American Journal of Multidisciplinary Research and Innovation (AJMRI)

ISSN: 2158-8155 (Online), 2832-4854 (Print)

VOLUME 3 ISSUE 4 (2024)

PUBLISHED BY: E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Multidisciplinary Research and Innovation (AJMRI)

Volume 3 Issue 4, Year 2024
ISSN: 2158-8155 (Online), 2832-4854 (Print)
DOI: https://doi.org/10.54536/ajmri.v3i4.2761
https://journals.e-palli.com/home/index.php/ajmri

Sources of Technical Inefficiency for Smallholder Field Pea Producers in Ethiopia

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Article Information

Received: April 15, 2024

Accepted: June 10, 2024

Published: June 24, 2024

Keywords

Technical Efficiency, Field Pea, Stochastic Frontier Model, Ethiopia

ABSTRACT

This study intended to measure the technical efficiency and sources of inefficiency for field pea producers in Ethiopia. The study used primary data collected from 207 smallholder farmers. A multi-stage sampling technique was followed to select sample households. A stochastic frontier was the model used, and a single-step estimation approach was followed. The result indicated that the mean technical efficiency is 49.23 %, and the average productivity of the crop is 0.96 tons/hectare. This indicates that the technical efficiency could be increased by 51.77 % through proper utilization of production variables, i.e. agrochemicals, oxen power, plot size, and seed rate. The inefficiency model result also confirmed that the technical inefficiency of field pea production was negatively affected by access to off-farm income, access to credit services, extension contacts, adoption of new technologies, access to training, and participation in contract farming of the crop. Therefore, this study recommends agricultural policies favoring vocational training to farmers on the new agricultural technology packages, availing access to off-farm incomes, facilitating credit services to farmers, and establishing legal frameworks that encourage contract farming.

INTRODUCTION

Field pea (Pisum sativum L.) is among the most important cool season legumes mainly cultivated for food and feed across the globe (Muoni *et al.*, 2019). It is a nutritionally rich crop with high protein, vitamins, minerals, and carbohydrates that are affordable for resource-poor consumers. This enables the crop to be called 'poor man's meat'. Furthermore, it is naturally rich in iron, zinc, and magnesium, and contributes much to alleviating hidden hunger (Amarakoon *et al.*, 2012; Kandel *et al.*, 2016; Rezene *et al.*, 2015).

Pulses in general, and field peas in particular, are very important crops in terms of assuring sustainable agriculture by being used as crop rotation and intercropping that will contribute much in atmospheric nitrogen fixing and providing essential nutrients back to the soil (Powers and Thavarajah, 2019). It is the most efficient Nitrogen-fixing crop, and it obtains 80% of its Nitrogen requirement from fixation. As a result, the crop is considered environmentally friendly and economically feasible (Blaine *et al.*, 2021). This legume-based nitrogen use efficiency offers a sustainable and cost-effective alternative. Pulses also foster other benefits like maintaining soil health, improving biodiversity, enhancing soil organic carbon, improving the water retention capacity of the soil, and reducing greenhouse gas emissions (Foyer *et al.*, 2016; Peoples *et al.*, 2019; Stagnari *et al.*, 2017).

Globally, legume crops are reported to fix about 21 metric tons of nitrogen, out of which 5 to 7 metric tons are returned to the soil by pulse crops, which saves 8 to 12 billion USD (Christine *et al.*, 2019). Reports also confirmed that Field peas have a positive effect in improving soil organic carbon through their ability of nitrogen fixation (Stagnari *et al.*, 2017). They also have a positive effect in improving cereal productivity when used as crop rotation. In Australia, wheat production increased by 30% as a result of crop rotation compared to monocropping. In Denmark, the nitrogen uptake of different crops increased by 23 to 59% as a result of crop rotation (Foyer *et al.*, 2016; Peoples *et al.*, 2019). It is also reported to have ecological and economic importance, minimize the negative impacts of cereal-based mono-cropping, and amend soil fertility through crop rotation (Fikere *et al.*, 2014; Muoni *et al.*, 2019).

Canada, Russia, France, China, India, Ukraine, USA, Australia, Germany, and Ethiopia were the top 10 countries in terms of production. The average cultivated land has decreased from 7,646,813 to 7,159,958 hectares, while the average yield decreased from 14,323,297.26 to 14,166,029.75 tons between 1994 and 2022 (FAOSTAT, 2024).

