DISTRIBUTION PATTERNS AND FACTORS INFLUENCING ADOPTION OF IMPROVED MANGO VARIETIES IN LOWER EASTERN KENYA

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Abstract

Varietal distribution and performance of mango (*Mangifera indica* L.) along rainfall and temperature gradients in Kenya is largely undocumented. The objective of this study was to document the distribution patterns and factors influencing adoption of improved mango varieties across a broad spectrum of agro-ecological zones (AEZs). Data on mango distribution, cultivation and farm characteristics were collected from 280 farms in 28 quadrats spread in four transects of Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru Counties. The 29 different mango varieties found belonged to three categories: Floridan (F), Kenyan Large (KL) and Kenyan Small (KS). The varieties in the 'F' and 'KL' categories have small tree canopy, bear large sized high-quality fruits and are improved mango varieties (IMVs). The varieties in the 'KS' category (traditional landraces) have large canopy and bear small sized, low quality fruits. Mean mango tree density per farm was 65 and Apple variety had highest abundance of 35%. While all varieties occurred below 1500 m a.s.l. only 19 varieties were found above 1500 m a.s.l. Spearman's rank correlation and stepwise linear regression analysis indicated that altitude, farmers' selection of planting material, availability of profitable and reliable market and farmer's perception that rainfall had decreased all had significant ($p < 0.001$) positive influence on the abundance of IMVs adopted. These findings suggest that farmers adoption of IMVs was not a passive process. The wide range of AEZs versatility of the IMVs indicates farmers' increased adoption of suitable IMVs can provide higher quality mango fruit to mitigate poverty and food insecurity as an adaptation to climate change.

Key words: mango varieties; distribution; agro-ecological zones; adoption; farm characteristics

Introduction

Agricultural adaptation to climate change is crucial not just for farmers, rural communities and economic sustainability but for a growing population and global food security (Schmidhuber & Tubiello, 2007). Increasing the adaptive capacity of agriculture requires a better understanding of the drivers and barriers related to adoption of climate smart practices (Niles *et al.,* 2015). Adaptation strategies and farmer responses vary depending on agro-ecological contexts and socio-economic factors (Adger, 2006). The adoption of new technology represents a significant shift in a farmer's production strategy and the adoption decision is analogous to an investment decision in which benefits accrue over time but the initial fixed costs are substantial

(Caswell *et al.*, 2001). According to (Morris *et al*., 2017a), the farmer has to decide whether to adopt technology to enhance increased yield and diversification or look to improve the income potential off-farm to maintain household income. Climate-smart agriculture' can be developed and implemented to improve food security and rural livelihoods, facilitate climate change adaptation and provide mitigation benefits (Scherr *et al*., (2012).

Mango fruit trees are generally widespread across different regions of Kenya (Kehlenbeck *et al*. 2012). Varieties found in country fall into three categories: Floridan, Kenyan Large (KL) and Kenyan Small (KS). Floridan and KL categories are the improved mango varieties (IMVs). Generally KL varieties are grown more in hotter agro-ecological zones at lower altitude while the Floridan varieties are grown more at cooler AEZs at higher elevation (ADB, 2015; Kehlenbeck et al. 2012). The Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru (which are within AEZ range from IL6 to UH3) constitute the leading mango producing counties in Kenya and contributed over 50% of the mangoes harvested in 2014 (HCDA, 2015). In Kenya, many farmers grow mango varieties without due consideration of which variety is most suitable for the agro-ecological conditions at their farm. The spatial distribution, evaluation of performance of different mango varieties along rainfall and temperature gradients is largely un-documented (Kehlenbeck *et al.* 2012). Knowledge on the distribution of mango varieties is essential for developing ecological niche models for evaluating climate change impacts on varieties and identifying suitable varieties for different climate change scenarios (Luedeling, 2012; Ranjitkar *et al.* 2014). The objective of the study was to determine the socio-economic factors influencing the distribution and abundance of different mango varieties across these leading mango production counties in Kenya.

Materials and methods

Study site

The study, conducted in 2016 across the Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru Counties (Fig. 1) spanned across five AEZs. According to Jaetzold *et al*. (2006), conditions in these AEZs were as follows: Inner Lowlands (IL) are semi-arid, within an altitude of 700-800 m a.s.l., receive rainfall of 400-600 mm yr^{-1} and experience mean annual temperatures of 24-31°C. Lower Midlands (LM) are semi-arid to sub-humid, within an altitude of 800-1300 m a.s.l., receive rainfall of 600-1000 mm yr^{-1} and experience mean annual temperatures of 21-24°C. Upper Midlands (UM) are sub humid, within an altitude of 1300-1800 m a.s.l., receive rainfall of 1000-1250 mm yr^{-1} and experience mean annual temperatures of 18-24°C. Lower Highlands (LH) are humid, within an altitude of 1800-2000 m a.s.l., receive rainfall of 1000-1600 mm yr^{-1} and of experience mean annual temperatures 15-18°C. Upper Highlands (UH) are humid, at altitude above 2000 m a.s.l., receive mean annual rainfall > 1600 mm yr^{-1} and experience mean annual temperatures below 15°C.

