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Household Food Security in a Subsistence Economy: Application of Translog Cost Function to Cross-sectional data in Vihiga District, Kenya

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Abstract

Vihiga, one of the poorest and densely populated districts in Kenya is perpetually food deficit (GOK, 2005). While food demand continued to rise, production fell behind both targeted production and district demand. To make matters worse food deficit situation worsened over the last decade. Rising population and competition for resources have curtailed efforts to improve household food production in the district. Unfavorable poverty indicators in the district only make matters worse. About 57.6 percent of the population and more than 50 percent of households live below absolute poverty line while 57 percent of the population and households live below food poverty line (GOK, 2005). Poor welfare indicators for Vihiga district underscore the importance and urgency for addressing its basic needs. Understanding determinants of food security in Vihiga district will improve targeting, the focus and success of policies for addressing food insecurity.The paper examines food security in a subsistence economy with an application of a Translog cost function to household survey data in Vihiga district to determine the supply side constraints. Cluster sampling was used with divisions forming the main clusters in the district. Using systematic random sampling, 50 households were selected from each cluster resulting in a sample of 300. Results show that scale of production, number of adults, household head, business income, employment; human resource development, capital, and land size significantly influence household food security. Food security programmes, in subsistence economies, aimed at revamping production should focus more on enhancing accessibility to production resources and improving the quality of labor through training.

Key Words: Food security, Translog cost function, Vihiga, Kenya

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Introduction

Despite having the potential to meet domestic food demand, Kenya has continued to grapple with persistent food deficits over the last two decades. Over the last six years the annual demand for maize in the country rose from 29.5 million bags to 32.9 million bags (GOK, 2004). However, production in the same period ranged between 25 and 30 million bags per year thus necessitating importation of food to meet the deficit.

Vihiga, one of the poorest and densely populated districts in Kenya with an average household land size of less than 0.4 hectares is perpetually food deficit (GOK, 2004). This has been attributed to limited land, high poverty levels, limited off-farm income, and non-adoption of recommended farm technologies. Vihiga district is a perfect case of why the Kenyan government will be unable to meet millennium development goals especially as regards eradication of extreme poverty and hunger (UN, 2005). Maize is the main staple food for residents of Vihiga district thus its insufficiency is synonymous with food insecurity. Over the last decade, the district maize demand outpaced local production worsening the already bad food deficit situation.

Food security describes a situation in which people do not live in hunger or fear of starvation. According to FAO (2003), food security exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This study defines household food security as access to nutritionally adequate and safe foods by all households at all times to meet their dietary needs and food preferences for an active and healthy life.

As poverty levels rise, household food insecurity in the district worsens. Families with the financial resources to escape extreme poverty rarely suffer from chronic hunger; while poor families not only suffer the most from chronic hunger, but are also the segment of the population most at risk during food shortages and famines (FAO, 2003). Vihiga district has unfavorable poverty indicators as measured by food poverty, absolute poverty and hard-core poverty. About 57.6

percent of the population in Vihiga district lives below the absolute poverty line, which is set at Kshs. 2648, and Kshs. 1238 per month for urban and rural areas respectively (GOK, 2004). Similarly, more than half of the households in Vihiga, which is one of the worst hit districts in Kenya, fell below the absolute poverty line. To make matters worse, about 57 percent of both individuals and households in the district live below the food poverty line. While 45 percent of the households live in hard-core poverty, more than half of the individuals in these households live in hard-core poverty. Poverty has a twin impact on household food security. It not only reduces the capacity of households to access farm inputs due to capital limitations thus hindering expanded food production, but also prevents households from accessing food due to their low or non-existent purchasing power. Consequently, malnutrition among households has become a big issue since if basic food needs can not be met very few household would care about the quality of food they eat. Poor welfare indicators for Vihiga district underscore the importance and urgency for addressing the basic needs of its residents. Understanding determinants of household food security in a subsistence economy prevalent in Vihiga district presents an opportunity for improving targeting, the focus and success of policies for addressing food insecurity. The paper examines the composition of farm inputs and their contribution to the total cost of food production. Additionally, the major supply side constraints to food security among households in Vihiga district of Kenya are examined. The paper is subdivided into four sections. In section one, an introductory exposition of the problem is presented. In section two, materials and methods are presented with key considerations being the review of the theoretical framework and various methodologies used. In sections three and four, results and discussions followed by conclusions of the study are presented.