In Ethiopia, field pea is the second most important pulse crop in terms of total production following the Faba bean, and the third crop in terms of area coverage following the Faba bean and Haricot bean. The average cultivated area and the total production for field pea were 220,194.82 ha and 3,803,35.89 tons respectively while that of fababean was 520,551.70 ha and 10,916,09.34 tons respectively. The national average productivity of the crop is estimated to be 1.73 tons per hectare during the 2022 main season (ESS, 2022).

Despite all the contributions of the crop, the advancements made to improve the production and productivity of field peas lagged behind other crops (Amarakoon *et al.*, 2012). Even though the national and regional

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research institutions of the country released more than 30 improved varieties of field pea, the average national productivity of the crop is yet about 1.7t/ha (ESS, 2022; Kindie *et al.*, 2019). This result is very low compared to the potentials of the improved varieties which is 4.17 t/ha reported by Mogiso, (2017), and that of the world which is 1.98 tons/hectare (FAOSTAT, 2024)

This yield reduction is the result of biotic and abiotic factors. Scholars reported that diseases like Ascochyta blight and Powdery mildew, Aphids, Lodging, Pod shattering, and the use of low-yielding local varieties were among the major yield-limiting constraints (Rezene *et al.*, 2015). Additionally, the technical efficiency of the farm households also matters as the yield reported from the research field and the farm household plots show big differences. Therefore, this research aimed to assess the level of the technical efficiency of smallholder field pea producers and their sources of technical inefficiency in Ethiopia.

MATERIALS AND METHODS

Data

This study used primary data collected from households randomly selected from the two giant Field Pea producing, Ethiopia's Oromia and Amhara regions. These two regions account for more than 75% of the national field pea production. A multi-stage random sampling procedure was followed. The two regions were purposively selected based on their high potential in field pea production. One zone from the Amhara region and four zones from the Oromia region were randomly selected out of the potential fababean-producing zones of the two regions. In the third stage, ten districts from the Oromia and three districts from the Amhara region were randomly selected. Then a total of twenty peasant associations were randomly selected from thirteen districts. Finally, a total of 207 sample households, (71 from Amhara and 136 from Oromia region) were randomly selected and interviewed for the data collection.

Variables

Based on the literature reviewed, the production variables and the inefficiency variables listed in Table 1 were selected to be included in this study.

Table 1: Lists of variables and their expected effect on the profit efficiency of fababean producers

Var. code	Description and measurements	Expected effect
y_i	Field pea output per plot measured in kg	
p_i	Production Variables	
p_1	Plot size allocated for field pea measured in hectares	+
p_2	The adult labor force used per plot measured in an hour	+
p_3	Oxen hours used in farming activities are measured in hour	+
p_4	Quantity of fertilizer used per plot measured in kg	+
p_5	Quantity of seed used per plot measured in kg	+
p_6	Quantity of agrochemicals used per plot measured in kg	+
x_i	Inefficiency Variables	
x_1	Age of the household head	-
x_2	Education of the household head	+
x_3	Membership in improved seed producers' group	+
x_4	Experience in Field Pea production	+
x_5	Access to extension services	+
x_6	Market distance	-
x_7	Access to credit service	+
x_8	Sex of the household head	+
x_9	Participation in contract farming	+
x_{10}	Livestock owned	+
x_{11}	Access to off-farm income	+/-
x_{12}	Total land owned	+
x_{13}	Adoption of Field Pea improved seed	+
x_{14}	Access to training in pulse production	+
x_{14}	Family size	+
x_{14}	Plot distance from the residence	-

Source: Authors' compiled based on reviewed literature

Analytical Framework

In the production process, farmers aim to maximize their profit by maximizing their production and minimizing their costs of production. Though some farmers produce efficiently compared to others, not all farmers become successful in their farming practices. The deviation from the optimal production is the failure to optimize their production, which may result from the inefficiency of the farmers and/or the random shocks. Therefore, a farm household can deviate from the optimal production frontier as the result of both the farmer's inefficiency and possible random fluctuations that are out of the control of the farmers.

