# Determinants of Productivity and Technical Efficiency of Upland Rice Farming System in Sarangani Province, Philippines

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## Abstract

*This study identified the determinants of productivity and technical efficiency (TE) of upland rice in Sarangani Province, Philippines. Data were taken from 326 randomly identified beneficiaries of the Special Area for Agricultural Development (SAAD) program. Descriptive statistics, cost and return analysis, probit regression and the stochastic production frontier were employed in the analysis. The probit estimation revealed that age, the tribe of the farmers, educational attainment, years in farming, membership in an organization, farm income, number of extension visits, and planted area were found to significantly influence the productivity of upland rice farmers. Concerning stochastic frontier estimation, labor, seeds, nitrogen, phosphorus and two varieties of upland rice seeds were found to be significant factors affecting upland rice productivity. These played an important role in terms of changing their TE score. The mean TE score was 77% indicating that there was a 23% allowance for improving efficiency. Meanwhile, farm and farmers' characteristics were unable to explain why farms were less technically efficient. With these, farmers should minimize the use of nitrogen application to avoid a possible oversupply of nutrients and expand the utilization of labor, seeds, and phosphorus fertilizer to achieve a higher yield of upland rice.*

***Keywords****:* productivity, stochastic frontier analysis, upland rice

## 1. Introduction

In developing countries like the Philippines, it is very important to attain self-sufficiency in rice because rice constitutes 75% of the total consumption of every Filipino with a consumption of 110 kg of rice per year or equivalent to three cups per day. In 2010, the Philippine government implemented the program on self-sufficiency in rice production to decrease the importation of rice to 70% – from 2.3 million tons in 2010 to 700,000 tons of rice in 2011 (Koirala *et al*., 2014). With the increasing population in the Philippines (1.9% growth rate), it is evident that there is a huge demand of rice than its supply. Part of an important initiative to achieve rice sufficiency in the region and country is through upland rice farming.

Upland rice has been seen as the best solution to increase the supply of rice in Sarangani, Philippines. Sarangani has ventured to its upland areas for additional supply. Aside from targeting increase in rice supply, upland rice industry reaches out to the Indigenous People (IPs), Muslims and local farmers living in the highlands of Sarangani. These people are mostly poor despite owning large farmlands.

Turner (2008) found out that in Sarangani Province, irrigated high yielding varieties were grown in lowland areas of Kiamba and Maitum while the traditional upland rice varieties were cultivated in the upland areas of Alabel, Malapatan, Malungon, Maasim, and Glan. It was also observed that the farmers cultivating high yielding varieties were supported by the national and local government units (LGUs). In Quirino Province, Benabise *et al*. (2015) analyzed the factors affecting rice productivity and technical efficiency (TE) of farmers using the Cobb-Douglas stochastic frontier model across six municipalities in the said province. Results revealed that there was a positive output-and-input relationship among all variables, namely labor, seeds, chemicals, and nitrogen fertilizer used in farming. Moreover, the number of training attended by farmers, topography, irrigation, and land ownership were found significant factors contributing to farms' technical inefficiency.

In 1999, the Upland Development Program in Southern Mindanao was implemented. It was observed that the average yield harvested by upland farmers was 600 kg per hectare. In 2016, the Sarangani provincial government accelerated its implementation of the diversified upland rice farming development project. This was funded by Special Area for Agricultural Development (SAAD) program of the Department of Agriculture amounting to 100 million pesos to provide farmers with upland rice seeds, organic fertilizers, seminars, and training, among others. Under the program, the average harvested yield of upland farmers reached 1,000 kg per hectare. This implies that the program achieved significant results in increasing the yield. However, it is still unknown which among the inputs given to the farmers significantly contributed to the yield increase. This study analyzed the factors influencing the productivity and TE of upland rice farmers' farming practices. This study was also anchored on the hypotheses that inefficiency factors do not affect the output of upland rice farmers; however, they are not producing along the production frontier. The results of this study could serve as basis for the LGU in improving their intervention towards the upland rice farmers.

