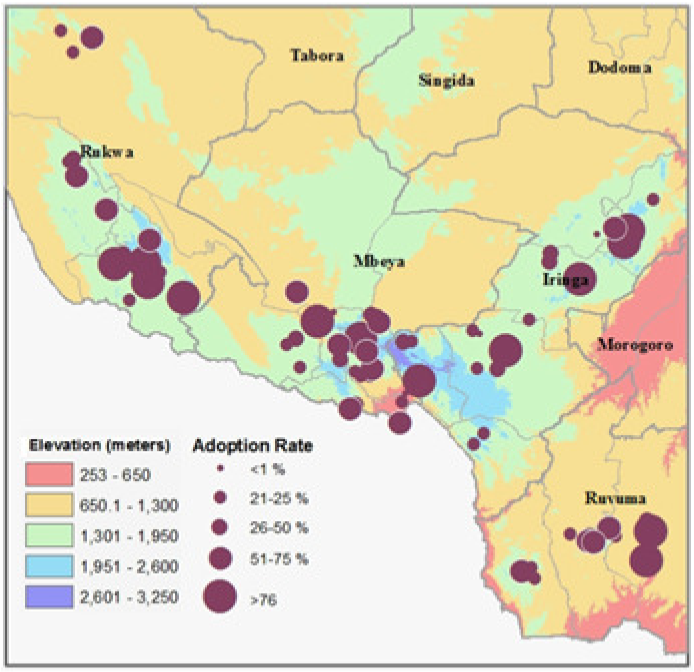
The dependent variable was defined as a dummy equal to one, if the farmer cultivated new improved variety (N) in 2013 cropping season; and 0 otherwise. Similarly, for old improved varieties denoted by O, the dependent variable was defined as a dummy equal to one if the farmer planted the old improved varieties and 0 otherwise in 2013 cropping season.

In selecting factors to include in the analysis of improved bean varieties in Southern Tanzania Highlands, we were guided by the literature on adoption of crop varieties and the theory of non-separable household model (Singh *et al*., 1986; de Janvry *et al*., 1991; Sadoulet and de Janvry, 1995) described above. A wealth of literature from empirical studies on the determinants of agricultural technology adoption in Tanzania (Sitomwe, 2011; Kassie, 2012; Gregory and Sewando, 2013) and that from elsewhere (Katungi *et al*., 2011; Bamuller, 2012; Ramakers *et al*., 2013) has shown several specific household, farm as well as village related factors that influence agricultural technology adoption.

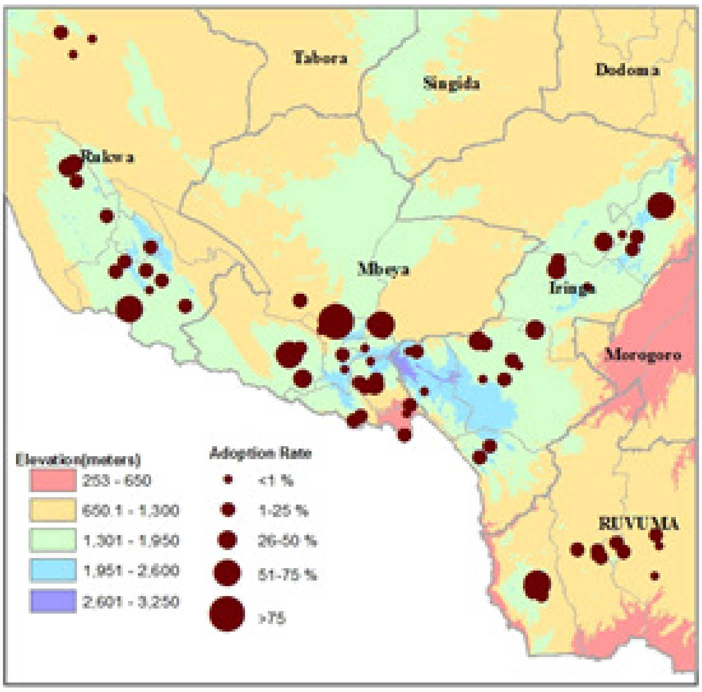
Individual and household characteristics. Individual demographic factors included: education, age, gender and experience. Education level of the decision maker enhances ability to obtain, use and process information relevant to a technology, thus leading to the use of the technology (Schultz, 1975). Highly educated individuals are also more likely to earn higher wages from off-farm than on-farm employment given the same proportion of off-farm and on-farm time. Thus, the expected sign of education on the adoption of new improved bean varieties is indeterminate. Similarly, experience of the farmer (represented as years in bean growing divided by age of the household head to correct for multicolinearity) is linked to adoption of new technologies through learning by doing (Foster and Rosenzweig, 2010).