The stochastic Frontier model is widely used in the field of agricultural economics for econometric modeling of production and assessing technical efficiency. Technical efficiency can be modeled as either output-oriented or input-oriented (S. C. Kumbhakar *et al.*, 2015). Following Aigner *et al.*, (1977) and Meeusen and van Den Broeck, (1977), the functional form of the output-oriented stochastic production frontier model that we used for this specific research can be expressed as:

$$\ln y_i = \ln y_i^* - u_i,\ u_i \geq 0 \quad (1)$$

Where: y_i^* is the frontier output level, y_i is the observed output level, and $u_i \geq 0$ is the production inefficiency that reducing farm output.

$$\ln y_i^* = f(x_i; \beta) + v_i \quad (2)$$

Where: f is the functional form to be used, x_i is a vector of input variables, β is a vector of coefficients to be estimated, and v_i is a zero mean random error.

For the simplicity, equation 2 can be re-written as:

$$\ln y_i = f(x_i; \beta) + \varepsilon_i \quad (3)$$

Where: ε_i is the composite error term, while y_i, x_i, β and f are as defined earlier.

$$\varepsilon_i = v_i - u_i \quad (4)$$

From equation 1, the term u_i is the log difference between the maximum output and the actual output that can be expressed as:

$$u_i = \ln y_i^* - \ln y_i \quad (5)$$

This implies that u_i x 100 is the percentage by which the actual output can be increased if the production is fully efficient, or the percentage of the output lost due to the technical inefficiency of the farmer.

By rearranging equation 1, u_i can also be expressed as the ratio of the actual output to the frontier output.

$$e^{(-ui)} = y_i/y_i^* = TE_i \quad (6)$$

Production efficiency varies across companies, and over time (Battese and Coelli, 1992). Therefore, it is logical to ask about what factors are responsible for the variations in efficiency. Battese and Coelli further extended the stochastic frontier model and suggested that the determinants of inefficiency can be expressed as a linear function of a set of explanatory variables that reflect the characteristics inherent to a company (Battese and Coelli, 1995). The extended form of Battese and Coelli allows the estimation of efficiency, and factors affecting the inefficiency in a single step. This will overcome the estimation bias of the widely used two-step approach (Battese and Coelli, 1995; S. Kumbhakar *et al.*, 1991; S. C. Kumbhakar *et al.*, 2015; Wang and Schmidt, 2002).

The transcendental logarithmic function is the functional form used in this research. This functional form captures the effects of the interactions of the input variables that play a significant role in the process of maximum likelihood estimation. The functional form of the transcendental logarithmic function can be expressed as follows:

$$lny_i = \beta_0 + \sum_{j=1}^{n} \beta_j lnx_{ij} + \frac{1}{2}\sum_{j=1}^{n}\sum_{i=1}^{n} \beta_{ij}\, lnx_j\, lnx_i + v_i - u_i \quad (7)$$

Where: y_i is the total quantity of output, x_i is the quantity of input used, v_i is the two-sided error term, and u_i is the one-sided error term or the technical inefficiency effects

The linear functional form of the variables affecting the technical inefficiency can be expressed as:

$$u_i = \delta_o + \sum_{k=1}^{n} \delta_k z_i + \varepsilon_i \quad (8)$$

Where: δ_k is a vector of parameters (regression coefficient) to be estimated, z_i is a vector of inefficiency variables (institutional, demographic, and socio-economic variables), and ε_i is the random error of the model.

Consent to Participate

The sample households that participated in the primary data collection were asked for their consent to give the required data, and the researchers also assured them that the information they give will be kept confidential, and only used for the intended purpose. Based on this, all the participants gave verbal consent to the researcher and participated in the interview for data collection.

RESULTS AND DISCUSSIONS

Descriptive Results

The descriptive result of the production inputs and output variables is presented in Table 2. The quantity of field peas is used as a dependent variable. The mean plot size under the field pea in the study area was 0.45 hectares, indicating the smallholder farming system. This plot includes both the owned land and rented-in land. Man-equivalent labor used in the model was measured in hours, and it includes both family and hired. The fertilizer used is the amount of inorganic fertilizer measured in kilograms. Oxen hour is the total time it takes a pair of oxen to complete land preparation or plowing. Agrochemicals include the amounts of pesticides, herbicides, fungicides, and other chemicals used per the field pea plot. In recent years, different diseases have emerged, and fababean and field pea farmers in Ethiopia are spraying different agrochemicals.

Field pea production in the study area is dominated by male-headed households (89%). In terms of age, 61% of the respondents were aged between 30 to 50 years, with an average age of 48 years. The majority of respondents (90 %) had an experience of 10 years and above in field pea production, with an average experience of 26 years. The household size for more than 94 % of the respondents ranged from 1 to 8 with an average of 6 members. The average land holding in the study areas is about 1 ha (See Table 3).