## 2. Methodology

*2.1 Respondents, Time and Place of the Study*

The study was conducted in Sarangani Province, Philippines from August 2018 to February 2019. Selected through random sampling, the 326 upland farmers, who produce upland rice in their respective areas within Sarangani Province, were interviewed. The majority of these respondents are tribal members (B'laan, Tagakaolo, and T'boli). All of them were beneficiaries of SAAD program.

*2.2 Data Collection*

Coordination with the upland rice focal person per municipality was done to determine the location of the respondents. Data were gathered through personal interviews using a structured survey questionnaire.

*2.3 Statistical and Research Design*

Probit regression analysis was used to determine the factors affecting the productivity of farms. The model is specifically defined in Equation 1.

$$P_i = F\,(Y_i) = f\,(\beta_0 + \beta_1 X_1 + \ldots\ldots + \beta_n X_i + e_i) \sim NID\,(0,1)$$

$$P_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \Theta_1 D_1 + \Theta_2 D_2 + \Theta_3 D_3 + \Theta_4 D_4 + \Theta_5 D_5 + \Theta_6 D_6 + e \quad (1)$$

where:

$P_i$ = probability of high productivity
= 1 if yield > 401 kg/ha
= 0 if otherwise
$X_1$ = age of the farmer (years)

$X_2$ = educational attainment (number of years in formal schooling)
$X_3$ = household size
$X_4$ = number of years in farming
$X_5$ = farm income (pesos/month)
$X_6$ = number of extension visits
$X_7$ = total land owned by the farmer (ha)
$D_1$ = dummy variable for sex of farmer
= 1 if male
= 0 if otherwise
$D_2$ = dummy for religion
= 1 if Roman Catholic
= 0 if otherwise
$D_3$ = dummy for ethnicity of the farmer
= 1 if farmer is IP
= 0 if otherwise
$D_4$ = dummy variable for land tenure
= 1 if the land is owned
= 0 if otherwise
$D_5$ = dummy for membership in organization
= 1 if the farmer is a member of an organization
= 0 if otherwise
$D_6$ = dummy for the beneficiary of another program aside from SAAD
= 1 if the farmer is a beneficiary of another program
= 0 if otherwise
$e$ = error (0.05)

The variables included as potential factors determining the productivity of the farmers were age, educational attainment, sex, ethnicity, land tenure, household size, number of years in farming, farm income, number of extension visits, total land area, and membership in an organization. These explanatory variables, which contributed to the productivity of the rice farmers, were commonly used in the previous studies. Hence, these variables were considered and included in the probit regression analysis and inefficiency effects model.

Stochastic frontier Cobb-Douglas production function was utilized to estimate the efficiency of upland farmers and the factors affecting their inefficiency. The Cobb-Douglas functional form is defined in Equation 2.

$$InY_i = In\, ß_0 + ß_1 InX_{1i} + ß_2 InX_{2i} + ß_3 InX_{3i} + ß_4 InX_{4i} + ß_5 InX_{5i} + ß_6 InX_{6i} + \Theta_1 D_1 + \Theta_2 D_2 + v_i - \mu_i \quad (2)$$

where:

$ln$ = natural logarithm
$Y_i$ = volume of upland rice in kilogram per hectare of the $i^{th}$ farmer
$X_{1i}$ = quantity of labor (man-days) per hectare of the $i^{th}$ farmer
$X_{2i}$ = quantity of seed planted in kilogram per hectare of the $i^{th}$ farmer
$X_{3i}$ = quantity of nitrogen used in kilogram per hectare of the $i^{th}$ farmer
$X_{4i}$ = quantity of phosphorus used in kilogram per hectare of the $i^{th}$ farmer
$X_{5i}$ = quantity of potassium used in kilogram per hectare of the $i^{th}$ farmer
$X_{6i}$ = slope of farm (percent)
$D_1$ = dummy variable for Kasagpi variety
= 1 if Kasagpi variety
= 0 if otherwise
$D_2$ = dummy variable for Dinorado variety
= 1 if Dinorado variety
= 0 if otherwise
$v_i$ = random error (white noise)
$u_i$ = non-negative random variable called inefficiency effects

It is shown above that inputs considered in the present study were labor, quantity of seeds used and quantity of fertilizer, namely nitrogen, phosphorus, and potassium. Variety of rice and farm slope were also included as these factors also influence the output together with the previously mentioned inputs.