Gender of the household head captures the differences between household typologies with regard to access and control over productive resource. Women, for instance, have been reported to be generally more constrained in terms of access to external inputs and information (Dey, 1981); which, in turn, may limit their propensity to adopt new technologies. The number of dependents in the household may influence variety choice through its effect on consumption demand and risk preference (Katungi *et al*., 2011). Large numbers of children may also negatively affect adoption if it increases the opportunity cost of time spent on related agricultural activities.

Household wealth assets including communication devices (radio, mobile phone and Television set), and access to off-farm income are other factors that influence technology adoption (Katungi *et al*., 2011; Bamuller, 2012). Cash generated from engagement in off-farm economic activities can provide additional income for purchasing improved variety seed as well as increase the capacity of the household to take risks. Possession of Information Communication technology (ICTs) devices such



(a) Old improved varieties (1980-1999)



(b) New improved varieties (2002-2011)

Figure 1. Diffusion of improved bean varieties in Southern Tanzania during the 2012 cropping season, by year of release.

as a mobile phone is another factor expected to affect the use of the new varieties. Bamuller (2012) argued that ICTs help overcome some of the obstacles to technology adoption, by facilitating access to information sharing and learning, financial services, input and output markets.

Farm characteristics. Plot distance from the homestead, soil fertility status of the farm and the size of land holding are the farm characteristics included in the analysis. Larger farm size may increase the probability to adopt through its downward influence on the burden of financial constraint (Sain and Martinez, 1999) and the ability to overcome the high opportunity cost of experimentation (Sitomwe *et al*., 2009). On the other hand, land constrained households may derive higher incentives from new high yielding varieties because of the desire to increase productivity per unit area. Hence, the effect cannot be determined a priori. 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 improved common bean varieties on such distant plots. 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.

Location and contextual factors. Distance to market, extension service, access to seed distribution centres, participation in farmer associations and agricultural credit/ loan schemes; and the quality of road connecting the village to the outside communities, are the contextual factors hypothesized to influence adoption of improved bean varieties in Tanzania. Poorly functioning input and output markets erode the profitability of a technology to the farmer, and hence demotivates technology uptake (Jack, 2011). Rural markets in Tanzania are generally poorly developed and are characterised by high transaction costs arising from high search, transportation and monitoring costs; and limited access to information (Soudulet *et al*., 1996). Thus, longer distances to the market centres and poor road infrastructure were expected to negatively influence adoption of the new bean varieties, through increasing time of travel and transport cost. Village input distribution centers for improved seeds on the other hand were expected to increase access to new seeds and facilitate adoption.

Extension was expected to increase farmers' access to information on the availability and properties of the new technologies (Kaliba *et al*., 2000; Akudugu *et al*., 2012). Similarly, new technologies come at a cost to the poor smallholder farmers, both in terms of acquiring seeds and the complimentary inputs such as fertilisers. Thus, village agricultural credit/ loan services could help reduce credit constraint for the resource constrained smallholder farmers. Furthermore, farmer associations represent a form of social capital for disseminating important agricultural information (Isham, 2000; Chirwa, 2005).