Sampling and Data collection

In this study on the distribution of mango varieties in Kenya, a survey was carried out along four transects. Transect 1 had twelve quadrats 30 km apart, set from Kibwezi northwards through Kitui, Machakos and Embu to the border of the forest reserve of Mt Kenya. Transect 2 had seven quadrats 10 km apart set from Ishiara through Runyenjes to the border of the forest reserve of Mt. Kenya. Transect 3 had four quadrats 10 km apart set from Tunyai through Meru to the border of the forest reserve of Mt. Kenya. Transect 4 had five quadrats 10 km apart set from Mitavoni through Tala/Kangundo to Mwala. All the four transects were established along the local road network to facilitate access to the sample farms (Figure 1). Within each transect, quadrats of equal area were systematically selected. At IL and the lower elevation LM AEZs, sampling quadrats were spread further from each other at 30 km apart due to low land potential, extensive farming activities and low human population density. At the higher elevation LM, UM and LH AEZs sampling quadrats were spread more closely at 10 km apart due to higher land potential, more intense farming and higher population density.

Within each quadrat, place marks for 20 farms were randomly established, out of which ten farms were randomly selected and sampling was carried out at five of the ten farms located far from the road (6-8 km) and five of the ten farms located close to the road (0-2 km). All co-ordinates for each of the 280 farms were logged into Global Positioning System (GPS) in advance, farm location maps established using Google Earth and hard copies of maps printed to facilitate accurate physical access to each sample farm. Using semi-structured questionnaires at each farm, documentation was made relating to farm size, farmer's age, education, gender, household size, income, source of planting material, market access, names of mango varieties, prevalent pests and diseases and reasons for choice of varieties planted.

Data Analysis

In SPSS and BioversityR, Stepwise Linear Regression model was used to identify the socio-economic and/or agro-climatic factors influencing the levels of adoption of mango varieties by farmers. Calculations of differences between means in the total abundance of mango trees and total number of mango varieties was done. Also, correlations between socio-economic and agro-climatic factors on the one hand and the total abundance and number of varieties cultivated by farmers on the other hand were determined. Mann Whitney U-test was used to determine if there were significant differences in first, the abundance and secondly, the number of varieties cultivated across two contrasting socio-economic and/or agro-climatic conditions. Outliers were excluded from data analysis.

Results and Discussion

Abundance of mango varieties in the six counties of Kenya

In Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru, twenty-nine mango varieties were inventoried. Majority (18) of the varieties were of the Kenyan Small (KS), six were of the Floridan (F) and five were of the Kenyan Large (KL) categories. The total abundance was 15,500 mango trees (rounded off to 100 trees), which consisted of 7400 Floridan, 6300 Kenyan Large and 1800 Kenyan Small categories (Fig. 2). Adoption of improved mango varieties was high with approximately 88.4% of the trees found in the sampled farms consisting of varieties that are in Floridan and KL mango categories. Farmers' prefer to invest in IMVs which are of higher quality, command greater market demand and provide better financial returns compared to the low-quality traditional landraces. The most abundant variety in the sampled farms was Apple (37%), a KL – fruited variety followed by Floridan varieties Tommy Atkins (21%) and Kent (15%) (Fig. 2). Apple, which is the farmers' flagship (market leader) variety in Kenya, is also the most abundant. This occurrence is largely due to the variety's early maturity, refreshing juicy fibre-free flesh of excellent flavor and relatively good shelf life (Griesbach, 2003). Most fruit tree nurseries in sampled rural areas have mainly apple variety seedlings and since most farmers source seedlings from the nearest nursery, this has enhanced adoption of the variety. The source of planting material is a challenge since in many rural areas, where mango cultivation has a high potential, this study found few (if any) fruit tree nurseries within reasonable accessibility. The Floridan varieties are more abundant than KL mainly due to greater market appeal so farmers find it profitable to plant them.