Labor is an important factor in any production process particularly in agriculture that is considered to be labor-intensive. It is hypothesized that in rice production, more labor will result in higher output (Jude, 2007; Gomez and Neyra, 2010; Benabise *et al*., 2015).

The quantity of fertilizer applied is another important input in rice production. Fertilizers provide nutrients necessary for plant growth. If these are applied at optimum levels, this will result in higher yield.

One of the factors contributing to low crop production is the lack of necessary fertilizers. This claim is supported by previous studies (Gomez and Neyra, 2010); Cañete and Temanel, 2013; Binabise *et al*., 2015; Perpetua, 2015).

The quantity of seed is also crucial in upland rice production. If the quantity used is lower than the seeding rate, then this will lower the production.

Similarly, if this is over applied, this will result in crowding that eventually reduces the crop yield because plants compete for sunlight and soil nutrients (Jude, 2007; Cañete and Temanel, 2013; Benabise *et al.*, 2015; Perpetua, 2015).

Also considered in the study of Kikuta *et al.* (2016) as an important factor in agricultural production, the slope of the farm was also included in the present study although it is not a direct input due to the fact that steep slope areas are more prone to soil erosion. Hence, the slope of the farm is important to consider in upland agriculture.

The variety of upland rice was also included since different varieties yield differently. Hence, this was likewise considered as an important factor in the present study.

The linear form of the inefficiency effects model for the ith farm can be specified in Equation 3.

$$u_i = \gamma_o + \gamma_1 Z_{1i} + \gamma_2 Z_{2i} + \gamma_3 Z_{3i} + \gamma_4 Z_{4i} + \gamma_5 Z_{5i} + \gamma_6 Z_{6i} + \gamma_7 Z_{7i} + \gamma_8 Z_{8i} + \gamma_9 Z_{9i} + \Theta_1 D_1 + \Theta_2 D_2 + \Theta_3 D_3 + \Theta_4 D_4 \quad (3)$$

where:

$Z_{1i}$ = age of farmer
$Z_{2i}$ = farming experience in years
$Z_{3i}$ = educational attainment (number of years in formal schooling)
$Z_{4i}$ = household size
$Z_{5i}$ = farm income (pesos/month)
$Z_{6i}$ = number of extension visit
$Z_{7i}$ = number of seminars and trainings attended
$Z_{8i}$ = distance of farm to the nearest market (km)
$Z_{9i}$= total land owned by the farmer (ha)
$D_1$ = dummy for sex of farmer
= 1 if male
= 0 if otherwise
$D_2$ = dummy for ethnicity of the farmer
= 1 if farmer is IP
= 0 if otherwise
$D_3$ = dummy for land tenure
= 1 if land is owned
= 0 if otherwise
$D_4$ = dummy for SAAD batch
= 1 if the farmer belongs to the 1st batch
= 0 if otherwise
$\gamma_o$ = inefficiency parameters to be estimated

## 3. Results and Discussion

### *3.1 Determinants of Productivity*

The probit regression analysis disclosed that age had a negative sign implying that the higher the age of the farmer, the lower the probability of high productivity (Table 1). This indicates that young farmers are more efficient than old farmers (Ogundari and Ojo, 2005). Likewise, Oladimeji and Abdulsalam (2013) underscored that labor productivity is a function of age where young people tend to be more willing to adopt new production methods to increase their rice output than old people. Ayoola (2011) also revealed that when the farmer is older, his vigor to rice farming is decreasing which influences rice production negatively.

