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Smallholder Wheat Production Efficiency in Selected Agro-ecological Zones of Ethiopia: A Parametric Approach

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Abstract

Wheat productivity is very low in Ethiopia. Improving production efficiency is one of the options for enhancing wheat productivity. To identify the level of production efficiency and sources of inefficiencies, this study was carried out in three major wheat producing agro-ecologies. It used cross-sectional data collected from randomly selected 381 farm households for 2012/13 cropping season. A Cobb-Douglas Production Function and Stochastic Frontier Analysis were employed to achieve the objectives. The study found considerable variation in production efficiency among agro-ecologies and within agro-ecology. The mean technical efficiency estimates for lowland, midland and highland agro-ecologies were 57 percent, 82 percent and 78 percent, respectively. The technical efficiency ranges from 24.4 to 88.6 percents in the lowland, 51.6 to 94.4 percents in the midland, and 34.5 to 94.3 percents in the highland agro-ecologies. There is more capacity to increase wheat yield given the current state of technology and input levels. Wheat output elasticities associated with land, labor, chemical fertilizers and other inputs (seed and pesticides) were positive and significant in the lowland whereas in mid and highland agro-ecologies, output elasticities of land and chemical fertilizers were significant. Age of household head, livestock holding size, practice of crop rotation, access to credit and improved seed, and family size were significant factors that affect wheat production efficiency. To enhance wheat production and productivity, agricultural extension activities need to target agro-ecological orientation, the identified efficiency determining socioeconomic characteristics, and farm inputs utilization of households.

Keywords: Wheat in Ethiopia, Efficiency, Cobb-Douglas, Stochastic Frontier Analysis

1. Introduction

Wheat was one of the first domesticated food crops. It is grown on more than 240 million hectares exceeding other commercial crops and continues to be the most important food grain source for humans (Dixon *et al.*, 2009). Accounting for a fifth of humanity's food, wheat is second only to rice as a source of calories in the diets of developing country consumers, and it is first as a source of protein (Braun *et al*., 2010). Wheat is an especially critical "staff of life" for the approximately 1.2 billion "wheat dependent" to 2.5 billion "wheat consuming" poor men, women and children who live on less than USD 2 per day, and approximately 30 million poor wheat producers and their families (CIMMYT, 2012).

If population growth continues at double the growth of wheat production, there will likely be serious difficulties in maintaining a wheat food supply for future generations (Dixon *et al*., 2009; CIMMYT, 2012). Demand for wheat in Africa is growing faster than for any other food crop. This will be a major challenge, particularly in African countries, where population growth is forecasted to increase by higher percents. Several countries could achieve wheat yields exceeding 6 t/ha but are faced with many challenges in realizing this potential (Rosegrant and Agcaoili, 2010; CIMMYT, 2012). The challenges of globally stagnating wheat production, rising consumer demand and higher food prices effects require efforts that dramatically boost farm-level wheat productivity and reduce supply fluctuations. Productivity growth is considered to be one of the long term solutions to these challenges (Diao *et al*., 2008).

In Ethiopia, wheat is one of the major food and cash crops to smallholder farm households. However, major challenges are facing wheat production. It is mainly composed of smallholder farmers characterized by subsistence production with low input use and low productivity, and dependency on traditional farming and rainfall. The low productivity has made the country unable to meet the high demand and it remains net importer of wheat despite its huge potential in wheat production (Rashid, 2010). Consequently, food insecurity is prevalent in many parts of the country. Hence, the issue of increasing wheat productivity has become the main concern of the government of Ethiopia.

Improving efficiency in production is one of the factors for productivity enhancement. Efficient production is the basis for achieving overall food security and poverty reduction objectives particularly in major food crops producing potential areas of the country. The knowledge of the level of efficiency of production and its influencing factors will help for targeted policy measures and agricultural extension activities. However, agro-ecology based comparative analysis of wheat production efficiency and the sources of inefficiencies are limited, and have not been fully documented.

Therefore, this study was undertaken in three agro-ecologies (highland, midland, and lowland) of the country representing major wheat producing areas in their respective agro-ecological setting, with the objectives of analyzing production efficiency and identification of the sources of inefficiency in wheat production. A Cobb-Douglas Stochastic Frontier Production Function was used to achieve the objectives of the study.