Materials and Methods

Theoretical considerations

Modeling Production Behavior

Producer's objective is to maximize output so as to reap more profits. Such behavior can be modeled using a profit function approach, production function approach or cost function approach. Given price taking, profit maximizing and a model of the physical production process, it is possible to derive a model of producer output and input decisions. When using the profit function approach, the model can be specified as: -

$$\pi(p,\mathbf{w}) = max_y\, p.y - c(y,\mathbf{w}) \qquad (1)$$

Where p, y, **w, x** and C(y,**w**) are output price, output quantity, price vector of n inputs, $(w_1...w_n)$, vector of n physical input quantities used in production, $(x_1...x_n)$ and cost function respectively. Maximization of the profit requires that price equals marginal cost and the value of y that maximizes profits is supply. Using Hotteling lemma (Varian, 1993, Jehle and Reny, 1998), the derivative of the profit function, with respect to input price, is a factor demand function and, with respect to an output price, is the supply function. However, we could easily achieve the same result by proceeding from the cost function. This study adopted the cost function approach in which the producer is assumed to minimize costs to produce a given level of output. Since a majority of the households in Vihiga district are subsistence farmers the profitability approach may not be appropriate. However, the cost function approach, without loss of generality, still results in the same optimal solution since it is the dual of the production function approach (Epstein, 1981, Varian, 1992, Jehle, 1998, Mas colell et al, 1995). The cost function is one of the behavioral relationships that arise from producers' optimizing decisions. The cost function, *c (w, z, y),* is the minimum variable cost of producing the given output. This function completely characterizes the producer behavior, as it includes both the technological constraint from the production function and the behavior of the producer (De Janvry, 1993). The cost function is defined for output vectors, $\mathbf{y}= (y_1, y_{2\,...yn})$ and all positive input price vectors, $\mathbf{w}= (w_1, w_{2...}\, w_n)$. An output vector **y** can only be produced if **y** belongs to the effective domain of the input requirement set, **V (y)** such that:

$$Dom\ V = \{y \in R^m{}_+ : V(y) \neq \phi\} \qquad (2)$$

This also implies that a cost function cannot exist if there is no technical way to produce the output in question. The cost function can be specified for many outputs as below: -

$$C(y, w, z) = \min_x \{wx: x \in V(y)\},\ y \in Dom\ V,\ w > 0\} \qquad (3)$$

However, for a single output the specification changes to

$$C(y, w, z) = \min_x \{\mathbf{wx}: f(\mathbf{x}) \geq y\} \qquad (4)$$

The solution to this minimization problem is a set of input demand functions:

$$\boldsymbol{x} = \boldsymbol{x}(\boldsymbol{w}, \boldsymbol{z}, \boldsymbol{y}) \qquad (5)$$

Through Shepherd's duality theorem the input demand functions can be shown to be the derivatives of the cost functions with respect to the input prices:

$$x_i = \partial c / \partial w_i \qquad (6)$$

Given the following cost function (7) and its associated Lagrangian function (8):

$$C(y, w, z) = \min_{x} \mathbf{wx}: f(\mathbf{x}) - y = 0 \qquad (7)$$

$$L = \mathbf{wx} - \lambda \left(f(\mathbf{x}) - y\right) \qquad (8)$$

The first order condition for optimal cost minimization problem can be expressed as (9) which occur when the rate of technical substitution (RTS) between inputs i and j is equal to the negative inverse of the factor price ratio.

$$L(\boldsymbol{x}^*, \lambda^*) = 0 \quad \nabla \qquad (9)$$

The sufficient conditions for this cost minimization problem when *f(x)* and *g(x)* are twice differentiable and vectors $\mathbf{x}^* \in R^n$, $\boldsymbol{\lambda}^* \in R^m$ exist such that

$L(x^*, \lambda^*) \nabla = 0$ and $g(\mathbf{x}^*) = 0$, occur for $p = 2, 3, \ldots, n$, if the bordered Hessian of the second derivative of the Lagrange function is negative semi definite.