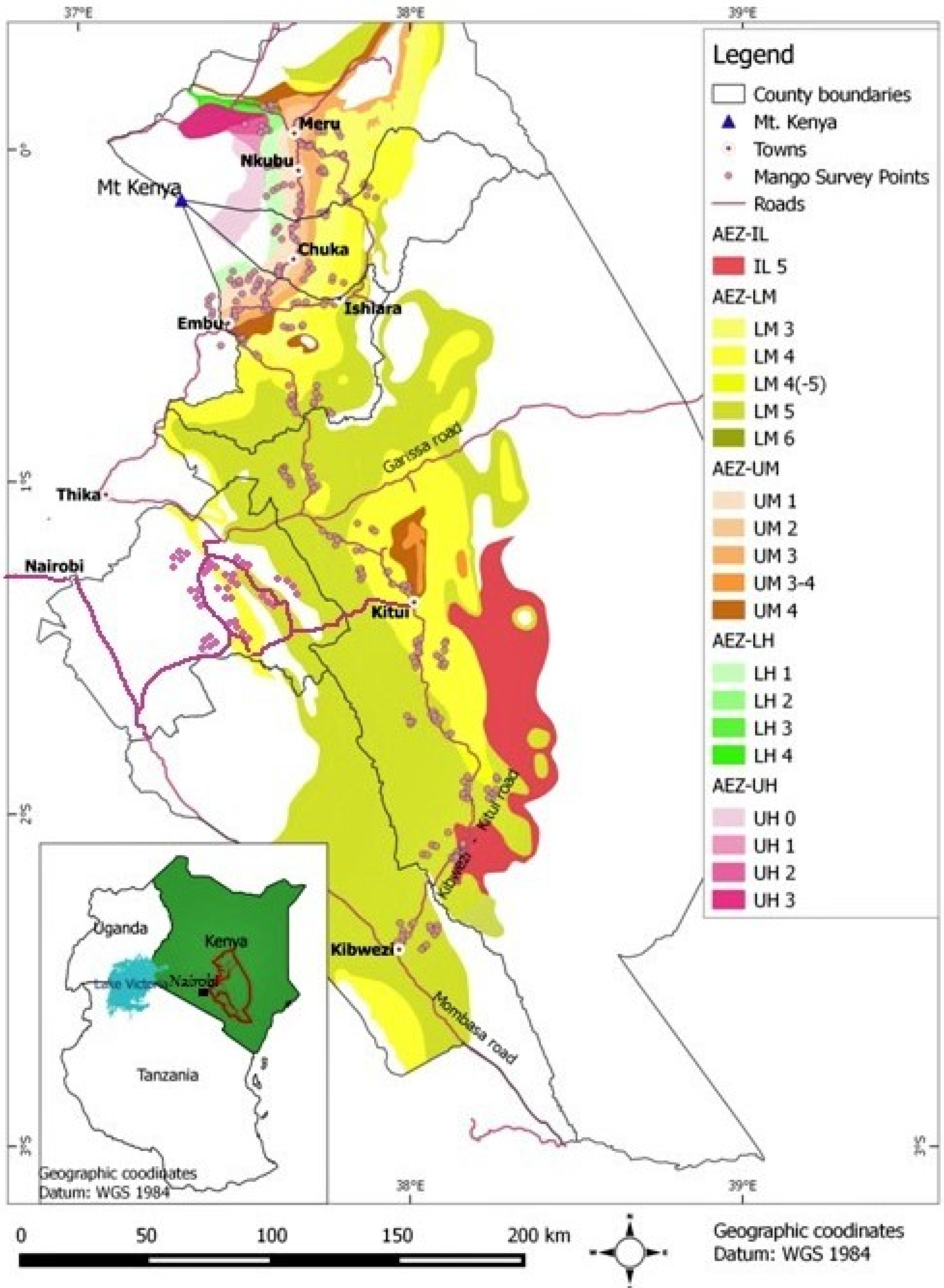

Figure 1: Map of the study area of the six counties of Kenya showing the locations of the 280 sampled farms (closed dots) across Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru spanning five AEZs. Inset: Map of East Africa with study area enclosed in red located east of Nairobi, Kenya's capital city.