2. Research Methodology

2.1. The Study Area

The study area, Arsi Zone, is found in the central part of the Oromia National Regional State of Ethiopia. The zone astronomically lies between 60 45' N to 8^0 58'N and 38^0 32 E to 40^0 50' E. The area is divided into five agro-climatic zones mainly due to variation in altitude. It is dominantly characterized by moderately cool (about 40 percent) followed by cool (about 34 percent) annual temperature. Cool/cold type of thermal zone is found in the highland areas of *Chilalo*, *Gugu*, *Onkolo* and *Kaka* Mountains. The category of moderately warm temperature is found in the low land areas of *Dodota*, *Amigna*, *Seru* and *Merti* districts. Some highland districts include *Lemu-bilbilo* and *Onkolo-wabe*, whereas *Hetosa* and *Tiyo* districts mainly fall in mid altitude. The mean annual temperature of the Zone is found between 20-25^0c in the low land and 10-15^0c in the central high land.

The mean annual rainfall varies from 633.7 mm at *Dhera* station which is in *Dodota* district, and located at altitude of 1680 meters above sea level to 1059.3 mm at *Bekoji* station in *Lemu-bilbilo* district located at an altitude of 2760 meters above sea level. On average, the zone gets a monthly mean rainfall of 85 mm and an annual mean rainfall of 1020 mm. The area receives well distributed rainfall both in amount and season. This characteristics makes the zone good potential for production of various agricultural crops. Wheat production accounts for 41% of the total cereal area cultivated in the study area in 2012(CSA, 2013). Ethiopia has traditionally six agro-ecological zones which are grouped based on major physical conditions and homogenous areas with similar agricultural land uses. In the country, elevation is associated with the level of temperature and rainfall. Due to this reason, elevation of an area above sea level is the basis for the traditional agro-ecological divisions (EIAR, 2011). Wheat is grown in three major agro-ecological zones of the study area.

2.2. Sampling Technique

A combination of purposive sampling and two stages probability sampling procedures were used for sample selection. In the first case, three major wheat producing districts representing major agro-ecologies (one from each high land, mid altitude and low land areas) were purposively selected. The three districts namely, Lemu-Bilbilo from the high land, Hetosa from the mid altitude, and Dodota from the lowland areas were selected. The main reason for purposive selection was due to their representativeness in wheat production both in regional and national perspectives. There are also strong research and extension intervention programs embracing wheat producers in the area. Moreover, newly released improved wheat varieties for high, mid and lowland agro-ecologies were relatively more disseminated in these areas by district agricultural offices and Kulumsa Agricultural Research Center, and the varieties are well adopted by farmers. Hence, it was feasible to assess wheat production efficiency in these areas.

In the first stage of the probability sampling, a list of major wheat growing lower administrative divisions (*kebeles*) within the selected districts was prepared. Taking in to account the cost of data collection, two *kebeles* were selected from each district representing the three agro-ecologies with simple random sampling. In the second and final stage, a list of farm households was prepared for each district. Sample farm households were selected by simple random sampling technique. The sample size was determined based on the formula given by Krejice and Morgan (1970), and allocation of sample size to each agro-ecological zone was made proportionate to the size of farm household heads population of each selected agro-ecology.

Table 1. Selected *kebeles* and their sample sizes

District/Kebele	Household head size	Sample size
Highland	21,457	165
Lemu-Dima	749	86
Chiba-Michael	684	79
Midland	17,296	133
Gonde-Finchema	533	54
Boru-Lencha	781	79
Lowland	10,793	83
Amigna-Debeso	502	36
Dodota-Alem	656	47
Total	49,546	381

2.3. Data Collection

The data for study was collected from both primary and secondary sources. Cross-sectional data was collected from the survey of randomly selected sample farm household heads. For the primary data collection, specifically designed and pre-tested questionnaire based on the objective of the study, and trained data enumerators was used. Both quantitative and qualitative information were collected. The data collection included households' demographic and socioeconomic characteristics (family sizes, age and sex structures, education, etc), land holding (agricultural, grazing, wheat land, and others), farm inputs utilization (seeds, fertilizers, herbicides and fungicides, labor utilization, credit, extension services), farm outputs, input and output prices, agronomic practices including crop rotation, row planting and hand weeding, etc.

Secondary information on rainfall amounts (annual mean and cropping season), temperature, etc were also collected. Published and unpublished documents were used as source of the secondary information. The survey was carried out in the months of May and June 2013.