Model Specification

The functional forms that may be chosen to model producer behavior are Cobb-Douglas, Constant elasticity of substitution (CES), Leontief production functions (Diewert, 1971) and Translog cost function (Holly and Smith, 2002; Rovolis and Spence, 2004; Truett, 2003; Kumbhakara and Wang, 2006). Each model is associated with unique input-demand or cost shares equations that result from each choice. Model selection is governed by advantages and disadvantages of each form. The Cobb-Douglas production function is given in (10) as: -

$$y = A \prod_{i=1,n} x_i^{\alpha_i} \qquad (10)$$

Where A is a scalar for productivity, α_i, is a parameter for each factor used and the sum of α_i is the scale parameter, s. This functional form is attractive because of the simplicity of cost shares functions ($S_i = x_i w_i / c(y,w) = \alpha_i$), unit elasticity of substitution, simple estimation and embodiment of technological progress in the model(Yanikkaya, 2004). However, the Cobb-Douglas model has some drawbacks. The inputs tend to be highly substitutable for each other and there is no simple way to model biased progress with this function.

The CES function as developed by Arrow et al (1961) is specified in (11) as: -

$$y = A\left[\sum \left(\alpha_i x_i\right)^{\rho}\right]^{\frac{1}{\rho}} \qquad (11)$$

Where α_i are parameters related to share, A is a scale parameter, and ρ is a parameter related to the elasticity of substitution. With $r = \rho / (\rho - 1)$, the share of total cost of the i^{th} input and elasticity of substitution are given by (12) and (13) respectively: -

$$S_i = \frac{\left(\frac{x_i}{\alpha_i}\right)^r}{\sum \left(\frac{x_i}{\alpha_i}\right)^r} \qquad (12)$$

$$\sigma = \frac{1}{1+\rho} \qquad (13)$$

The CES function has both desirable and non-desirable elements. It can be used to represent substitution between inputs more realistically than the Cobb-Douglas function. However, its major drawback is that it requires building of a complex "nest" of CES functions to have different rates of substitutions if more than two inputs are used. There is also conflicting empirical evidence for rates of substitution.

The Leontief production function requires a fixed amount of each input to produce a given unit of output. The production function and the cost share of the i^{th} factor can be specified as (14) and (15) respectively:-

(14) and (15) respectively:-

$$y = \min \left[\frac{x_1}{\alpha_1} \ldots \ldots \frac{x_n}{\alpha_n} \right] \qquad (14)$$

$$S_i = \frac{\alpha_i w_i}{\sum_j \alpha_j w_j} \qquad (15)$$

The Leontief production function is easy to estimate since only factor shares are needed to estimate the function. However, it is overly restrictive since there is no room for substitution of inputs.

The Translog cost function approximates an arbitrary cost structure and therefore an arbitrary production structure. It does not impose theoretical requirements of symmetry of cross elasticities so that it can be used to test these assumptions. The ability to test assumptions of theory, rather than convenience in estimation, is the chief reason for the recent popularity of this functional form (Yanikkaya, 2004, Liu, 2005). The Translog cost function yields nice functional forms for factor demands while the Translog production function does not; thus explaining the preference for cost function over the production function. It is also versatile for allowing full modeling of substitution or complementarity between inputs. The Translog cost function can be specified as (16): -

$$\ln C = \ln\alpha_i + \alpha_y \ln y + \sum_i \alpha_i \ln w_i + \tfrac{1}{2}\beta_{yy}(\ln y)^2 + \tfrac{1}{2}\sum_i\sum_j \beta_{ij} \ln w_i \ln w_j + \sum_i \beta_{iy} \ln y \ln w_i \qquad (16)$$

Differentiating this equation with respect to the log of the price of one input (w_i) yields the cost share for this input (S_i)(17): -

$$S_i = \alpha_i + \sum_j \beta_{ij} \ln w_j + \beta_{iy} \ln y \qquad (17)$$

The elasticity of substitution is given by (18): -

$$\sigma_{ij} \equiv \left(1 + \frac{\beta_{ij}}{S_i S_j}\right) \qquad (18)$$

The intercept term in equation (17) is augmented to allow for influence of household composition, production factors and environmental factors. The model to be estimated is: -

$$S = \alpha + \beta \ln Y + \sum \beta_{ij} \ln w_j + \psi F + \zeta Z + \lambda P + \mu \qquad (19)$$

Where Y = a vector of household annual maize output.