RESULTS AND DISCUSSION

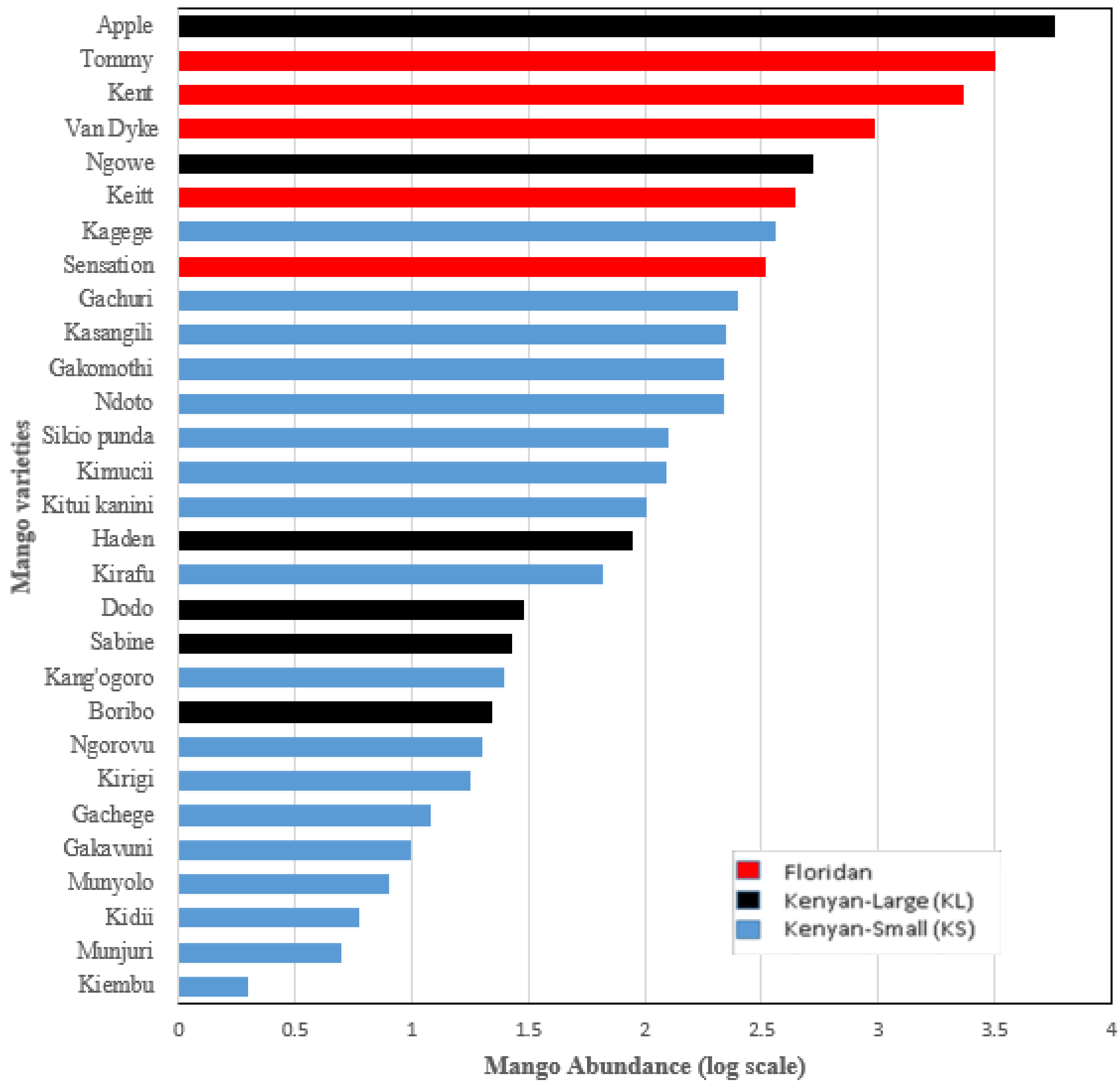

Figure 2: Variety–abundance curve (in log-scale) of 29 mango varieties documented in 280 farms along an altitude gradient across different AEZs in six counties of Kenya**.**

Of the top six most abundant varieties, four (Tommy Atkins, Kent, Van Dyke and Keitt) are of the Floridan category. The preference of Tommy Atkins and Van Dyke relates partly to their consistent fruit production, bearing very attractive fruits which have an excellent shelf-life. Too, the trees exhibit good resistance to notorious anthracnose and powdery mildew fungal diseases (Griesbach, 2003). The preference for Kent is partly because the ripe fruit has excellent internal quality and good shelf life. Additionally, fruits of the latter mature late so farmers get a higher price since the supply of ripe mangoes has declined by the time the variety's fruits are ready. According to Griesbach, (2003), Kent's appearance is not as attractive and also has a shorter shelf life because its prone to storage diseases, which might explain its relatively lower preference. Ngowe is preferred for having fibreless flesh of excellent quality and without turpentine taste, but adoption is limited by its susceptibility to powdery mildew disease. Abundance for the remaining Floridan and KL varieties is lower mainly because they are less known at market level. For the rest of the varieties, abundance of the majority (17) continuously declines. These comprise Kenyan small fruited varieties which also have high fibre-content. The proportionately large seed leaves little flesh for consumption and consequently fetch low market prices. The KS tree canopy is very large and shades-off large areas of the farm so new farmers prefer to adopt the Floridan and KL varieties; where else the older mango farmers are replacing KS with Floridan and KL varieties.

Distribution of mango varieties along the altitude gradient

The mean total abundance of mango trees was highest (103 trees per farm) at an altitude of between 1000 and 1250 m above sea level – a.s.l. Suggesting that at this altitude the climatic conditions are optimally suitable for cultivation of mango trees. This abundance then varied showing a downward trend with increasing altitude to a minimum of less than ten trees per farm. A similar trend was observed for Floridan varieties, peaking at 67 trees per farm between 1000 and 1250 m a.s.l. then dropping to very few trees at 751-1000 m a.s.l (Fig. 3). The findings showed a widely varied mean abundance of KL mango trees, from below 20 trees per farm at 500-750 m to more than double (at 49 trees per farm) at 751-1000 m a.s.l, then declining back to 29 trees per farm at 1001 to 1250 m a.s.l (Fig. 3). Few mango trees occurred above 1500 m above sea level. However, the abundance of KS varieties occurred in low abundance relative to the KL and Floridan categories throughout the altitude gradient. Most (24 and 27 out of 29) mango varieties were found within low altitudes of between 751 - 1000 m a.s.l and 1001 - 1250 m a.s.l respectively (Fig. 3). The highest densities of mango trees per hectare were found between 1001 and 1250m a.s.l. Mangoes of the Floridan category, Tommy Atkins and Van Dyke and Kenyan large Apple variety were well spread out from low to high altitude. While Kagege was the most abundant KS variety, only two KS varieties Kasangili and Sikio punda were found in the low altitudes between 500 and 750 m a.s.l.