Table 1. Probit estimate of the determinants of productivity of upland rice farmers in Sarangani Province (2018)

| Variable | Estimated coefficient | Standard error |
|---|---|---|
| Constant | 1.8447 | 0.7895 |
| Age of the farmer | -0.0150* | 0.0084 |
| Sex | 0.2309 | 0.2138 |
| Religion | -0.2809 | 0.2264 |
| Tribe | 1.5026* | 0.8311 |
| Educational attainment | 0.1306*** | 0.0408 |
| Household size | -0.0577 | 0.0480 |
| Number of years in farming | 0.0432*** | 0.0087 |
| Land tenure | -0.0528 | 0.2587 |
| Membership in Organization | -1.1179*** | 0.2368 |
| Farm income | 0.0001*** | 0.0000 |
| Number of extension visit | -0.4542*** | 0.1819 |
| Area planted with upland rice | -0.8419*** | 0.1608 |
| Beneficiary of another program | 0.4306 | 0.2845 |
| LR $chi^2$ (13) = 161.79 | | |
| Prob $>x^2$ = 0.0000 | | |
| Psuedo $R^2$ = 0.365 | | |

*** indicates significant at 1%, and * at 10%

The tribe of the farmer implied that IP farmers (B'laan, T'boli, and Tagakaolo) had a higher probability of achieving high productivity since they are the original producers of upland rice in the province compared with Muslims. In the study of Perpetua (2015), it was found out that majority of the upland farmers were IPs. In terms of educational attainment, the result exhibited that higher number of years of farmers' education translates to higher probability of achieving high productivity since education could affect the chances of using improved and sophisticated inputs, which can boost rice output.

Previous works also highlighted that educated farmers had higher productivity (Jude, 2007; Cañete and Temanel, 2013; Oladimeji and Abdulsalam, 2013).

With regards to the number of years in farming, results showed that higher the number of years into upland rice farming would mean higher probability of achieving an increased upland rice production. Likewise, in the study of Ajani (2000), Gomez and Neyra (2010), and Cañete and Temanel (2013), years of farming experience was a factor enhancing agricultural productivity among farming households.

Membership in an organization obtained a negative sign implying that if the farmer is a member of an organization, it lowers the probability of achieving higher productivity. It was captured that the upland farmers are members of different organizations, which are unrelated to farming activities. This result is opposite to the findings of Sibiko *et al*. (2012) in which membership in an organization was a significant factor. In addition, Effiong (2005) cited that farmers' organization membership aided them in the form of information sharing on improved technologies, and interacting and enabling the relaxation of farm inputs utilization and acquisition constraints faced by farmers. Hence, an organizational membership related to the famer's farming activities would enhance their knowledge and practices.

As for the farm income, higher farmer's income was equated to higher probability of achieving higher productivity since farmers can purchase farm inputs on time. The number of extension visits recorded a negative sign indicating that higher number of extension visits decreases the probability of achieving productivity. Upland farmers living in a far-flung area had a lower probability of achieving higher productivity since they do not only focus on upland rice production but also on other crops despite the high number of visits done by an extension agent. Also, the extension visits are not only concerned with rice alone but also other crops.

Area planted with upland rice had a negative sign implying that wider farm areas reduces probability of attaining higher productivity. Upland farmer, who owns a big area, would have a difficulty in managing the area since upland farmers are beyond the economies of scale. This result concurs well with the findings of Helfand *et al*. (2014) that as the farm size rises, the farmers' productivity falls.

### *3.2 Technical Efficiency*

The quantity of seed planted had the highest elasticity of 0.22 signifying that 1% increase in seed quantity brings about 0.22% increase in yield because farmers were still in the first stage of production. Labor elasticity says that 1% increase in labor quantity generates 0.17% increase in yield. Phosphorus elasticity indicates that 1% increase in the quantity of phosphorus begets 0.12% rise in yield (Table 2).

Table 2. Maximum likelihood estimates of the stochastic frontier production function of upland rice farmers in Sarangani Province (2018)