S = a vector of share of survey year cost on each input i of total input cost.

β_{ij} = parameter to be estimated.

Z, F, and P are vectors of household characteristics, production factors and environmental factors while α, β, ψ, ζ and λ are corresponding vectors of parameters to be estimated, and μ is a normally distributed random error term. Since during a single survey period there is limited variation in input prices the model to be estimated reduces to (20)

$$S = \alpha + \beta \ln Y + \psi F + \zeta Z + \lambda P + \mu \qquad (20)$$

Methodologies

The study targeted all farm households in Vihiga district. Cluster sampling was adopted on the basis of the six divisions. Using systematic random sampling procedure, 50 households were selected from each cluster generating a sample of 300 respondents. Both primary and secondary data was used. Types of data collected encompassed area allocated to maize in acres, yield in tons per acre, output in metric tons, household characteristics (education, family size, head of household, employment, geographical location) farm input prices, input quantities, availability of credit, access to extension and markets. Primary data was collected through a survey while secondary data was acquired through perusal of annual agricultural reports, economic surveys, statistical abstracts and development plans. Both interviews and questionnaires were used as instruments for data collection.

To validate survey instruments, 10 questionnaires were pre-tested in one of the divisions, revised and forwarded to enumerators. Trained enumerators were used to administer the questionnaires. Focused group discussion was used to elicit information from key informants who included district agricultural officer, district development officer, heads of district non-governmental organizations, divisional agricultural extension officers, field extension workers and local administration.

Observation was used to countercheck some of the findings. Descriptive statistics such as bar charts, and measures of central tendency were used to describe emerging relationships between variables. Multiple regression analysis was used to estimate a system of cost share equations from the survey data using Statistical Package for Social Sciences (SPSS) version.

Multi-collinearity was tested using Pearson's correlation coefficient.

Results and Discussion

Results show that labor is the single most predominant farm input followed by fertilizers and seed maize with cost shares of 64.2 percent, 20.5 percent and 8.7 percent respectively (fig 1).

Out of the total labor cost, land preparation, weeding and shelling contribute 73 percent (fig 2) with the balance being accounted for by planting, harvesting, topdressing and transport activities. However, of the total soil amendments and pest control costs diamonium phosphate (DAP), calcium ammonium nitrate (CAN) and farm yard manure (FYM) account for 44.18, 30.5 and 24.8 percent respectively(fig 3) indicating that chemical fertilizers are the most predominant contributor to the soil amendment costs. Results further show that hybrid (H614), local variety and hybrid (H512) account for 40.1, 42.3 and 12.8 percent respectively of the total seed cost (fig 4). Thus by implication Vihiga farmers who are not growing the local variety are likely to be growing H614. Incidentally H614 which is a high altitude variety seems to be more popular in Vihiga district than the low altitude maize varieties such as H511, H512, and H513.