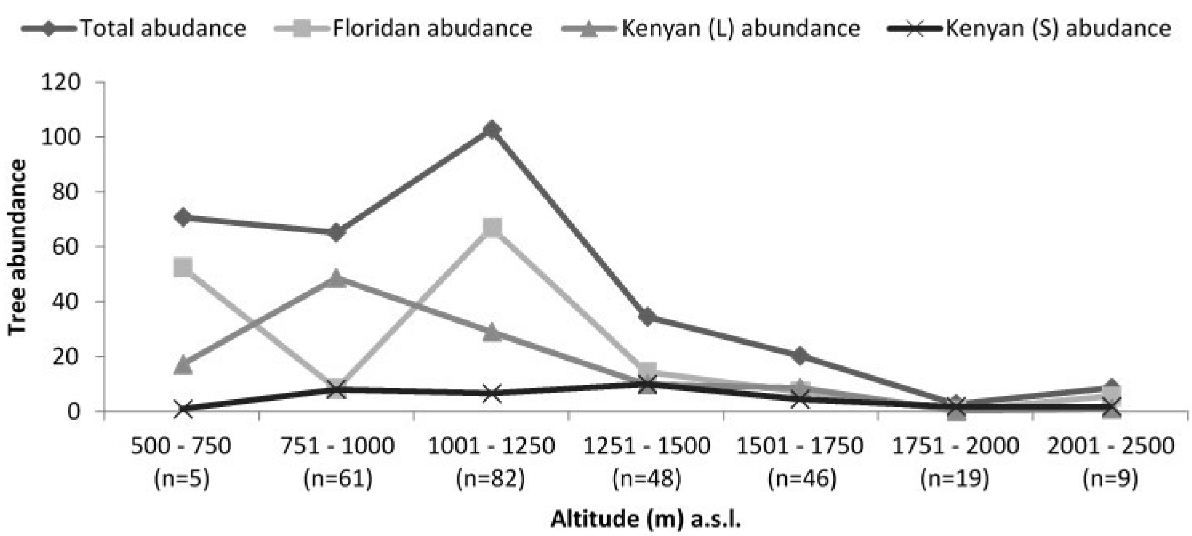

Figure 3: Mean abundance of mango trees per farm in total and separately for the variety's three categories across altitude zones where 280 farms were surveyed in six counties in lower eastern region of Kenya.

According to Griesbach, (2003) essential prerequisites for good development of mango trees are rainfall of 500-1000 mm, altitude of <1200 m a.s.l, temperatures of 20-26°C. The latter is providing sufficient heat during the time of fruit ripening. These conditions also discourage anthracnose and powdery mildew fungal diseases which pose major plant growth problems and are very common in cold humid conditions. This explains why the highest total abundance and abundances of Floridan and Kenyan Large varieties occurs below 1500 m a.s.l. The study findings also showed that the highest densities of mango trees per hectare were at altitudes between 1001 and 1250 m a.s.l. where AEZ conditions are more suitable and also farmers can afford the inputs. This study found the Floridan varieties Tommy Atkins and Van Dyke were generally spread throughout the altitude gradient. Farms located in lower rainfall areas had higher mango abundance and number of mango varieties than farms at higher altitudes. This is partly due to higher incidence of fungal diseases like powdery mildew and anthracnose which are more prevalent in cooler, more humid high altitudes (Griesbach, 2003). From farmers experience, ripe fruits such as mango are sweeter when grown in the warm temperatures (at lower altitudes) and are therefore more appealing to customers. This is because these fruits have more sugar when ripe than those grown at higher attitudes. At altitudes below 1500m there was noticeable clustering of farms with certain mango varieties, part of the reason being that farmers often plant what their neighbours do or plant mango seedlings available from the nearest fruit tree nursery. This is in agreement with other studies that found farmers are more likely to adopt agricultural technology if their neighbours would support their decision (Wollni & Andersson, 2014) Farmers who were trained by early adopters committed more land to the technology, since they have had more time to implement it, than those who did not receive such training at all or received it later.

Socio-economic characteristics

The mean household size was 5.4 persons, majority (43%) of farmers were aged 46-60 years while more than half (57%) of the farmers attained primary level education (Table 1). The main occupation of most (63%) of the farmers was specifically farming but only 33% had membership to a farmers' association. Mean farm size was 2.1ha (range 0.4-8.9ha). The largest farms were found in LH4 (8.9ha) and smallest in LH2 (0.4ha). Day to day management of most (79%) farms was done by the farmer (owner) and mean length of time farmers had cultivated the current farm land was 22.6 years. A high (72%) proportion of the farmers could easily access mango planting materials within a distance of 5km. Less than half (44%) of the farmers planted mangoes as their main cash crop where else 20% of them discontinued farming of other crops due to decline in yield mainly attributing it to increased temperatures or decreased rainfall locally. The mean number of mango trees per farm was 57 and mean number of varieties of 5 per farm. The overall densities of mango tress per hectare was also higher for male-headed households (64.7 trees/ha). A high proportion (73% and 86%) of the farmers perceived that rainfall had decreased and temperature had increased, respectively, in the past 30 years. Nearly half (43.7%) of the farmers had a strong perception that the decrease in the mango yield was due to climate change along rainfall and temperature parameters. The harvested mango fruits were sold to either brokers (47%) or to the local market (53%) making a mean annual income of US$ 364.4 per farm. The sale of mango fruits contributed a mean of 26% to the total household. Farmers' main challenge was marketing of the harvested fruits with majority (74%) stating that available market was non-profitable and unreliable.

Results from this study indicating that farmers of improved mango varieties generated more income from sale of mangoes than those of KS varieties. Income from sale of mango fruits contributed significantly to the total household income (26%); this is lower than findings by ADB (2015) of 40% for farmers in Makueni, Kitui, Machakos, Embu, Tharaka-Nithi and Meru Counties.

