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Research Article

Assessment of Input-Output Transformation in Purple Passion Fruit Production in Central-Eastern and North-Rift, Kenya

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Abstract: Over the last decade, there has been increasing economic importance of purple passion fruit in Kenya. The primary objective of this study was to assess the input-output transformation process in purple passion fruit production in Central-Eastern and North-Rift Kenya in order to identify avenues for improving and sustaining productivity. Cross-sectional data from 123 multistage sampled farmers was collected using a structured questionnaire, which was subjected to stochastic frontier in STATA 11 for analysis. The results showed that the purple passion fruit production input elasticity was 0.95 which represented Decreasing Returns to Scale (DRS). The results also indicated that passion fruit farm size and manure had a negative and positive significant effect on purple passion fruit yields at 1% significance level, respectively. On the other hand, number of seedlings and hired labor variables had positive and significant effect on the fruit yields at 5% level. The results implied that passion farm size was overused while manure, number of seedlings and hired labor were underused. The gamma parameter (&gamma) was 0.86 which indicates that 86% of the total variation in purple passion fruit output was due to technical inefficiencies. The overall mean Technical Efficiency (TE) was 59% which indicated a cost saving estimate of 32% for the average farmer in attaining the TE of the most technically efficient farmer (86%). The study recommends up-scaling of passion fruit farming information systems so as to provide a basis for optimal use of production resources.

Keywords: Productivity, stochastic frontier analysis, technical efficiency

INTRODUCTION

In Kenya, the horticulture industry sustains millions of livelihoods through local and export markets. Horticultural exports sustain the livelihoods of approximately 1.20 million people and are an important source of foreign exchange in Kenya, accounting for 14% of total export earnings. Kenya earned Kshs. 77.70 billion (approximately $914.12 million) from horticultural exports (HCDA, 2011). Aside from exports, a large portion (96%) of horticultural produce is consumed locally (Kibe, 2009). Approximately 80% of horticultural producers are small holder farmers (Namu, 2007; Government of Kenya, 2010).

The horticultural industry across the world is well-known for realizing higher returns compared to other enterprises (Kibet *et al*., 2011) at the farm level, ceteris paribus. It is also a quick avenue for food production since many horticultural crops are early maturing and are harvested more than once. Like other horticultural crops, passion fruit can realize high returns since it can be harvested on a weekly basis for two 3 months seasons (6 months) annually thus good investment in income generation, employment creation and eventual improvement of livelihoods among the fruit producers. However, in order to realize these benefits, optimization in use of inputs must be ensured. Fintrac (2009) estimates passion fruit gross returns at Ksh. 629,850/ha (approximately $7,410) in Kenya which is overly higher than maize (common crop in passion fruit producing areas).

The establishment and expansion of local large scale processors of fruit juice, expanding export markets and increasing population of health conscious consumers (Wangungu, 2012) in the last decade have made the passion fruit sub-sector lucrative. In Government of Kenya (2010), passion fruit was ranked third after avocado and mango in terms of foreign exchange earnings. Passion fruit contributed Kshs. 1.90 billion, 1.19% of the domestic value of the total horticultural produce and 4.55% for the fruit sub-sector (HCDA, 2011).

In Kenya, the purple passion fruit enterprise operates below potential thereby realizing low average yields of 8-9 ton/ha in contrast to 19-24 ton/ha in South Africa and Australia (HDC, 2005; Mbaka *et al*., 2006).

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The demand for the fruit highly exceeds supply. This has contributed to importation of fruit pulp to satisfy the growing demand of the local processors. The factors contributing to the low productivity are yet to be assessed although they are predicted to be mainly production in nature; efficiency in resource use.

Over the last 6 years, passion fruit production in Kenya has recorded fluctuations (HCDA, 2011). Passion fruit production reduced from 71283 Mt in 2007 to 55094 Mt in 2010. Instances of output increase were associated with expansion of land under passion fruit rather than improved productivity per hectare (HCDA, 2011).