2.4. Analytical Methods

Productivity of a farm household has been commonly defined as the ratio of the output(s) of the farm to the inputs it uses. Production function shows the relationship between input and output; and production frontier shows the maximum output level produced with current level of technology. Farm households operating on the frontier are technically efficient whereas farm households operating at below the frontier are inefficient because they could increase output to the level on the frontier without requiring more input. Points below the frontier are not technically efficient, and the technical efficiency shows the physical relationship of input and output.

If farm households wish to estimate the maximum possible production, but not average production or average cost, given a set of inputs, an ordinary least square (OLS) regression cannot be used. This is because the OLS estimates the mean of the dependent variable conditional on the explanatory variables, but not the maximum possible outputs given a set of inputs or the minimum possible cost of a set of outputs. To estimate the maxima or the minima of the dependent variable given explanatory variables, the frontier functions, either econometric stochastic frontier analysis (SFA) or linear programming data envelopment analysis (DEA) is used. DEA is a non-parametric method that estimates the efficiency of production of a group of farms, in which no information is provided by the analysis as to the reasons or sources of inefficiencies (Coelli *et al.*, 2005). It also does not make allowance in the analytical method for measurement error or missing data or information in estimating the efficiencies of production. This can lead to DEA results that are difficult to interpret (Headey *et al*., 2010).

On the other hand, SFA is a parametric method of analysis that is estimated using maximum likelihood, which is similar to standard ordinary least squares (OLS) analysis. The use of this approach enables missing information or data and measurement errors to be captured in the error term (Coelli *et al*., 2005). The most important potential advantage of SFA is that it can separate noise in the data from genuine variations in efficiency. Stochastic frontier analysis has stochastic frontier, i.e. there is a probability distribution which is the basis of maximum likelihood estimation. In frontier functions, the disturbance has a distribution all on one side of zero. Models with one-sided errors that represent inefficiency are known as stochastic frontier models.

The functional form of the production function is a crucial issue in the measurement of efficiency because specification error can bring systematic error. In the present study, wheat production of sample famers was represented by a Cobb-Douglas production function. Because a series of preliminary likelihood ratio tests revealed that Cobb-Douglas stochastic frontier model best fit the data given the more flexible translog frontier model. The stochastic production function (frontier) for n sample size of farms can be written as:

$$Y_i = f(X_i; \beta) + \varepsilon \quad (1)$$

Where Y_i is wheat output of the j[th] household farm, i = (1, 2, 3,……, n) are sample household farms, X_{ij} is the i[th] input used by the j[th] farm and β is a vector of unknown parameters and ε is composed of error term which can be written as:

$$\varepsilon = v_i - u_i, \quad (2)$$

where v_i is a symmetric random error which represents random variations, or random shocks in the production of the i[th] farm, outside the control of the farmer assumed independently and identically distributed as $N(0, \sigma^2)$. The error term u_i is a one-sided non-negative variable which measures technical inefficiency of the i[th] farm, the extent to which observed output falls short of the potential output for a given technology and input levels. The method helps to decompose deviation of the actual observed wheat output from the estimated frontier into random variations and inefficiency. Hence,

$$u_i = Z_i\delta + w_i \quad (3)$$

Where,

Z_i is a vector of variables that explain inefficiency of i^{th} farm. δ is a vector of unknown coefficients that are to be estimated in the model, and $w_i \geq -Z_i\delta$ to ensure that $u_i \geq 0$ (Battese and Coelli, 1995).

The technical efficiency of production of the i^{th} farm in the data set, given the level of inputs, is defined by the conditional expectation evaluated at the maximum likelihood estimates of the parameters in the model, where the expected maximum value of Y is conditional on u =0. The measure of technical efficiency (TE) must have a value between zero and one. Following from equations 1 and 3, technical efficiency will be estimated as:

$$TE_i = E(Y_i|u_i, X_i)/E(Y_i|u_i = 0, X_i) = exp^{(-u_i)} = exp(-Z_i\delta - w_i) \quad (4)$$

Given the specifications of the stochastic frontier model expressed in equations (4), the stochastic frontier output (potential output) for the i^{th} farm is the observed output divided by the technical efficiency, and TE_i is given by:

$$Y^* = \frac{Y_i}{TE_i} = \frac{E(X_i\beta + v_i - u_i)}{E(-u_i)} = \exp(X_i\beta + v_i) \quad (5)$$

The parametric specification of frontier in the Cobb-Douglas form for one output and n inputs is given by:

$$lny_i = \beta_0 + \sum_{i=1}^{n} \beta_i \, lnx_i + v_i - u_i \quad (6)$$

Where,

y_i is wheat output of i[th] household

x_i represents vector of farm inputs used

β_0 is intercept

β_i is vector of production function parameters to be estimated.