Variety attribute related demand. Adoption of a new technology will ultimately depend on its relative advantages (Rogers, 1983). Farmers were presented with a list of common bean attributes, namely drought tolerance, pest tolerance, disease resistance, early maturity, uniformity in maturity, grain size, grain colour, cooking time, taste, nutritional value and palatability of leaves. For each attribute, respondents rated its importance to them on a scale of 1-5 (1-not important, 5-extremely important). In order to get a manageable set of variables, the ten attributes were subjected to factor analysis using Principal Component Analysis. Two groups of latent factors: "stress tolerant" and "market" attributes were obtained from factor analysis based on the criterion of eigenvalues greater than unity. Pests and disease tolerance loaded heavily on the first factor described as stress tolerant attributes that explained 70.8 percent of the variation in the 11 variety attributes (Table 1). Factor two, described as market attributes loaded heavily on grain colour and taste (Table 1). Using scoring

TABLE 1. [a] Scores after factor analysis of variety attributes

	Agronomic related attributes	Market related attributes
Drought tolerance	0.09	-0.01
Disease resistance	0.34	-0.09
Pest tolerance	0.27	-0.07
Early maturity	0.13	-0.02
Uniformity in maturity	0.13	0.02
Grain size	0.08	0.01
Grain color	-0.31	1.03
Cooking time	0.14	0.01
Taste	0.00	0.00
Nutritional value	0.15	-0.02
Palatability of leaves	0.08	0.02

[a] Scores for the weights attached to variety attributes by farmers derived after factor analysis of variety attribute demand

command after factor analysis, the two factors were recovered from the data and included as explanatory variables in the model.

RESULTS AND DISCUSSION

Descriptive analysis. Figure 1 shows that both new and old improved bean varieties diffused extensively in the study area, grown in almost every sampled village. However, improved bean varieties released since 2002 accounted for a small proportion of area planted in 2012 (Fig. 1b), perhaps because they were still in the early stage of diffusion. For example, this category of varieties occupied between 1-25 percent of the cultivated bean plots in 53.3 percent of the sampled villages; while they accounted for between 26-50 percent of the plots in 12 percent of the villages. Similar to the new improved bean varieties, varieties released in 1990s and earlier were widely spread across the study area; grown almost evenly in all villages. In 2011/2012, old improved bean varieties occupied over 51 percent of the bean plots in 40 of the sampled villages (Fig. 1a).

In both cases, adoption of improved bean varieties was more concentrated in mid- to high-elevation areas (i.e. altitude 1301-1950 masl), which were also the most suitable for bean production (Fig. 1 a-b). On the other hand, landraces dominated the semi-arid low-to-mid altitude (1000-1500masl) areas of Iringa region - where mean annual rainfall ranged from 500 to 800mm. In these areas, improved bean varieties accounted for only 42 percent of the bean area cultivated in 2011/2012 (Fig. 1).

Old improved bean varieties dominated new improved bean varieties in the 2012 cropping season in terms of number of plots planted (Fig. 1), though there was a reverse in the 2013 cropping season (Table 2). Among the adopters of improved bean varieties (53. 8 percent of smallholder bean growers) in 2013 cropping season, 30.6 percent grew new bean varieties; while 23.2 percent grew old improved bean varieties (Table 2). In terms of area, improved bean varieties occupied 38.23 percent of the land pre-allocated to bean production, in the same season with new improved varieties accounting for 21.04 percent of that land (Table 2).

Comparatively, the proportion of households growing new improved bean varieties rose by 7.23 percent between 2012 and 2013 cropping season; while the area occupied by the same varieties increased by 5.14 percent. On the other hand, the proportion of growers of old improved bean varieties dropped by 24.9 %, being replaced by new improved bean varieties and landraces. This result suggests that new improved bean varieties released recently (2002-2012) are rapidly diffusing, while the diffusion of the old improved bean varieties reached its maturity stage, and was thus being replaced by new improved ones.

Both push and pull factors are expected to have played a role in the variety adoption dynamics between the two cropping seasons (2012 and 2013). On the demand side, season 2011/2012 was generally dry, which affected harvests, resulting in price hikes (Food security early warning system at http://www.wami.org accessed on 29/07/2015). Since landraces fetch a premium price on the market, higher market prices could have further increased the incentive of growing such varieties. Besides, landraces are highly preferred by farmers because of their palatability, local demand and compatibility to agro-climatic conditions of the area (Sanga and Mahonge, 2014).

On the supply side, the increase in diffusion of new improved bean varieties reflects the improvements in the seed production and dissemination, especially of new improved varieties between 2012 and 2013. During this period, the quantity of seed produced by various partners and the Pan African Bean Research Alliance (PABRA) through its partners in Southern Tanzania nearly doubled, from 321.7 tonnes in 2012 to 611.5 tonnes in 2013 (PABRA, 2014a). Similarly, the number of farmers that accessed seed also increased from 109,023 in 2012 to 130,398 in 2013 (PABRA, 2014a).