The aim of the study was to assess the input-output transformation process in purple passion fruit production in order to identify avenues for enhancing and sustaining productivity at the farm level. During the study, determinants of productivity and Technical Efficiency (TE) among the purple passion fruit farmers were also identified.

MATERIALS AND METHODS

Study area: The study was undertaken in the Eastern (Meru and Embu Counties) and North-Rift highlands (Uasin Gishu County) of Kenya. Meru County measures 6936 Km^2, has a population of 1,356,301 persons and borders Tharaka Nithi County to the South-East, Isiolo County to the East and North, Laikipia to the West and Kitui to the East. Embu County covers 2818 Km^2, has a population of 516,212 persons and borders Kirinyaga County to the West, Kitui County to the East, Machakos to the South and Meru to the North. Uasin Gishu County measures 3345.2 Km^2, has a population of 894,175 people as per 2009 Census and borders Trans-Nzoia to the North, Kericho to the South, Elgeyo Marakwet to the East and Bungoma and Nandi Counties to the West. The three Counties have an altitude of above 1050 m asl, temperature range of 8.4-27°C and bi-modal rainfall (long rains start from mid March to late May and short rains starts from mid October to late December) ranging 500-2600 mm/annum (Government of Kenya, 2012). All the three Counties cuts across the highlands but are composed of high potential (>1200 m asl, <=18°C and ≥1000 mm rainfall annually) and low potential (<1200 m asl, >18°C and ≤900 mm rainfall annually) agro-ecological zones (Leeuw *et al*., 1989). Areas bordering Isiolo, Kitui and Machakos and Bungoma Counties are the low potential zones for Meru, Embu and Uasin Gishu Counties, respectively. The study was undertaken in the high potential agro-ecological zones of the Counties which are suitable for passion fruit farming mainly the purple variety. The main economic activity in the study Counties is Agriculture; mixed farming (Government of Kenya, 2012).

Data and sampling design: The sample size of farmers used in the study was first determined, 123. Then the sample size was proportionally divided among the three study Counties; 53, 48 and 22 farmers were selected from Meru, Uasin Gishu and Embu Counties respectively. A multi-stage sampling design was employed. The study areas were selected purposively owing to their importance in purple passion fruit farming. Then systematic random sampling at an interval of 1 respondent was used to select the desired sample; every second passion fruit farmer was selected. Respondents were identified with the assistance of government extension officers.

The sampling frame was made up of farmers who had purple passion fruit orchards measuring 0.04 to 3 ha. Data collection was done using a personally administered structured questionnaire in July and August, 2012. The data collected included household, input and output data for period of 1 year (May 2011 to June 2012).

Data analysis: The cross-sectional data from the study was subjected to heteroscedasticity test using Breusch-Pagan/Cook-Weisberg test (Berry and Feldman, 1985) and normality test using Kernel density function (Kibaara, 2005) to ensure reliability of the data. The data was corrected for heteroscedasticity by employing natural logarithms.

Stochastic frontier model in STATA was used for data analysis in this study based on Aigner *et al*. (1977) approach of an imperfect world. The model is expressed as:

$$Y_i = f(x_i;\ \beta) + \varepsilon_i \tag{1}$$

where,

i	= 1, 2… N
Y	= The output
x	= Inputs
ε (error term)	= ν_i-μ_i

A decomposition approach is employed to measure the TE in purple passion fruit production whereby the ε_i is decomposed to ν (random error that represents the random variability of passion fruit production that cannot be influenced by farmers) and μ (non-negative random variable associated with technical inefficiency in passion fruit production). The ν_i and μ_i terms are assumed to be independently and identically distributed as N $(0, \sigma^2_\nu)$ and normal N $(0, \sigma^2_\mu)$ respectively.

In order to assess the input-output transformation, determinants of productivity and technical efficiency among purple passion fruit farmers, the stochastic frontier model in STATA was adopted. In this approach output was the dependent variable while inputs were the independent variables. Technical inefficiencies of the purple passion fruit farmers are determined in the process. The Cobb Douglas functional form of the stochastic frontier was used due to its appropriateness in computation and interpretation.