Table 2: Descriptive results

Variable	Mean	Std. Dev.	Min	Max
Field pea yield (kg)	429.25	489.99	5	2500
Labor used (hr.)	83.89	53.28	12	333
Fertilizer used (kg)	16.66	27.34	0.1	120
Seed used (kg)	59.76	42.26	10	260
Oxen power (hr.)	30.03	23.55	5	120
Agrochemicals (kg)	0.489	0.664	0.1	2.75
Plot size (ha)	0.446	0.375	0.1	2.50
Livestock (TLU)	7.990	4.330	0.1	22.1
Plot distance (minutes)	24.79	41.89	0	400
Market distance (minutes)	82.65	53.81	0	180
Age of the head (yr.)	48.25	12.21	25	79
Experience in field pea	25.94	11.71	2	55
Family size (AE)	5.750	2.020	1	15
Education of the head (yr.)	5.950	3.380	0	14
Land owned (ha)	1.52	1.270	0	6
Sex of the head	0.89	0.309	0	1
Access to off-farm income	0.76	0.429	0	1
Seed production (no/yes)	0.44	0.498	0	1
Training on pulse (no/yes)	0.67	0.473	0	1
Access to credit services	0.46	0.500	0	1
Access to extension contacts	0.88	0.321	0	1
Field pea adoption (no/yes)	0.65	0.479	0	1
Contract farm (no/yes)	0.15	0.362	0	1

Source: Authors' survey result

The field pea yield per hectare in the study area is very low compared to both the national average productivity of the crop and the yield potentials of the varieties that the majority of the sample households are using. The national average productivity of the crop is 1.73 tons per hectare (ESS, 2022), while the average productivity of the crop in the study area is 0.96 tons/hectare. The result of the focus group discussion showed that the yield reduction was mainly due to diseases and pests that have been devastatingly affecting the crop in recent years.

Econometric Results

This study used the stochastic frontier model to assess the technical efficiency of field pea producers in the study area. Labor, fertilizer, seed, plot size, agrochemicals, and oxen power were the first-order variables (production variables) included in the model. Besides, the squared values of all the production variables and their interactions were also included. Finally, sex, age, education, livestock holding, experience in field pea production, access to off-farm income, plot distance, distance from the main market, access to extension services, access to credit, participation in contract farming, adoption of field pea technologies, access to training in pulse production, land ownership and participation in field pea improved seed production were the variables included as the variables affecting the inefficiency of field pea producers.

After testing for heteroscedasticity and multicollinearity, all the production variables, the squared values of all the production variables, and their interactions, along with the inefficiency variables, were fitted in the model. The assumption behind this is that multiple relationships may exist among the variables and the linear and quadratic associations may also co-exist among the variables and their interactions with the dependent variables. The result depicted that seed, agrochemicals, and oxen power were the production variables that positively and significantly affected the field pea yield at a 1 % significance level (See Table 3).

The interaction effect of the production variables denotes the complementarities of the production inputs in agricultural production. The negative complement suggests that a joint increase of the variables decreases the production efficiency, while the positive complementarity suggests a joint increase of the variables increases the production efficiency. The result of this study disclosed that the squared values and the interaction of some variables were found to be the most important variables. The squared value of labor and the squared value of the plot size positively and significantly affected field pea production efficiency at 5 %.