Generally, households cultivated about 1.25 bean plots (Table 3), majority of which were planted with single variety. Approximately 25 and 20.48 percent of cultivated bean plots were planted with new and old improved bean variety category, respectively. Only 1.68 percent of the bean plots were planted with a mixture of both new and old improved bean varieties, while the remaining over fifty percent of the bean plots were cultivated with land races (Table 3).

These results reveal market driven production behavior. Firstly, results show that though the practice of bean cultivar mixture has been extensively used to control major bean diseases in the African Great Lakes region (Pyndji and Trutman, 1992), it is less common in Southern Tanzania, reflecting a commercial oriented production. This supports the findings of Mishili *et al.* (2009) that bean consumers in Tanzania prefer pure to mixed grain (i.e. grain of different varieties). Secondly, the significant area allocated to landraces is consistence with the observations made earlier that local varieties are highly palatable and preferred on the market (Katungi *et al*., 2009; Sanga and Mahonge, 2014).

Results reported in Table 4 indicate that adopters and non-adopters of improved bean varieties are distinguishable by household and farm characteristics, variety attribute demand, as well as market conditions. Overall, adopters of new improved bean varieties had more years of schooling (6.04 years), and were more likely to own a mobile phone (63 percent), oxen (73 percent) and participate in off farm activity (59 percent), compared to non-adopters (Table 4). This implies that adoption of new improved

TABLE 2. Adoption rates and area share under improved bean varieties for the 2012 and 2013 cropping seasons, Southern Tanzania

Variety	Percentage of growers[a] (%)		Area share (%)	
	2012	2013	2012	2013
Old improved	48.07	23.19	41.5	17.19
New improved	23.34	30.57	15.9	21.04
Land races	42.54	61.14	42.6	61.77
Total	113.95	114.9	100	100

[a] The total percentage of growers is greater than 100 because of cases of multiple varieties cultivated per household. For example, a household growing both old and new improved varieties, new improved and local varieties, Local and old improved varieties

TABLE 3. Plot level adoption of improved common bean in 2013/14 season in the highlands of Southern Tanzania

Adoption status	% plots(N= 835)	Total number of plots	Number of bean plots	
			Mean	SD
Non adopters	53.05	443	1.58	0.85
Only new improved variety adopters	24.79	207	1.36	0.58
Only old improved variety adopters	20.48	171	1.56	0.85
Adopters of both old and new	1.68	14	1.07	0.27

TABLE 4. Summary statistics for adopters and non-adopters of old and new improved common bean varieties in the highlands of Southern Tanzania