Cultivation of fruit trees does improve socio-economic status of farmers. That availability of reliable and profitable market influences adoption is related to varietal attribute since Floridan and KL varieties have greater market appeal, a factor that influences farmers to adopt the IMVs. This is supported by studies by Harvey *et al*., (2014) which showed that Floridan and KL varieties produce fruits of high market value. In alignment with this, 37% of the farmers had increased the acreage of improved mango varieties (adoption) in the previous 5 years. Male-headed households had a higher mean (64 trees) total abundance of mango trees compared to female-headed household (16 trees). A similar trend was observed for the total number of varieties cultivated and especially the Floridan and Kenyan Large varieties which were higher for male than female-headed households. Further, income generated from mangoes for male headed households is higher (US$ 401.9) than for female-headed households (US$120.6) (Table 1). Apparently, the farmer's age does not have significant influence on abundance of IMVs adopted. This contradicts findings by Akudugu *et al*., (2012a) that age is an important factor that influences the probability of adoption of new technologies because it is said to be a primary latent characteristic in adoption decisions.

Factors influencing farmers' adoption decisions

Since adoption of IMVs mainly targeted to replace KS varieties, their inclusion here is meant for comparison but is not being studied per se. The stepwise linear regression model was generally weak. The model effectively explained 16% of the variation in the abundance of Floridan varieties with the remaining 84% of the variation explained by variables not included in the model. Important significant ($p=0.05$) factors included farmer's awareness that rainfall had decreased in the last 30 years (12%) as an explanation for the level of abundance of Floridan varieties adopted. The model only effectively explained about 10% of the abundance of KL varieties, the remaining over 90% of the variation is explained by variables not included in the model. The model effectively explained about 20% of the variation in number of varieties of KL and 10% ($p=0.05$) of the variation in abundance of Floridan varieties, the remaining variation is explained by variables not included in the model. Almost 10% ($p=0.05$) of the abundance of KL varieties is influenced by altitude as an important factor considered by farmer at pre-adoption decision making. Important significant factors included farmer's selection of the scion (15%, $p=0.01$), availability of profitable and reliable market (8%, $p=0.05$) and altitude (about 10%, $p=0.05$) and marketing as the main challenge to farming (about 10%, $p=0.05$). Membership to farmers association had a notable influence (17%, $p\leq0.01$) on the yield of mango varieties.

Table 1 Mean abundances of all mangoes and variety numbers for the Floridan, KL and KS types as related to different socio-economic variables for 280 farms surveyed in six counties in lower Eastern region of Kenya.

		Total		Floridan (F)		Kenyan (L)		Kenyan (S)	
		Abundance	No. of varieties	Abundance	No. of varieties	Abundance	No. of varieties	Abundance	No. of varieties
Farmer's education	Up to Primary	42a	5a	22a	1a	14a	1b	6a	3a
	Above Primary	69a	5a	32a	1a	31a	1a	7a	2b
Gender	Female	16b	3b	9b	1b	4b	1b	3a	2a
	Male	64a	5a	30a	1a	26a	1a	7a	3a
Availability of planting material	Not easily	9b	4b	2b	1b	3b	1b	4a	2b
	Easily	76a	5a	37a	1a	31a	1a	8a	3a
Membership to farmers assoc.	No	53a	5a	22b	1b	24a	1a	7a	2b
	Yes	67a	6a	38a	2a	23b	1a	6a	3a
Available Market	Non-profitable	58a	5a	28a	1a	23b	1b	7a	3a
	Profitable	56b	4a	25a	1a	24a	1a	7a	2b
Main market outlet	Local market	24b	6a	8b	1a	9b	1a	7a	3a
	Brokers	95a	4a	49a	1a	40a	1a	6a	2b
Perception that the rainfall has changed	No	28b	4b	14a	1b	10b	1b	3a	2a
	Yes	69a	5a	32a	1a	29a	1a	8a	3a
Main challenges	Marketing	81a	6a	37a	1a	36a	1a	7a	3a
	Others	30b	4b	16b	1b	9b	1b	6a	2a

Where significant difference was observed within a column (Mann U-Whitney test; P≤0.05) values are lettered differently (***ab***) in a descending order of size.

Socio-economic characteristics' influence on adoption of mango varieties analysis was assessed using correlation and linear regression (Table 2). It indicated that farmers whose highest education level was primary school cultivated significantly more total number of mango varieties than those who were educated above primary level. This could be because the more educated farmers engaged in other paying engagements and did not concentrate as much on mango farming. This is supported by a study by Ghimire *et al*, (2015) which found that education plays significant roles in adoption decisions by the farmer. This can influence individual farmers by counter balancing the negative effect the lack of years of formal education has on the overall decision to adopt (Yaron *et al*., 1992). Additionally, farmers who perceived that rainfall had decreased over the last 30 years had significantly higher total abundance of mango trees and number of varieties than those who perceived no change in rainfall patterns.