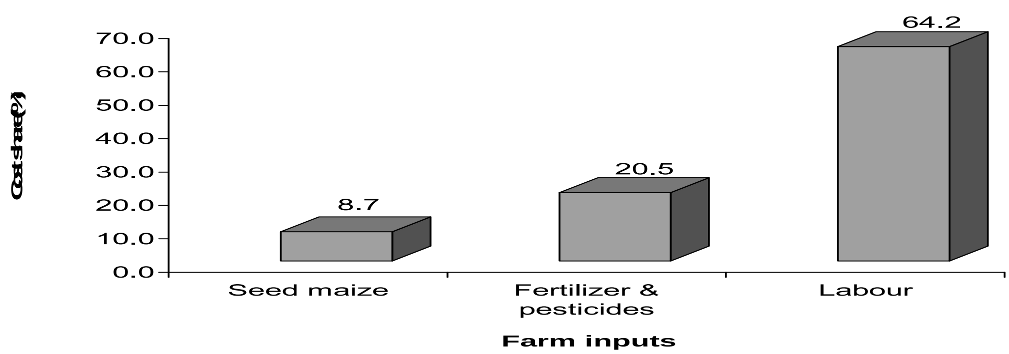

Fig 1: Average cost shares across farm inputs

Fig 2: Key contributors to the labour cost of production

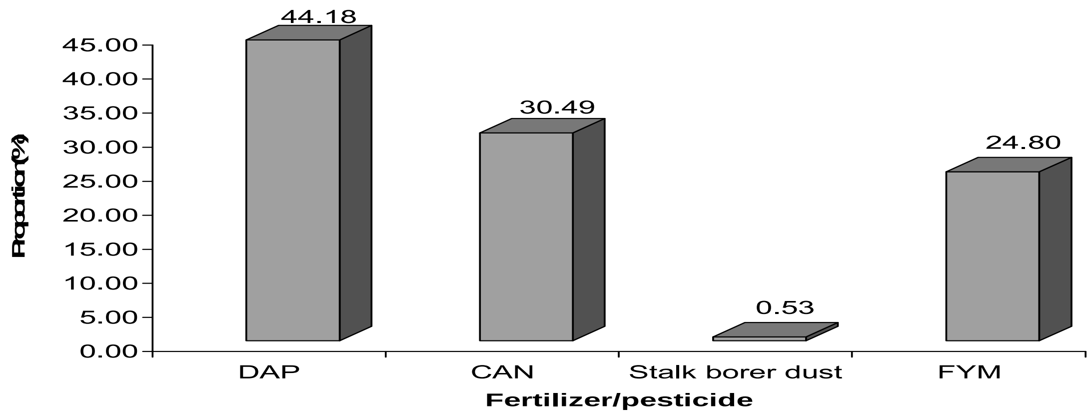

Fig 3: Contributors to fertilizer/pesticide cost

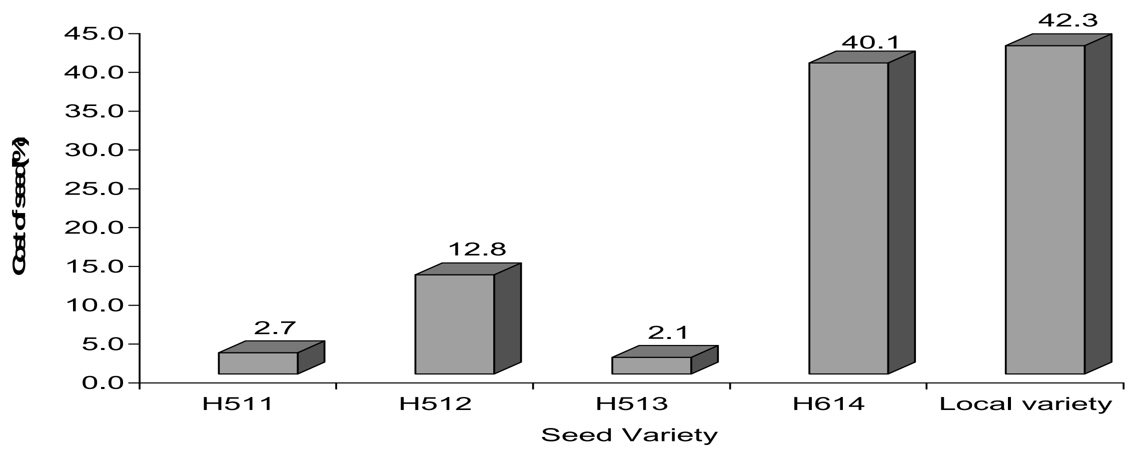

Fig 4: Predominant seed varieties across households

Results for supply side constraints parameters are presented in table 1. Results show that the scale of food production significantly influences the level of cost shares for labor, fertilizer and some seed varieties. As the scale of food production increases the share of total cost attributable to labor declines indicating possibilities of substituting labor with machinery when it becomes uneconomical to continue hiring labor. As the scale of production increases the cost share of artificial fertilizers increases thus justifying the need to invest a bit more in artificial fertilizers to realize a reasonable food output. On the contrary, increasing the scale of food production significantly reduces the level of farm yard manure used because of the associated acquisition and application bottlenecks. In addition, the choice of the maize seed variety for use in production is significantly influenced by the scale of production. As the scale of production increases farmers replace local variety with hybrids (H614) because of the desire to get value for money from intensive utilization of commercial fertilizers.