Variables	Overall sample (n = 835)	New improved varieties		Old improved varieties	
		Adopters (n = 221)	Non adopters (n = 614)	Adopters (n = 185)	Non-adopters (n = 650)
Individual and household specific characteristics					
Education of household head (years of formal schooling)	5.75 (2.55)	6.04 (2.68)**	5.65 (2.50)	5.71 (2.54)	5.76 (2.55)
Experience-age ratio	0.30 (0.21)	0.30 (0.21)	0.29 (0.21)	0.27 (0.21)*	0.30(0.21)
Livestock units	4.84 (5.69)	5.36 (7.71)	4.66 (6.12)	5.41 (6.66)	4.69 (6.56)
Amount of agricultural equipment	22.40 (37.26)	21.86 (36.40)	22.62(37.59)	27.51 (35.54)**	20.97(37.63)
Household has oxen (1= yes)	0.60 (0.49)	0.73 (0.45)***	0.56 (0.50)	0.49 (0.50)***	0.64 (0.48)
Household possess a mobile phone (1= yes)	0.32 (0.47)	0.63 (0.48)***	0.20 (0.40)	0.15 (0.35)***	0.36(0.48)
Frequency Extension contact	0.94 (3.33)	1.43 (4.53)**	0.76 (2.76)	0.78 (2.20)	0.98(3.58)
Number of dependents	2.40 (1.65)	2.54 (1.69)	2.34 (1.63)	2.45 (1.77)	2.38(1.61)
Household has off farm activity (1= yes)	0.49 (0.50)	0.59 (0.49)***	0.45(0.50)	0.44 (0.50)	0.50(0.50)
Farm characteristics					
Plot distance from home (minutes)	41.64 (44.21)	37.70 (34.77)	43.06 (47.09)	49.79 (39.15)***	39.33(45.30)
Soil fertility					
Good	21.69	28.05**	19.22	20.54	21.85
Medium	61.01	64.71	60.10	55.66	62.92
Poor	17.23	23.78	20.68	23.78**	15.25
Total land owned	9.55 (16.04)	10.89 (18.41)	9.07 (15.08)	11.90 (21.49)**	8.88(14.05)
Variety attribute demand					
Index of agronomic attributes	0.03 (0.92)	0.40(0.73)***	-0.10(0.95)	0.06 (0.89)	0.06(0.93)
Index of market attributes	-0.03 (1.01)	0.06 (1.02)	-0.02(1.01)	0.05 (0.99)	-0.05 (1.01)
Market conditions and location specific factors					
Village has farmer associations/ cooperatives (1= yes)	0.59 (0.49)	0.71 (0.45)***	0.55(0.50)	0.55 (0.50)	0.61(0.49)
Village has agricultural credit/ loan services in the (1= yes)	0.71 (0.45)	0.73 (0.44)	0.71(0.45)	0.76 (0.43)	0.70 (0.46)
Distance to market (km)	8.82 (16.87)	9.05 (15.50)	8.73(17.34)	9.14 (15.90)	8.73(17.14)
Village has input distribution center for improved seeds (1= yes)	0.27 (0.44)	0.33 (0.47)**	0.25(0.43)	0.19 (0.40)***	0.29(0.46)
Village road is accessible throughout the year (1= yes)	0.41 (0.49)	0.57 (0.50)***	0.35(0.49)	0.56 (0.50)***	0.37(0.48)

Figures in brackets are standard deviations; *; ** and *** denote 10%, 5% and 1% significance levels, respectively varieties might be associated with endowment of human capital (education) and household wealth important for obtaining and processing information (Schultz, 1975) and acquiring the improved varieties (Awotide *et al.*, 2012), respectively.

The descriptive results further show that adopters of new improved bean varieties had better access to the technology than non-adopters. The former were relatively more frequently visited by extension agents, located in villages with comparatively better access to input distribution centres (33 percent) and farmer cooperatives or associations (71 percent). Consistent with the literature (Isham, 2000; Doss and Morris, 2001; Abebaw and Haile, 2013), this is evidence that bean growers who did not plant new improved bean variety seed were disadvantaged, in terms of technology supply. Moreover, presence of input distribution centres nearer to the farming communities is associated with lower transaction costs to farmers. Likewise, farmer associations/ cooperatives provides a form of social capital and facilitates consultative norms that facilitate adoption of new technologies in rural Tanzania (Isham, 2000). Furthermore, group members may engage in delivery of services such as dissemination of improved farm inputs, provision of loans and marketing of farm inputs (Abebaw and Haile, 2013).

Table 4 also compares the characteristics of households that grew old and new improved bean varieties. Generally, adopters of old improved bean varieties had relatively bigger landholdings (about 11.9 ha) compared with those who grew new improved varieties or land races. In terms of variety attribute demand, adopters of old improved bean varieties attached low weight to stress tolerance bean attributes than non adopters of these varieties, perhaps because the former had more land to compensate for yield loss or alternative strategies to manage environmental stresses (Table 4).

Finally, results show that adopters of new and old improved bean varieties face similar market conditions, as captured by the distance from the farm to the main roads, quality of village feeder road, and household access to credit. A respective 56 and 57 percent of households that grew new and old improved bean varieties were in villages with roads accessible throughout the year; while access to credit facilities did not differ across villages. This implies that adoption of improved varieties could be associated with improved road infrastructure (Kiprono and Matsumoto, 2014), perhaps through its effect on lowering transportation costs, thereby facilitating mobility and information diffusion