The input-output transformation hypothesized relationship was as expressed below:

$$\mathrm{LnY} = \mathrm{LnA} + \sum_{I=1}^{7} \mathrm{B_i LnX_i} + \mathrm{V} - \mu \tag{2}$$

where,
Ln : Natural logarithms
A, B & βs : The unknown parameters for estimation:

$$\text{LnY} = \beta_0 + \beta_1 \text{lnnumberofseedlings} + \beta_2 \text{lnfarmsize} + \beta_3 \text{lnfertilizer} + \beta_4 \text{lnmanure} + \beta_5 \text{lnpesticides} + \beta_6 \text{lnhiredlabour} + \beta_7 \text{lnfamily labour} + (v - \mu) \quad (3)$$

RESULTS AND DISCUSSION

The results of the heteroscedasticity test showed high levels of heteroscedasticity (chi-square of 231.75 and p-value of 0.00) thus needed correction. Once the cross-sectional data was converted to natural logarithms at the base of 10 and heteroscedasticity retest run, absence of heteroscedasticity was confirmed (chi-square of 0.18 and p-value of 0.67 were recorded).

A kernel density function plotted (Fig. 1) in STATA 11 assessed the correctness of the normality assumption where a normal curve was superimposed on the kernel density curve to test for normality. Figure 1 confirms that μ had a fairly normal distribution. Therefore, technical efficiency estimation in the study was made possible.

Passion fruit farm size and manure had negative and positive significant effect on TE at 1% significance level, respectively. Number of seedlings and hired labor had a positive significant relationship with purple passion fruit output at 5% significance level.

The log likelihood (-117.61) for the study area stochastic frontier model was different from zero while the chi-square value (74.99) was strongly significant at 1% which implied that the explanatory variables used in the model were collectively able to explain the variations in purple passion fruit productivity.

Four out of seven production variables (passion fruit farm size and manure quantity at 1% level, number of seedlings and hired labor at 5% level) had significant effect on the purple passion fruit yield. Therefore, the four factors of production were the major determinants of productivity and technical efficiency in the study area. This meant that their intervention would influence the resultant productivity and TE.

There was significant positive effect of production factors (number of seedlings, manure and hired labor) on output which indicated underuse. Significant overuse of some production factors (passion fruit farm size) was also recorded which had a negative relationship with passion fruit yield. This meant that farmers were not operating at optimal levels.

The gamma (γ) coefficient (0.86) for the study indicated that 86% of variations in purple passion fruit output among the farmers were caused by technical inefficiencies, that is, factors within the farmer's control especially in the use of inputs and general orchard management. Kibaara (2005) and Msuya *et al*. (2008) also found that maize in Kenya and Tanzania had high gamma values of 79 and 96%, respectively.

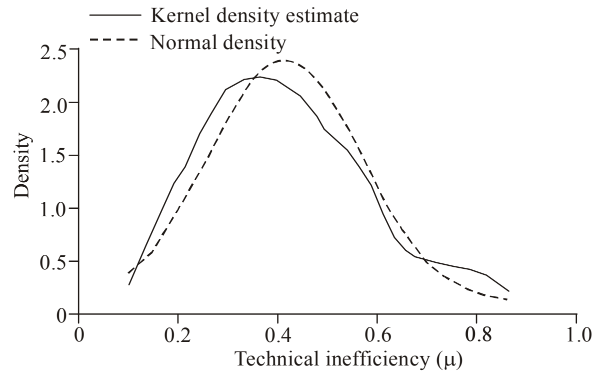

Fig. 1: Kernel density estimation of technical inefficiency (μ)

The large lambda (λ) value was an indication that the one sided error term μ dominated the symmetric error v. Therefore, the disparities in the actual purple passion fruit output emanated from differences in farmers' practices rather than random variability. The large value of λ also indicated goodness of fit and correctness of the specified normal/half-normal distribution assumption as observed by Kibaara (2005).