Farms of male headed house-holds had significantly higher mean abundance of IMVs and number of varieties than female headed house-holds. This is supported by other studies done on adoption of cocoa, coffee crops and other agricultural technologies that gender has positive influence on adoption decision due the influence (Akudugu *et al*., 2012a; Baffoe-asare & Danquah, 2013; Overfield & Fleming, 2008) . Also most of the household decisions in farming operations including technology adoption are made by the male head who also controls production resources such as land, labour and capital which are critical for the adoption of new technologies (Akudugu *et al*., 2012b). Where planting material was easily available, the farmers had significantly greater abundance (total, Floridan and Kenyan Large) than where planting material was not easily available. Also, farmers who had membership to a Farmers' Association had significantly higher abundance of Floridan mango variety and abundance of Kenyan large variety (IMVs) on-farm.

Farmers association are the sources of information for the would be adopter. An individual's assessment of the new technology is subjective and as a farmer learns more about the technology from neighbours who have already adopted it, uncertainty about a technology's performance reduces which then reinforcing their decision to adopt it (Caswell *et al*., 2001). Such membership reduces technology demonstration costs, improves farmers' access to innovations and provides opportunity for agencies promoting adoption of mangoes to interact. Marketing of the fresh mango fruits was reported as main challenge to mango adoption and those who regarded the mango markets as profitable and reliable had significantly more KL number of varieties cultivated than those who did not; too availability of market for the mango fruits was a major factor influencing the total abundance of both Floridan and Kenyan Large. Farmers who sold their mangoes through a broker had a significantly higher mean abundance of Floridan and KL compared to farmers who sold their produce in the local market (Table 2).

Table 2 Results from Spearman's rank-order correlation of the explanatory power of socio-economic and agro-climatic explanatory factors on abundance and number of mango varieties for 280 farms surveyed in six counties in lower Eastern region of Kenya

	Total		**Floridan**		**Kenyan (L)**		**Kenyan (S)**	
Characteristics	Abundance	No. of varieties	Abundance	No. of varieties	Abundance	No. of varieties	Abundance	No. of varieties
Rainfall (range 1-very high to 5-very low)	0.223**	0.283**	ns	0.144*	0.294**	0.403**	0.122*	0.127*
Farmers education (0= ≤primary, 1= ≥prim.)	ns	ns	ns	ns	ns	0.134*	ns	-.0158**
Gender of HH head (Male =1 female = 0)	0.228**	0.280**	0.120*	0.192**	0.196**	0.226**	ns	ns
No. of HH members (≤ 5 (0=No, 1=Yes)	ns	-0.138*	ns	-0.126*	ns	ns	ns	ns
Farm management (1= farmer, 0= other)	-0.154*	ns	ns	ns	-0.277**	-0.214**	ns	ns
Farm size (Ha.)	0.194**	0.242**	0.124*	0.201**	ns	0.187**	ns	ns
Total Income (Kshs)	0.367**	ns	0.266**	ns	0.311**	ns	-0.120*	-0.314**
Income from Mangoes (Kshs)	0.677**	0.196**	0.473**	0.250**	0.515**	0.237**	ns	-0.298**
% income from mangoes	0.399**	0.218**	0.295**	0.173**	0.256**	0.126*	ns	ns
Planting material available (0=No, 1=Yes)	0.406**	0.231**	0.260**	0.246**	0.359**	0.318**	ns	-0.154*
Selected scion 1=Yes, 0=No	0.487**	0.285**	0.302**	0.307**	0.468**	0.426**	ns	-0.216**
Mango is main cash crop (0=No, 1=Yes)	0.400**	0.163**	0.261**	0.216**	0.372**	0.268**	-0.148*	-0.246**
Farmers assoc. membership (1=Yes, 0=No)	ns	ns	0.175**	0.138*	-0.136*	ns	ns	0.136*
Market profitable & reliable (0=No, 1=Yes)	0.199**	ns	ns	ns	0.292**	0.141*	ns	-0.276**
Broker's main market outlet (0=N, 1=Yes)	0.408**	ns	0.233**	ns	0.347**	ns	ns	-0.323**
Road proximity key factor (1=Yes, 0=No)	ns	ns	-0.120*	ns	ns	0.150*	ns	ns
Added IMV acreage recently (1=Yes, 0=No)	0.226**	0.183**	ns	ns	0.222**	0.215**	0.185**	0126*
Rainfall has decreased in the past 30yrs (0=No, 1=Yes)	0.268**	0.233**	ns	0.157**	0.293**	0.348**	ns	ns
Temperature has decreased in the past 30 years (1=Yes, 0=No)	ns	0.177**	ns	0.144*	0.223**	0.249**	ns	ns
Yield has decreased due to climate change (1=Yes, 0=No)	ns	ns	ns	ns	ns	ns	ns	-0.244**

[a]Rainfall and temperature values from the WorldClim database. 'ns' = not significant; *, **, *** significant at P≤0.05, ≤0.01, ≤0.001 respectively. Only the factors with at least one significant influence are included. HH- house hold.