Econometric results. The econometric results from the biprobit estimation of the determinants of the new and old improved common bean varieties are presented in Table 5. The model diagnostic test results show that Rho (ρ) was significant, which is evidence that the error terms in the two equations are correlated, thereby lending support to use of a bivariate model rather than univariate probit model in the analysis (Nkamleu and Adesina, 2000). Different household, farm and location specific factors capturing different dimensions of technology adoption were significant with the hypothesized signs. Likelihood ratio test results further revealed that variety attributes (P = 0.000), information access factors (P = 0.000), village variables (P = 0.000), farm characteristics (P = 0.0000) and household demographic characteristics (P = 0.0603) were all significant factors that explained variation in adoption of improved common beans in Southern Tanzania Highlands. Household characteristics found to significantly influence adoption of improved bean varieties were: number of dependents, oxen, agriculture wealth, possession of mobile phone, farmer experience and off farm employment (Table 5).

The number of household members aged below 14 years and above 65 years, positively and significantly influenced the adoption of new improved common bean varieties. An additional one dependent member was associated with 1.5 percent higher chances of adopting new improved bean varieties. This results implies that because households with a large number of dependents face higher risk of food insecurity, adoption of new improved bean varieties offer them opportunities to avert food insecurity. This is because the new improved varieties have enhanced resistance to multiple stresses that enable them to stabilise yield. Similar findings

TABLE 5. Bivariate probit results of adoption of new and old improved common bean varieties in the highlands of Southern Tanzania

Variables	New improved varieties		Old improved varieties	
	dy/ dx	Delta method Standard error	dy/ dx	Delta method Standard error
Years of schooling	0.001	0.005	-0.000	0.005
Experience - age ratio	0.135**	0.060	-0.160***	0.062
Livestock physical units	0.13	0.012	-0.007	0.012
Livestock physical units (Correction factor)	0.089	0.138	-0.016	0.141
Number of agricultural equipment	-0.010	0.016	0.040***	0.015
Household possess an oxen (1= yes)	0.083***	0.030	-0.049	0.030
Household possess a mobile phone (1= yes)	0.302***	0.032	-0.168***	0.023
Final decision maker to grow beans (base man)				
2. Woman	0.029	0.025	0.004	0.026
3. Son/ daughter	-0.236	0.428	0.243	0.326
Frequency Extension contact	0.004	0.003	-0.004	0.004
Distance to market (km)	-0.001	0.001	0.000	0.001
Number of dependents	0.015**	0.007	-0.012	0.008
Household has off farm activity (1= yes)	0.093***	0.024	-0.049*	0.024
Availability of input distribution center for improved seeds in the village (1= yes)	0.041	0.028	-0.051*	0.028
Village road is accessible throughout the year (1= yes)	0.132***	0.024	0.094***	0.026
Availability of farmer associations/ cooperatives in the village (1= yes)	0.082***	0.024	-0.027	0.029
Presence of agricultural credit in the village (1= yes)	0.067***	0.027	0.038	0.029
Index of agronomic attributes	0.088***	0.013	-0.020	0.013
Index of market attributes	-0.003	0.011	0.027**	0.013
Soil fertility (base good)				
1 = Medium	-0.052	0.031	0.011	0.029
2= Poor	-0.186***	0.036	0.101	0.043
Plot distance from home (minutes)	-0.000	0.000	0.001**	0.000
Total land owned (acres)	0.006	0.015	-0.003	0.016

Log likelihood=-663.221: LR test (ñ=0)= c^2 (1) = 29.753***; Number of observations =782. *; ** and *** denote 10%, 5% and 1% significance levels

were reported from Zambia (Hamzakaza *et al.*, 2014) where the likelihood of adopting multiple stress resistant improved common bean varieties was found to increase with household dependency ratio.

The effect of agricultural wealth (i.e., value of agricultural equipment and possession of oxen) on the adoption of improved bean varieties depended on the type of varieties. Households in possession of oxen had 8.3 percent higher chances of adopting new improved bean varieties than those without oxen. On the other hand, one additional unit of agriculture equipment increased the likelihood of using old improved bean varieties by 4.0 percent (Table 5), but had no effect on adoption of new improved varieties. In the study areas, oxen are important sources of draught power in crop production, which reduces drudgery and enables farmers to prepare land on time. Positive influence of oxen ownership and farm technology have previously been noted by earlier researchers (Degu *et al.*, 2000). Similarly, the households with mobile phones had 30 percent higher chance of adopting new improved varieties, which is consistent with the findings of Awotide *et al*. (2012). On the other hand, possession of mobile phones reduced the likelihood of planting old improved varieties, implying that access to mobile phones increases access to new information on source and availability of a new technology. This result is plausible and indicates that integration of mobile phone communication in agriculture holds potential to speed up the adoption of new crop varieties.