The number of adults, gender of household head, business income, employment, education, heads of cattle, poultry number, land size and credit access significantly influence input cost shares for some commodities with mixed results. As the number of adults per household increases possibilities of generating off-farm income are higher thus increasing chances of utilization of commercial fertilizers and hybrid seed and reduced use of farm yard manure which is a bit cumbersome. While female headed households seem to favor use of hybrid seed varieties male headed households prefer local varieties because of their low acquisition costs. Engagement in some kind of business seems to supplement household capital thus enhancing household accessibility to commercial fertilizers. Off- farm employment - considered both a source of household income and competitor for scarce household labor, significantly reduces labor available for planting and enables some households to opt for hybrid seed varieties in place of the local varieties. The influence of education can either be positive or negative. As the level of education increases in the household the supply of individuals who are willing to engage in manual labor declines resulting scarcity of labor for land preparation and weeding activities. On the contrary, highly educated households will easily appreciate the need to utilize hybrid seed varieties to boost food production. The number of heads of cattle can be perceived as a source of farm yard manure which can as well be used to substitute organic fertilizers. As the number of heads of cattle increases the proportion of the soil amendments accounted for by FYM increases while that proportion accounted for by commercial fertilizers declines. Poultry as an enterprise has a mixed influence on farm input cost shares because it is very labor intensive and also supplements income earnings by households. As the poultry enterprise becomes big and commercialized it competes for labor available for food production. However, earnings from the poultry enterprise can be used to increase investment in commercial fertilizers and hybrid maize seed varieties. As the size of land under food production increases the cost share of commercial seed varieties and other food production activities increases. While credit access enhances the ability of farmers in Vihiga district to use commercial fertilizers and hybrid seed, it makes farmers to ignore use of farm yard manure and local seed varieties. Results further show that market access and extension have mixed influence on the cost shares of selected inputs. The extent of commitment of labor and commercial hybrid seed varieties to production will depend on the accessibility to the market. Extension on the other hand is critical when it comes to implementation of cultural practices in food production.

Conclusions

Vihiga, one of the poorest and densely populated districts in Kenya is perpetually food deficit (GOK, 2005). While food demand continued to rise, production fell behind both targeted production and district demand. To make matters worse food deficit situation worsened over the last decade. Rising population and competition for resources have curtailed efforts to improve household food production in the district. In an effort to address supply side constraints to food security in Vihiga district, a number of issues are isolated. Some of the factors critical to the implementation of food security programmes in the district are the scale of production, number of adults, household head, business income, employment; human resource development, capital, and land size. These fall into two categories- production resources and household decision dynamics. It is concluded that food security programmes, in subsistence economies, focusing on revamping production should not only endeavor to improve accessibility to production resources but also address the quality of labor through training. Household decision dynamics are critical to the success of the food security programmes.

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Table 1: Estimated input cost share parameters