Notably, since brokers collected the mango produce at the farm gate, whether the farm was close to the road (0-2km) or away from the road (6-8km) was not of significant influence. Considering that brokers buy fruit produce in bulk then the broker plays a role of reducing post-harvest losses incurred by the farmer and can therefore encourages adoption. Those farmers with greater abundance of the IMVs apparently stated that marketing was the main challenge to adoption of IMVs considering the difficult in selling a perishable one-peak-season a year crop. Farmers who held the perception that rainfall had declined in recent years had significantly higher abundance of IMVs (Table 2). This is an indication that farmers' adoption of IMVs could have been influenced by the perception that future reduction of rainfall due to climate change could negatively impact yield of their traditional crops. According to Table 2, farmers with farms located in the lower rainfall areas had significantly (r_s=0.223, $p \leq 0.01$) higher abundance of IMVs and greater varietal diversity than those in higher rainfall areas. There was a strong correlation (r_s=0.403, $p \leq 0.01$) between lower rainfall and number of varieties of KL (r_s=0.294, $p \leq 0.01$) category. This could be an indicator of some drought tolerance and better growth and/or yield by KL varieties compared to Floridan IMVs. Unlike the analysis of means, farmer's education did not have any significant correlation with abundance and /or number of IMVs adopted. An operator's education has a significantly positive effect on his or her adoption of information-intensive technologies (Caswell *et al*., 2001). Also gender of house hold head had a weak correlation (r_s=0.226, $p \leq 0.01$) with the number of KL varieties and the abundance of IMVs too (Table 2).

There was also a weak correlation between farmers who could easily access planting material and total abundance, abundance of Floridan and KL varieties (r_s=0.406, r_s=0.250 and r_s=0.359, $p \leq 0.01$ respectively) (Table 2). Availability of planting materials had strong enough positive influence on adoption of improved mango varieties. Farmer's ability to easily acquire the planting materials enables them to cultivate more mangoes particularly of the Floridan and KL varieties which are propagated through grafting. Nearly all farmers sampled never grafted their own seedlings but relied on sourcing grafted planting material from nurseries or relied on services of skilled 'grafters'. Related to this for farmers who were involved in selection of the scion, there was greater abundance of the improved (Floridan and KL) varieties (weak to strong enough correlation where r_s=0.302, $p \leq 0.01$ and r_s=0.426, $p \leq 0.01$ respectively) and therefore had greater total abundance as indicated by a strong enough correlation (r_s=0.487, $p \leq 0.01$). Knowledge about the characteristics of specific target mango varieties is important in adoption of IMVs and this is reliant on farmer's level of networking and information sourcing. Farmers who had greater abundance of the IMVs also received greater income from mango sales and there was a strong correlation with adoption of the IMVs (r_s=0.677, $p \leq 0.01$). There is a cause and effect scenario here since technology adoption is costly and large fixed costs can become a constraint to technology adoption so a farmer who has greater income (total or from IMV sales) is in a better position to adopt IMVs (Gabre-Madhin, 2002). Higher income from the mango sales motivates the farmer to adopt more IMVs as long as the other limiting factors are favourable. There was strong correlation (r_s=0.400, $p \leq 0.01$) between farmers who had mangoes as the main cash and greater abundance of IMVs (Floridan r_s=0.261, $p \leq 0.01$ and KL r_s=0.372, $p \leq 0.01$) (Table 2). A farmer cultivating mangoes as the main cash crop is more likely to access credit; an important facilitating factor of agricultural production technology adoption since high poverty levels among farmers in the area of study makes it more difficult for them to afford technologies.

Where farmers had increased the farm acreage under mango crop, they adopted more IMVs as indicated by the greater abundance and number of KL varieties indicated by a weak correlation (r_s=0.226, p≤0.01). There was a strong enough correlation (r_s=0.408, p≤0.01 and r_s=0.348, p≤0.01 respectively) between farmers who sold their mangoes through a broker and the total abundance and abundance of Kenyan large varieties. There was a strong correlation between farmer's perception that the rainfall had decreased in the last 30 years and total abundance and number of KL varieties (r_s=0.268 and 0.233, p≤0.01 respectively). Too, farmers' perception that temperature had increased in the last 30 years was found to have a positive correlation with adoption of improved mango varieties (r_s=0.249, p≤0.01). Logically investing in IMVs in previous scenario of climate change where productivity of traditional cereals had declined is an adaptation for the farmer to sustain profitability in their farm business. According to Morris *et al*, (2017) farmers are reactive dynamic business operators facing physical constraints of weather, land and social expectations who view technology adoption within the implications of farm business models.

Conclusion and Recommendations

Farmers' adoption of the Floridan and Kenyan Large varieties (IMVs) was found to be widely spread across the five main AEZs. In the lower Eastern region of Kenya, the highest tree densities, abundance and varietal diversity were found to occur within altitude range of 751-1250 m a.s.l. in LM 4 and LM 5 AEZs. Findings of the study indicate a positive correlation between abundances of IMVs adopted and three factors; size of the farm, availability of planting material and availability of profitable/reliable market. Also, the study found that Kenyan Large varieties, especially Apple variety, were the preferred IMVs by farmers followed by the Floridan varieties. Results from this study support the hypothesis that there are specific socio-economic and environmental factors influencing the farmers' decision to adopt improved mango varieties in lower Eastern Kenya. Farmers need to make informed decisions on suitability of varieties selected for adoption and implement appropriate mango farming practices. This requires County governments to operationalize agricultural extension services. To enhance increased adoption, these governments need to support farmers in securing profitable and reliable markets, encourage farmers associations and facilitate mango value addition processes. Suitability modelling of mango varieties for AEZs in future climate scenarios could guide farmers on the appropriate germplasm for adoption.

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Conflict of interest

There is no conflict of interest among the authors.

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