The dependent variables is total wheat output in kilogram per hectare (kg/ha), and the independent variables or inputs are total land planted to wheat in hectares, amount of labor (which included family, exchange, and hired labors) used in wheat production in man-days per hectare, amount of chemical fertilizers used in wheat production in kilogram per hectare, and quantity index of other inputs (seed and pesticides) used, estimated as the value of seed and pesticides deflated by weighted price index of the inputs, the weights being the share of each input in total cost. Various farm household socioeconomic characteristics were assumed to affect wheat production efficiency, and they were included in the model as inefficiency factors. For data analysis, STATA version 11 software program was used. Table 2 summarizes and describes output, input and inefficiency variables used in the production efficiency analysis.

Table 2. Descriptions of output, inputs and inefficiency variables used in analysis

Variables	Descriptions
Ln output (Y)	Natural logarithm of household wheat output (kg/ha)
Inputs	
Ln area	Natural logarithm of cultivated wheat farm (ha)
Ln labor	Natural logarithm of man-days* per hectare
Ln fert	Natural logarithm of chemical fertilizers used (kg/ha)
Ln other	Natural logarithm of quantity index of other inputs
Age	Age of household head in years
Education	Educational level of household head in number of grades
Family size	Family size in adult equivalent
Livestock holding	Livestock holding size of household in tropical livestock unit (TLU)
Farming experience	Farming experience of household head in years
Crop types	Number of different types of crops cultivated
Improved seed	Access to improved seed(1 if yes, 0 otherwise)
Row planting	Household practice of planting wheat in row (1 if yes, 0 otherwise)
Credit	Access to credit service (1 if yes, 0 otherwise)
Crop rotation	Household practice of crop rotation(1 if yes, 0 otherwise)
Income	Household annual off farm income in thousand birr (ETB)

*A man-day is equivalent to 8 working hours in the study area.

3. Results and Discussion

3.1. Descriptive Results

Age and sex structures, family size, agricultural land holding size and educational status of households can have influences on the agricultural production activity. Social influences, experiences, flexibility in adopting new technologies and participation in social organizations may be associated with age and sex of households. These in turn have impact on households' adoption of improved inputs and farming techniques, and thereby affect production and productivity. Table 3 reveals that male headed households comprise about 93, 89, and 96 percents of sample households in lowland, midland and highland areas respectively, while the rest were female headed in each agro-ecology. Average age of household head was highest in midland (48.8 years) followed by highland area (46.5years). Similarly, average educational status of household heads in number of grade completed was 5.4, 4.6 and 4.7 for the lowland, midland and highland areas respectively.

Table 3. Some socioeconomic characteristics of the study area

Variables	Study Areas		
	Lowland	Midland	Highland
Sex of Household head (%)			
Female	7.2	11.3	4.2
Male	92.8	88.7	95.8
Age of Household head (mean)	43.3	48.8	46.5
Educational status (mean), grades	5.4	4.6	4.7
Household family Size (mean)	6.6	6.1	6.5
Female (mean)	3.2	2.7	3.0
Male (mean)	3.4	3.4	3.5
Minimum	1.0	1.0	2.0
Maximum	14.0	15.0	20.0
Land holding size in hectares (mean)	2.3	2.2	3.2
Minimum	5.0	0.3	0.4
Maximum	6.0	6.8	12.0

Source: Computation from own survey data

The Average family sizes for the lowland, midland, and highland areas were 6.6, 6.1, and 6.5 respectively. The minimum total number of family size was 1 and the maximum was 20, and slightly higher family size was observed among sampled households of the lowland area, and followed by sampled households of highland area. Average privately owned land was higher in highland area (3.2 ha). Relatively, the midland area was the least in the average land holding size. The maxima of total land holding (12 ha) was observed in highland, and the minima (0.3ha) was noticed in midland agro-ecology.

Crop production is one of the main agricultural activities in the study areas. The main crops include wheat, barley, faba bean, field peas, tef, and maize. Table 4 depicts average cultivated land and productivity for each crop for the 2012/13 cropping season. In terms of average area planted, wheat and barley constituted the major agricultural crops of the study area. Wheat was the major crop with average planted land of 1.6 hectares both in low and midland areas. But in the highland, malt and food barleys were the major crops followed by wheat in terms of land planted with these crops.