Manure had the highest positive influence on yields. A 10% increase in the quantity of manure per hectare applied translated to an increase in output of purple passion fruit productivity by 9%. The result for this variable presents nutrients as the major and important constraints to the improvement of the fruit yield. However, the results were contradictory to the findings of Kibaara (2005) and Sibiko (2012) who established manure use as being insignificant in determination of yields. This inconsistency could be due to high dependence of maize on compound fertilizers in Kenya while beans are leguminous (nitrogen fixation) thus productive without manure.

Number of seedlings per hectare was identified to be one of the major constraints in achieving the potential yield. These results showed that an increase in the number of seedlings by 10%/ha would increase output by 8% thus improved productivity. In addition, the average number of seedlings per hectare in the study area were 1146 against the recommended 1734 (3*2 m spacing); indicating underuse in number of seedlings. This suggests that an increase in the number of seedlings per hectare would increase the usage of the 3*2 m spaces recommended for purple passion fruit farming. The results considerably concurred with those of Gachanja and Ochieng (1985) who found out that total and marketable passion fruit outputs increased with narrower spacing between the rows, less than the recommended 3 m. This could explain why farmers undertaking purple passion fruit farming practice intercropping with other short stature crops in order to maximize the use of land (Lima, 2002). However, this would constrain management operations such as weeding, spraying and pruning (Table 1).

Table 1: Stochastic frontier production results for passion fruit farmers in eastern and north-rift Kenya

Variable	Coefficient	S.E.
Number of seedlings (number/ha)	0.80*	0.37
Passion farm size (ha)	-1.15**	0.45
Fertilizer (kg/ha)	0.14	0.11
Manure (kg/ha)	0.88**	0.28
Pesticide (kg/ha)	-0.07	0.19
Hired labor (person-days/ha)	0.37*	0.17
Family labor (person-days/ha)	-0.03	0.14
_cons	-2.84*	1.30
lnsig2v _cons	-1.85**	0.58
lnsig2μ_cons	-0.59	0.43
Variance parameters		
Sigma_v	0.31*	0.04
Sigma_μ	0.75*	0.25
Sigma^2	0.65*	0.20
Lambda (λ)	2.42*	0.35
Gamma (γ)	0.86	
Mean technical efficiency (overall)	59%	
Wald chi-square	74.99	0.00
Log likelihood	-117.61	

*: Significant at 5% level of significance; **: Significant at 1% level of significance; S.E.: Standard error

Table 2: Frequency distribution of technical efficiency estimates for the sampled passion fruit farmers in the study area

TE range	Frequency	Frequency (%)
11-20	3	2
21-30	5	4
31-40	6	5
41-50	24	20
51-60	22	18
61-70	33	27
71-80	21	17
81-90	9	7
Total	123	100

Table 3: Marginal effects of the productivity and efficiency measuring variables on passion fruit output

Variable	Marginal effect/elasticity	Marginal change in output per hectare (Kg/ha)
Number of seedlings	0.80	69.34
Passion farm size	-1.15	-99.68
Fertilizer	0.14	12.14
Manure	0.88	76.28
Pesticide	-0.07	-6.07
Hired labor	0.37	32.07
Family labor	-0.03	-2.60

Average productivity for eastern and north rift regions = 8.67 Mt/ha

Hired labor had a positive and significant influence on yields at 5% level. The results showed that a 10% increase in hired labor person-days per hectare led to an increase of the fruit yields by 4% among the purple passion fruit farmers. These results were consistent with those of Amaza *et al*. (2006) in study of food crop and Ogunniyi and Ajao (2011) study on swine technical efficiency in Nigeria who found out that hired labor was a significant determinant of food crop and swine performance. Further, the results suggest that use of more hired labor significantly increase productivity. This may imply that hired labor effect is higher due to full employment unlike the family labor which is mostly under-employed. The family labor is mainly compensated in kind (food, cloth, education, shelter provisions among others) rather than monetary terms. Therefore, family labor mode of working tend to deviate from the norm of hired labor who work for a certain period of time or finish a given task in order to be paid. Family labor tends to be non-committal on a working schedule which makes them less productive compared to hired labor. From the study it was clear that as more hired labor than family labor is used the output would increase. However, optimality of hired labor in the orchards should be considered to avoid underuse.