Table 3: Maximum likelihood estimation results

Variables	Coef.	St. Err.	z	P>z
Labor	0.408	0.459	0.890	0.374
Fertilizer	0.142	0.140	1.020	0.310
Seed	3.007 ***	0.712	4.220	0.000
Plot size	0.697	1.018	0.680	0.494
Chemical	0.912 ***	0.272	3.350	0.001
Oxen	0.664 ***	0.249	2.660	0.008
0.5 labor2	0.816 **	0.330	2.470	0.013
0.5 fertilizer2	-0.091	0.057	-1.600	0.109
0.5 Seed2	-0.159	0.355	-0.450	0.654
0.5 Plotsize2	0.822 **	0.346	2.380	0.017
0.5 Oxen2	-0.407	0.440	-0.920	0.356
0.5 Chemical2	-0.091	0.169	-0.540	0.590
Labor x Fertilizer	-0.064	0.039	-1.630	0.103
Labor x Seed	-0.865 ***	0.248	-3.480	0.000
Labor x Plot size	-0.118	0.228	-0.520	0.604
Labor x Oxen	-0.049	0.283	-0.170	0.863
Labor x Chemical	0.281 **	0.114	2.460	0.014
Fertilizer x Seed	0.075	0.055	1.360	0.174
Fertilizer x Plot size	-0.019	0.050	-0.370	0.709
Fertilizer x Oxen	-0.025	0.073	-0.340	0.736
Fertilizer x Chemical	-0.001	0.026	-0.020	0.983
Seed x Plot size	0.578 **	0.233	2.470	0.013
Seed x Oxen	0.299	0.362	0.830	0.409
Seed x Chemical	-0.846 ***	0.156	-5.410	0.000
Plot size x Oxen	-0.365	0.300	-1.220	0.223
Plot size x Chemical	0.050	0.128	0.390	0.698
Oxen x Chemical	0.472 ***	0.166	2.840	0.005
_cons	-0.456	2.061	-0.220	0.825
Sex of the head	-0.004	0.309	-0.010	0.990
Off-farm	-0.742 **	0.319	-2.320	0.020
Seed production	-0.238	0.252	-0.950	0.344
Livestock owned	0.001	0.024	0.060	0.953
Training on pulse	-0.512 *	0.267	-1.920	0.055
Age of the head	0.001	0.015	0.080	0.937
Family size	0.071	0.061	1.180	0.239
Land owned	0.071	0.090	0.790	0.431
Plot distance	0.001	0.002	0.650	0.517
Market distance	0.000	0.002	0.130	0.900
Access to credit	-0.628 *	0.330	-1.910	0.057
Access to extension	-0.684**	0.334	-2.050	0.040
Education of the head	-0.005	0.031	-0.160	0.873
Adoption of field pea	-0.428 *	0.250	-1.710	0.086
Experience in field pea	-0.006	0.015	-0.360	0.718

Contract farming	-1.077 *	0.624	-1.730	0.084
_cons	2.233 ***	0.836	2.670	0.008
U_sigma				
_cons	-0.536	0.512	-1.050	0.295
V_sigma				
_cons	-1.895***	0.512	-3.700	0.000
Sigma _u	0.765 ***	0.196	3.910	0.000
Sigma _v	0.388 ***	0.099	3.910	0.000
Lambda	1.973 ***	0.261	7.570	0.000
Log-likelihood = -201.6479, No. of obs. = 207, Wald $chi^2(27)$ = 266.36, and Prob > chi^2 = 0.0000				

Source: Authors' survey result

The complementary effects of some variables were also found to be important variables in this study. The interaction of labor with seed and seed with the chemical was found to have a negative effect on the field pea efficiency, while the interaction of labor with chemical, seed with plot size, and oxen with the chemical was found to have a positive effect on field pea production efficiency. The inefficiency variables also fitted in the model along with the production variables and their interactions in a single-step estimation, and the result revealed that access to off-farm income extension, credit, training on pulse production, adoption of field pea technologies, and participation in field pea contract farming were the important variables that affected technical efficiency in field pea production. Access to off-farm income had a negative effect, and a similar result was reported by (Adnan *et al.*, 2021). Access to credit also showed a negative effect, and this result is similar to the result reported by (Mujuru *et al.*, 2022; Wongnaa *et al.*, 2019). Similarly, access to extension services and adoption of new technologies were negatively related to the inefficiency, and this is in line with the finding reported by (Wongnaa *et al.*, 2019).

Estimation of the Technical Efficiency Scores

The technical efficiency score was estimated and presented in Table 4. The average technical efficiency score is 49.23% with a standard deviation of 21.90%, and the minimum and maximum efficiency scores are 5.01% and 99.13%, respectively. This result indicates that field pea producers in the study area are producing far below the frontier, and the production is 51.77% short of the potential. This implies that field pea producers in the study would increase their output by 51.77% through efficient utilization of their resources and solving all the sources of their technical inefficiencies.

Table 4: Summary of profit efficiency scores

Efficiency score range		**Frequency**	**Percent (%)**
< 0.1		006	2.90
0.1 – 0.2		023	11.11
0.2 – 0.3		017	8.21
0.3 – 0.4		026	12.56
0.4 – 0.5		030	14.49
0.5 – 0.6		028	13.53
0.6 – 0.7		038	18.36
0.7 – 0.8		026	12.56
0.8 – 0.9		012	5.80
> 0.9		001	0.48
Total		**207**	**100**
Mean	**0.4923**	**Minimum**	**0.0590**
Std. dev	**0.2190**	**Maximum**	**0.9913**

Source: Authors' survey result

The result of this research (Table 2) indicated that field pea producers in the study area are harvesting an average yield of 0.96 tons/hectare. However, the technical efficiency score presented in Table 4 indicates 51.77% technical inefficiency. This implies that solving all the sources of technical inefficiencies will boost the productivity of field peas to 1.95 tons/hectare.