Average wheat productivity was about 16 and 31 quintals per hectare in low and midland areas respectively. The average productivity of the midland area was almost equal to double of average productivity of the lowland area. Similarly, the productivity of the highland area (24.8q/ha) was higher than the lowland productivity (15.6q/ha). The midland productivity (30. 9q/ha) was higher than the lowland and highland productivity levels. This shows that the midland is more potential wheat producing area (Table 4).

Table 4. Average area cultivated (ha) and yield (q/ha) for major crops of study areas

	Study Areas					
	Lowland		Midland		Highland	
Crop	Area	Yield	Area	Yield	Area	Yield
Wheat	1.6	15.6	1.6	30.9	0.5	24.8
Malt barley	0.5	12.0	0.0	0.0	0.8	29.2
Food barley	0.6	19.1	0.3	22.0	0.7	33.8
Faba bean	0.1	8.0	0.3	22.1	0.4	22.0
Field pea	0.2	10.2	0.2	14.6	0.4	19.1
Tef	0.6	8.7	0.2	9.0	0.3	12.0
Maize	0.3	11.2	0.2	19.1	0.5	40.0

Source: Computation from own data.

3.2. Econometric Estimation Results

3.2.1. Coefficient and Technical Efficiency Estimates

Wheat production of sample famers was represented by a Cobb-Douglas Stochastic Frontier Model, and half-normal distribution of inefficiency. Because, a series of preliminary likelihood ratio tests revealed that Cobb-Douglas stochastic frontier model best fit the data given the more flexible translog frontier model, and the distribution of inefficiency best represented by the half-normal distribution. The natural logarithms of the data on the input and output variables were taken for efficiency analysis. Table 5 shows estimated coefficients of land, labor, fertilizer and other inputs for stochastic frontier model of Cobb-Douglas production function. The coefficients associated with the inputs measure the elasticity of output with respect to inputs.

Table 5. Maximum likelihood estimates of wheat production function

	Maximum Likelihood Estimates (Standard error)		
Variables	Lowland	Midland	Highland
Constant	4.316***	7.045***	6.955***
	(0.726)	(0.358)	(.489)
ln (land)	0.192***	0.086**	-0.586*
	(0.065)	(0.037)	(0.033)
ln (labor)	0.211**	0.059	-0.011
	(0.086)	(0.046)	(0.041)
ln (fertilizers)	0.182**	0.163***	0.163**
	(0.084)	(0.046)	(0.076)
ln (other inputs)	0.247***	0.024	0.040
	(0.069)	(0.028)	(0.041)
Wald chi- square statistic	25.78***	19.27***	8.89*
Log-likelihood	-6.195	37.3	15.269

***p< 0.01; **p< 0.05; *P< 0.10, and figures in parentheses are standard errors

The maximum likelihood estimate of the model (Table 5) shows that wheat output elasticities associated with land, labor, chemical fertilizers and other inputs (seed and pesticides) were positive and significant in the lowland area. The elasticity of output due to other inputs was highest (0.247), followed by elasticity of output due to labor (0.211) in the lowland. In midland, elasticities of output due to land and fertilizers were positive and significant, with the highest being elasticity of output due to chemical fertilizers (0.163). Similarly, the elasticities associated with land and fertilizers were significant in the highland area with negative elasticity of output due to land. This might be due to more suitability of the highland agro-ecology to barley production.

The mean technical efficiency was 75 percent for the whole study area with minimum and maximum technical efficiency of 24.4 and 94.4 percents respectively. Given the current state of technology and input levels, there is a scope of increasing wheat output up to 25 percents on average. However, on average, the scopes of wheat output increments in low, mid, and highland areas are about 43, 18, and 22 percents respectively (Table 6). Therefore, improving technical efficiency in wheat production can improve productivity of wheat in the agro-ecologies.