According to the results, an increase of farm size under passion fruit by 1% would on average reduce purple passion fruit yield by 1%. This suggests that as more land is put under purple passion fruit, the lesser the yields. In addition, it meant that most farmers were using more land than they could adequately manage. The implication of this is that farmers with smaller pieces of land are able to adequately cater for the management needs of the plants which require regular observation. The results were consistent with the findings of Zaeske (2012) in the study of aggregate technical efficiency and water use.

The issue of land area in relation to productivity has also been widely discussed and most authors like Amaza *et al*. (2006) in food crop research in Nigeria and Teryomenko (2008) in the study of farm size and productivity in Ukraine who established a positive relationship between farm size and productivity up to 120 ha beyond which a decline was recorded. The result suggests that farmers would ensure higher productivity under smaller pieces of land. This would ensure intensive management of the orchards since the fruit requires routine management practices like weeding, disease management and training of vines and pruning among others. Better management practices would increase technical efficiency.

The computed individual farmers' technical efficiency ranged from 17 to 86% (Table 2) which represented significant production inefficiency. A mean technical efficiency of 59% recorded in the study area implied that the farmers were operating at 41% technical inefficiency level. Most farmers could therefore nearly double their fruit yields by operating at efficiency level. These results show that currently the farmers are unable to convert the available inputs to output thereby attaining less than 100% TE. Further, a mean of 59% TE implied that purple passion fruit farmers could attain the current levels of output by reducing their inputs by 41% through improving on the existing technical efficiency levels. Therefore, the selected farmers would reduce their production costs and ultimately increase the profit margins in purple passion fruit production. The current mean technical efficiency of 59%, indicates that if an average farmer in the study attained the TE level of the most efficient counterpart (86%), then the average farmer could realize a 32% cost savings (Nyagaka *et al*., 2010).

The sum of the input elasticities (Table 3) of the study area was 0.95 which represents Decreasing Returns to Scale (DRS) in purple passion fruit production. This implied that for every one unit set of inputs utilized resulted to 0.95 units of output of purple passion fruit. This implied that most passion fruit farmers in Eastern and North-Rift Kenya employed production techniques which had become redundant over time (Sibiko, 2012).

The marginal effects results (Table 3) of the productivity and efficiency measuring variables on purple passion fruit output showed that by increasing production factors by 1%, passion fruit farm size, manure, number of seedlings and hired labor would have the highest effect on productivity respectively. This implied that in order to enhance and ensure sustainability of passion fruit orchards, farmers should address the optimality of these production factors satisfactorily.

CONCLUSION AND RECOMMENDATIONS

From this study, the results indicated that overuse and underuse of production factors had high effects on the purple passion fruit productivity. The input-output transformation process showed farmers' inability in using inputs efficiently; resource use inefficiency. Therefore, the study recommends that the fruits sub-sector actors need to up-scale the passion fruit farming information systems so as to provide a basis for enhancing and sustaining productivity. This would involve frequent training of farmers with up to date information on availability and optimal use of inputs.

Purple passion fruit farmers in the study areas were technically inefficient. The average productivity was 8.67 Mt/ha, 59% of productivity potential. This presented evidence that if farmers were to be technically efficient they would attain productivity of 14777 kg/ha using the same technology. This would eventually reduce the demand-supply gap as well as improving livelihoods of the producers through increased returns.

In order to tap the high demand opportunities from the purple passion fruit there is need for enhanced public and private actors' participation which is currently low. They can invest in training, capacity building, inputs provision, marketing and or funding the fruit production promotion. This would contribute in increasing farmers' knowhow thus improving efficiency and productivity and eventually livelihoods.

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