CONCLUSIONS

This study analyzed the level of technical efficiency and its determinant factors for field pea producers in Ethiopia. This crop is very important and is part of most dishes in Ethiopia. The result of this research revealed that Field pea producers in the study area are inefficient, and producing far below the potential. The average technical efficiency of field pea producers is 49.23 %, and its average productivity is 0.96 tons/hectare. Devastatingly increasing diseases and pests were reported to be responsible for the significant yield reduction in field pea production in the study area. The national average productivity of the crop is 1.76 tons/hectare. This indicates that farmers are producing the crop at 51.77 % grain loss. The amount of seed used, oxen power/plowing chemicals sprayed, access to off-farm income, extension, credit, training and adoption of new field pea technologies were among the most important variables that affected the technical efficiency of field pea producers in the study area.

The amount of seed used, sprayed agrochemicals, and oxen power for plowing were the production variables that positively affected the technical efficiency of field pea producers. The households in the study area are using an amount that is below the optimum level of these inputs. Along with the first-order variables, their squared values were included, and the squared values of labor and plot size were positively and significantly related to the technical efficiency of field pea producers. Moreover, the result confirmed that the complementarities among the inputs were also very important. The interaction of labor with chemicals, seed with plot size, and oxen with chemicals were among the variables positively and significantly affected the technical efficiency of field pea producers. Conversely, the interaction of seed with chemicals, and seed with labor were the variables that negatively related to the technical efficiency.

The finding of this research confirmed that access to off-farm income, access to credit services, access to extension contacts and training, adoption of improved technologies, and participation in contract farming were the responsible factors for the technical inefficiency of field pea producers in the study area. Households with access to these variables are technically more efficient compared to households with no access to these variables. Based on the findings of this research, giving vocational training to farmers, delivering technologies along with their packages to make farmers adopt new technologies, and facilitating ways in which smallholders get access to off-farm incomes and credit services will contribute much to opening the prospects for farmers to become more technically efficient in their farming business. Therefore, policies and incentives promoting such activities will positively impact the technical efficiency of the farmers and speed up the transformation of the sector.

REFERENCES

Adnan, K. M. M., Sarker, S. A., Zannat Tama, R. A., and Pooja, P. (2021). Profit efficiency and influencing factors for the inefficiency of maize production in Bangladesh. *Journal of Agriculture and Food Research, 5,* 100161. https://doi.org/10.1016/j.jafr.2021.100161

Aigner, D., Lovell, C. A. K., and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5

Amarakoon, D., Thavarajah, D., McPhee, K., and Thavarajah, P. (2012). Iron-, zinc-, and magnesium-rich field peas (Pisum sativum L.) with naturally low phytic acid: A potential food-based solution to global micronutrient malnutrition. *Journal of Food Composition and Analysis, 27*(1), 8–13. https://doi.org/10.1016/j.jfca.2012.05.007

Battese, G. E., and Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis, 3*(1), 153–169. https://doi.org/10.1007/BF00158774

Battese, G. E., and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics, 20*(2), 325–332. https://doi.org/10.1007/BF01205442

Blaine Schatz, and Greg Endres. (2021). Field Pea Production (A1166).

Christine, H., and Holger A. Kray. (2019). Productive Diversification in African Agriculture and its Effects on Resilience and Nutrition.

ESS. (2022). Area and Production for Major Crops (Private Peasant Holdings, Meher Season) 2021/22 (2014 E.C.). Ethiopian Statistical Service. https://www.statsethiopia.gov.et/our-survey-reports/

FAOSTAT. (2024). Crops and livestock products Data. Food and Agricultural Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL

Fikere, M., Bing, D. J., Tadesse, T., and Ayana, A. (2014). Comparison of biometrical methods to describe yield stability in field pea (Pisum sativum L.) under south eastern Ethiopian conditions. *African Journal of Agricultural Research, 9*(33), 2574–2583. https://doi.org/10.5897/AJAR09.602