Table 6. Summary of technical efficiency of stochastic frontier production model

Study areas	Obs	Mean	Std. Deviation	Minimum	Maximum
Total	381	0.749	0.143	0.244	0.944
Lowland	83	0.569	0.126	0.244	0.886
Midland	133	0.820	0.083	0.516	0.944
Highland	165	0.784	0.111	0.345	0.943

3.2.2. Factors Affecting Technical Efficiency

The existence of inefficiency factor was tested by Wald test. The null hypoyhesis for the test was no systematic inefficiency in the distribution. However, the test result gave significant chi-square statistic for the study areas (Wald chi2 = 52.1, prob > chi2 = 0.0000), depicting rejection of the null hypothesis. Table 7 shows that age of household head, livestock holding size, practice of crop rotation and access to credit were significant factors at p

< 0.05, and practice of planting wheat in row was significant factor at $p < 0.01$ whereas family size and access to improved wheat seed where significant at $p < 0.10$ level. Age affects farmers experience and skills in farm operation and decision makings. Experienced farmers can easily understand agricultural extension and apply their technical skills and experiences in production decisions and processes. Availability and access to improved wheat seed and credit can have impact on production efficiency. Practice of crop rotation helps in weed, crop disease and soil fertility management and thereby affects wheat production and productivity. Planting wheat in-row helps in fertilizers application, weed management and uses of agronomic practices that can enhance growth and productivity of wheat. Livestock can be a source of traction power and manures in farming activities. Besides, sale of livestock and livestock products are a source of cash income for farmers for the purchase of improved seeds, fertilizers and pesticides that can influence efficiency of production and productivity. Family members are sources of labor for agricultural activities.

The signs of the coefficients of age, livestock holding size, practice of crop rotation and planting wheat in-row were negatively related to inefficiency of wheat production. An increase in or practice of these positive variables will decrease wheat production inefficiency of households.

Table 7. Estimates of sources of technical inefficiency variables

Variables	Coefficient	Std. error	z	p>z
Age	-0.044**	0.021	-2.060	0.040
Education	-0.004	0.030	-0.130	0.900
Family size	0.120*	0.068	1.760	0.079
Livestock size	-0.063**	0.029	-2.200	0.028
Crops types	0.067	0.074	0.900	0.368
Seed	0.407*	0.217	1.880	0.060
Rotation	-0.514**	0.211	-2.440	0.015
Income	0.020	0.016	1.300	0.193
Experience	0.035	0.022	1.590	0.112
Row planing	-0.600***	0.208	-2.890	0.004
Credit	0.416**	0.205	2.030	0.042
Constant	-1.076	0.699	-1.540	0.124
sigma_v	0.201	0.023		

*p< 0.10; **p< 0.05; ***p< 0.01

4. Conclusion

The objective of this study was to analyze wheat production efficiency in different agro-ecologies, and identify the sources of inefficiencies in production. A Cobb-Douglas stochastic frontier model and cross-sectional data were used. Farm inputs and output data were collected from randomly selected farm households for 2012/13 cropping season. The analysis of the data resulted in mean technical efficiency estimates of 57 percent, 82 percent, and 78 percent for the lowland, midland, and highland agro-ecologies, respectively. This shows that smallholders were inefficient in wheat production in the study areas; and improvement in technical efficiency in wheat production needs attention as it provides significant source of enhancement in wheat output. The sources of inefficiencies were mainly related to farming experiences and skills, availability of labor and livestock for farm operations and other inputs, access to improved seed and credit as well as adoption of yield enhancing farming practices. Though production efficiency was relatively higher in the midland agro-ecology, there was disparity of production efficiency among agro-ecologies and within agro-ecology. The efficiency ranges from about 24 to 94 percents among all sample farm households, implying that there is more scope for increasing wheat output with the current technology and input levels.

Smallholders access to improved seed and credit, practice of crop rotation and planting seed in-row, availability of animal power and family labor, age of household head were significant factors that influenced wheat production efficiency. In the lowland agro-ecology, output elasticities associated with land, labor, chemical fertilizers and other inputs (seed and pesticides) were positive and significant, with output elasticities of other inputs being the highest. This implies increased utilization of these farm inputs can enhance wheat productivity

in the lowland agro-ecology. Similarly, the responsiveness of wheat output to the changes in the quantities of land and chemical fertilizers utilization was positive and significant in midland agro-ecology. In the highland, the output elasticities of land and chemical fertilizers were significant with negative elasticity of output due to land. This might be due to the less suitability of the high land agro-ecology for wheat production. The highland is more conducive to barley production. Farmers relatively prefer barley to wheat, and allocate more farm inputs to barley production.
The results suggest that improving wheat productivity needs due attention of technical efficiency and farm inputs utilizations in all agro-ecologies as well as farm households' socioeconomic characteristics that affect technical efficiency in wheat production. Agricultural research and extension activities need to target agro-ecological orientation, levels of farm inputs in production, and production efficiency determinant socioeconomic circumstances of farm households.

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