Input i	Constant α_i	Food Output β_i	Depend. ratio ζ_{i1}	No. of adults ζ_{i2}	H.Head ζ_{i3}	Business income ψ_{i1}	Employ. ψ_{i2}	Educ. ψ_{i3}	Heads of Cattle ψ_{i4}	Poultry No. ψ_{i5}	Land size ψ_{i6}	Credit access ψ_{i7}	Urban-rural λ_{i1}	Market access λ_{i2}	Extension. λ_{i3}	R	R^2
Labor	**0.726[a]**	**-0.029[b]**	**0.002**	**-0.003**	**-0.003**	**-0.017**	**-0.012**	**-0.021[b]**	**-0.002**	**-0.006[a]**	**0.014**	**0.007**	**-0.018**	**0.001**	**0.072[b]**		
L/preparation	0.22[a]	-0.007	0.00003	-0.003	0.013	-0.002	-0.01	-0.011[b]	-0.001	-0.002[a]	0.015	0.008	0.002	-0.007	0.056[a]	**0.3**	**0.09**
Planting	0.063[a]	-0.017[a]	0.003	0	0.002	-0.006	-0.016[b]	0	0.002	-0.001[b]	0.009[b]	-0.007	-0.01	-0.008	0.024[b]	**0.44**	**0.19**
Weeding	0.18[a]	-0.011	-0.008	0.004	-0.014	-0.012	0.001	-0.011[b]	-0.003	-0.001	-0.003	0.019	0.018	0.021[b]	0.007	**0.39**	**0.15**
Topdressing	0.014	0.003	0.001	0.001	0.002	0.001	-0.006	0.001	-0.001	0	-0.005	0.005	0.007[b]	-0.006	-0.00001	**0.22**	**0.05**
Harvesting	0.074[a]	-0.005	0.001	0	0.011	0.006	-0.01	-0.001	-0.001	-0.001	-0.001	0.004	0	-0.004	-0.005	**0.3**	**0.09**
Shelling	0.189[a]	0.011	0.001	-0.005	-0.009	-0.012	0.022	0.0001	0.003	0	-0.008	-0.017	-0.021	-0.021	-0.013	**0.28**	**0.08**
Transport	0.005	0.001	0.001	0	0.004	0.001	-0.004	0	-0.0001	-0.0001	0.002	-0.002	-0.001	-0.006[b]	-0.001	**0.21**	**0.04**
Fertilizer/Pesticides	**0.191[a]**	**0.019[b]**	**0.005**	**0**	**-0.014**	**0.031**	**0.023**	**0.008**	**0.007**	**0.004[a]**	**-0.023**	**0.004**	**0.028**	**-0.012**	**-0.028**	**0.34**	**0.11**
DAP	0.049[b]	0.018[a]	0.006	0.006[b]	0.001	0.02	-0.006	0.009	-0.009[a]	0.003[a]	0.003	0.018	0.014	0.01	-0.009	**0.41**	**0.17**
CAN	0.059[a]	0.02[a]	0.001	0	-0.006	0.027[a]	0.018	0.001	-0.001	0.001	-0.009	0.021[b]	0.023[a]	0.011	-0.005	**0.43**	**0.18**
Stalk borer dust	0.004	0.001	-0.001	0.0001	-0.003	0.002	0.002	0	0	0.00001	-0.00001	-0.001	0.002	-0.002	0	**0.2**	**0.04**
FYM	0.08[a]	-0.02[a]	-0.002	-0.006[b]	-0.006	-0.017	0.008	-0.002	0.017[a]	0.001	-0.016	-0.033[b]	-0.009	-0.032[b]	-0.013	**0.42**	**0.18**
Seed maize	**0.049[b]**	**0.007**	**-0.002**	**0.004**	**0.001**	**-0.006**	**0.003**	**0.015[a]**	**-0.004**	**0.002[b]**	**0.009**	**-0.012**	**-0.015**	**0.032[a]**	**-0.044[a]**	**0.45**	**0.2**
H511	-0.016[b]	0	0.003	0.005[a]	-0.006	0.001	-0.003	0.004[a]	-0.001	-0.0001	-0.002	-0.004	-0.001	0.002	-0.004	**0.37**	**0.13**
H512	0.01	0.001	0.002	-0.001	-0.014[b]	0.007	0.012[b]	0.002	0.002	-0.001	-0.005	0.007	0.002	0.01[b]	0.01	**0.28**	**0.08**
H513	-0.001	0.001	0	0	0.001	-0.002	-0.003	0.001	-0.001[b]	0.001[a]	-0.001	-0.001	0.00003	0.002	-0.006[b]	**0.32**	**0.1**
H614	0.013	0.01[b]	-0.007	-0.0001	0.008	-0.004	0.014	0.008[b]	-0.004	0.002[a]	0.016[b]	0.002	-0.008	0.021[b]	-0.036[b]	**0.48**	**0.23**
Local variety	0.043[a]	-0.005[b]	0	0.00002	0.012[b]	-0.009	-0.017[a]	0	0	0	0.001	-0.016[b]	-0.007	-0.003	-0.004	**0.34**	**0.12**
Total	**0.986**	**0.001**	**0.00103**	**0.00102**	**-0.004**	**0.001**	**0.002**	**0.0011**	**0.0019**	**0.00181**	**-0.00401**	**0.003**	**0.01103**	**-0.012**	**0.00099**		

Source: *Author's compilation from cross-sectional survey, 2007.* *[a]-significant at 1 percent, [b]-significant at 5 percent.*