Participation in off-farm employment had a positive and significant influence on the adoption of new improved varieties (Table 5). Households with a member (s) involved in off-farm activities had 9.3 percent higher chances to adopt the new improved varieties than those that did not. On the other hand, households that participated in off-farm activities had 4.9 percent less chance in adopting old improved common bean varieties. Off-farm employment presents two complementary effects to the adoption of new improved bean varieties. It reduces the cash constraint, thus enabling farmers to purchase seed of new improved varieties, or augment the capacity of the household to bear the consequences of risks associated with uncertainty of new crop varieties. Tura *et al.* (2010) reported a positive influence of off-farm activity on adoption of improved maize in Ethiopia.

Relative experience of the farmer had a significantly positive influence on the adoption of new improved bean varieties (Table 5). A one year increase in relative experience increased the likelihood of adopting new improved varieties by 13.5 percent, but reduced the probability of planting old improved varieties by 16 percent. This could be because experience enhances efficiency in resource allocation that motivates such farmers to shift from old to new varieties for better adaptability of the crop. Similar findings were reported in Rahman (2008) in Bangladesh, who noted that farmer education, farmers' experience, wealth and non-agricultural income all positively influence crop diversification.

Plot specific characteristics also emerged significant determinants of bean variety choice in Southern Tanzania. This is consistent with the literature that farmers match crop varieties with their soil characteristics (Bellon and Taylor, 1993). The likelihood that new improved common bean varieties will be adopted drops by 18.6 percent for a move from plots with good fertility to those of poor fertility. Similar finding was also reported by Rahman (2008). This might reflect the fact that when varieties are still new, seed will be expensive and those who incur expenditure will want to maximise yields in order to compensate for high cost of seed. Consistent with this argument, results showed that farmers planted new improved varieties nearer their residents, but planted old improved varieties in plots far from their residents because the latter required less monitoring during the growth cycle.

Results also depicted an important role market conditions (represented by road infrastructure, accessibility financial institutions and cooperatives) played in the adoption of improved common bean varieties in Southern Tanzania. Being located in villages with roads that were accessible throughout the year, provides 13.2 and 9.4 percent higher chances of adopting new and old improved common bean varieties, respectively. In light of the importance of bean trade in Tanzania, this is evidence that market access is a positive driver for improved bean variety adoption also reported by Dercon and Hoddinott (2005). As already alluded to, good road infrastructure and/or presence of farmer cooperatives/associations improves information diffusion thus resulting in in better access to the technology (Rahman, 2008; Kolade and Harpham, 2014; Abate *et al*., 2015).

Results support the well-established fact that farmers' preferences are important determinants of crop variety adoption. A one unit increase in index capturing the farmer demand for stress tolerant bean attributes was associated with an 8.8 percent increases in the likelihood of adopting new improved varieties, but had no effect on the adoption of old improved bean varieties. Instead, the probability of growing old improved bean varieties was found to increase with the demand for bean market attributes. An increase in demand for the market attribute by one unit increases the likelihood of adopting old improved variety by 2.2 percent.

CONCLUSION

A host of factors (i.e. household, farm, variety and market conditions) influence the adoption of improved bean varieties in the highlands of Southern Tanzania. Results reveal a trend of new improved varieties replacing old improved bean varieties, which implies that there might be farmers who consistently grow land races.

This implies that though new improved varieties may well be adapted to multiple constraints, their tolerance to drought conditions could be lower than that of landraces. Therefore, in the process of adapting bean crop to climate change, it is important that adaptation to drought, which is expected to increase in Tanzania, be given prominence in the current bean breeding research.

The significance of information acquisition factors such as the availability of mobile phones in the household reflects the importance of integrating new ICT technologies in seed systems.

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