Foyer, C. H., Lam, H.-M., Nguyen, H. T., Siddique, K. H. M., Varshney, R. K., Colmer, T. D., Cowling, W., Bramley, H., Mori, T. A., Hodgson, J. M., Cooper, J. W., Miller, A. J., Kunert, K., Vorster, J., Cullis, C., Ozga, J. A., Wahlqvist, M. L., Liang, Y., Shou, H., … Considine, M. J. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants, 2*(8), 1–10. https://doi.org/10.1038/nplants.2016.112

Kandel, H., McPhee, K., Akyüz, A., Schaubert, S., Bergman, J., Pradhan, G., Link, A., Link, E., Tjelde, T., and Jacobs, J. (2016). *North Dakota Dry Pea Variety Trial Results for 2016 and Selection Guide.*

Kindie, Y., Bezabih, A., Beshir, W., Nigusie, Z., Asemamaw, Z., Adem, A., Tebabele, B., Kebede, G., Alemayehu, T., and Assres, F. (2019). Field Pea (*Pisum sativum L.*) Variety Development for Moisture Deficit Areas of Eastern Amhara, Ethiopia. *Advances in Agriculture, 2019, e1398612.* https://doi.org/10.1155/2019/1398612

Kumbhakar, S. C., Wang, H.-J., and Horncastle, A. (2015). *A Practitioner's Guide to Stochastic Frontier Analysis Using Stata* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781139342070

Kumbhakar, S., Ghosh, S., and McGukin, J. (1991). A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms. *Journal of Business and Economics Statistics, 9.* https://doi.org/10.2307/1391292

Meeusen, W., and van Den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review, 18*(2), 435–444. https://doi.org/10.2307/2525757

Mogiso, M. (2017). Adaptation and Performance on Yield and Yield Components of Field Pea (Pisum sativum L.) Varieties at Adiyo District, Southwestern Ethiopia. *Journal of Biology.*

Mujuru, N. M., Obi, A., Mishi, S., and Mdoda, L. (2022). Profit efficiency in family-owned crop farms in Eastern Cape Province of South Africa: A translog profit function approach. *Agriculture & Food Security, 11*(1), 20. https://doi.org/10.1186/s40066-021-00345-2

Muoni, T., Barnes, A. P., Öborn, I., Watson, C. A., Bergkvist, G., Shiluli, M., and Duncan, A. J. (2019). Farmer perceptions of legumes and their functions in smallholder farming systems in east Africa. *International Journal of Agricultural Sustainability, 17*(3), 205–218. https://doi.org/10.1080/14735903.2019.1609166

Peoples, M. B., Hauggaard-Nielsen, H., Huguenin-Elie, O., Jensen, E. S., Justes, E., and Williams, M. (2019). The contributions of legumes to reducing the environmental risk of agricultural production. In G. Lemaire, P. C. D. F. Carvalho, S. Kronberg, and S. Recous (Eds.), *Agroecosystem Diversity* (pp. 123–143). Academic Press. https://doi.org/10.1016/B978-0-12-811050-8.00008-X

Powers, S. E., and Thavarajah, D. (2019). Checking Agriculture's Pulse: Field Pea (Pisum Sativum L.), Sustainability, and Phosphorus Use Efficiency. *Frontiers in Plant Science, 10.* https://doi.org/10.3389/fpls.2019.01489

Rezene, Y., Alemayehu, F., Gurmu, F., Negash, F., Banteyirgu, B., and Goa, Y. (2015). Registration of 'AMBERICHO' a Newly Released Field Pea (Pisum sativum L) Variety for the Southern Highlands of Ethiopia. *Journal of Plant Studies, 4*(2), Article 2. https://doi.org/10.5539/jps.v4n2p42

Stagnari, F., Maggio, A., Galieni, A., and Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: An overview. *Chemical and Biological Technologies in Agriculture, 4*(1), 2. https://doi.org/10.1186/s40538-016-0085-1

Wang, H.-J., and Schmidt, P. (2002). One-Step and Two-Step Estimation of the Effects of Exogenous Variables on Technical Efficiency Levels. *Journal of Productivity Analysis, 18,* 129–144. https://doi.org/10.1023/A:1016565719882

Wongnaa, C. A., Awunyo-Vitor, D., Mensah, A., and Adams, F. (2019). Profit efficiency among maize farmers and implications for poverty alleviation and food security in Ghana. *Scientific African, 6,* e00206. https://doi.org/10.1016/j.sciaf.2019.e00206