| Variables | Parameter | Coefficient | Standard error |
|---|---|---|---|
| Constant | $\beta_0$ | 2.153*** | 0.301 |
| Labor | $\beta_1$ | 0.172** | 0.143 |
| Seeds | $\beta_2$ | 0.222*** | 0.061 |
| Nitrogen | $\beta_3$ | -0.078*** | 0.029 |
| Phosphorus | $\beta_4$ | 0.123*** | 0.041 |
| Potassium | $\beta_5$ | 0.076 | 0.277 |
| Slope of farm | $\beta_7$ | 0.282 | 0.192 |
| Kasagpi | $\Theta_1$ | 0.103* | 0.062 |
| Dinorado | $\Theta_2$ | 0.072* | 0.047 |
| Inefficiency model | | | |
| Age | $\gamma_1$ | -0.002 | 0.002 |
| Farming experience | $\gamma_2$ | -0.006** | 0.002 |
| Educational attainment | $\gamma_3$ | -0.012 | 0.008 |
| Household size | $\gamma_4$ | 0.012 | 0.009 |
| Farm Income | $\gamma_5$ | -0.000*** | 0.000 |
| Number of extension visit | $\gamma_6$ | 0.056 | 0.035 |
| Number of seminars attended | $\gamma_7$ | -0.037*** | 0.009 |
| Distance from farm to market | $\gamma_8$ | -0.012** | 0.006 |
| Total land area owned | $\gamma_9$ | 0.013 | 0.006 |
| Sex | $\Theta_1$ | -0.018 | 0.047 |
| Ethnic Origin | $\Theta_2$ | -0.197 | 0.198 |
| Land Tenure | $\Theta_3$ | 0.033 | 0.056 |
| SAAD Program Batch Number | $\Theta_4$ | -0.020*** | 0.006 |
| Sigma Squared | $\sigma_u^2$ | -0.043*** | 0.053 |
| Gamma | $\gamma_m$ | 0.090 | 0.205 |
| Log Likelihood | | 39.14 | |

*** indicates significant at 1%; ** significant at 5%, and * at 10%

These findings are consistent with results of Ayinde (2009), Magreta (2011), Cañete and Temanel (2013), Benabise *et al*. (2015), and Perpetua (2015), who found out that quantity of seeds, labor and phosphorus fertilizer input were significant inputs in the farm.

Nitrogen fertilizer achieved a negative significant effect signaling that upland farmers had an over application of nitrogen. This was already in the third stage of the production wherein the marginal product was less than zero; hence, over application of nitrogen decreased the yield. This conforms to the study of Benabise *et al*. (2015) among rice farmers in Quirino Province where the over application of nitrogen was evident. Gomez and Neyra (2010) also disclosed a negative and significant effect of nitrogen fertilizer on high yielding rice areas in North Cotabato. In the study area of the present work, it was observed that all upland farmers use the same practices in preparing their land area before planting. The upland rice farmers clean the area by slashing, hand weeding and weed burning. Burning is commonly practiced since they believe that the ashes make the soil more fertile which greatly boosts plant growth and development. The upland farmers do this annually since they only plant rice once a year. Upland farmers follow minimum tillage because they only dibble the seed in the soil during planting. This has been part of their traditional practice. It is hard for them to plow and furrow the field because of the terrain. The upland farmers plant along the mountain and some of them cultivate vegetables as an additional crop.

With regards to the variety of upland rice seeds, the result revealed that the output was higher among upland farmers using Kasagpi and Dinorado varieties. However, higher coefficient of the Kasagpi's dummy showed that Kasagpi had greater yield than Dinorado.

The estimated sigma square indicated the goodness of fit and correctness of the specified distribution assumption of the composite error terms. Thus, the result suggested that the Cobb-Douglas Stochastic frontier production function was an adequate representation of the data. This result agrees to that of Rahman (2002), Tijani *et al*. (2006) and Adebayo, (2008), who disclosed that the production function estimation was an adequate representation of their data gathered.

However, gamma ($\gamma_m$) value was found to be not significant. The result implied that inefficiency did not exist in the model specification. This result is supported by Battese (1992) who stated that gamma is bound between zero and one. When the result is one, inefficiency is significant and not random; when it is zero, inefficiency effects are inexistent in the model. Based on the results of the frontier, the gamma value was closer to zero. Hence, the observed deviation from the frontier was not due to inefficiency but to other factors. Aquino *et al*. (2013) cited that a lower and insignificant value of gamma implies that technical inefficiency effects are likely not significant in the analysis of farm yields. Hence, farm and farmer characteristics were unable to explain the farms' low TE.

The mean TE was 77% as shown in Table 3. It suggests that the upland rice farmers were technically inefficient since they were below the frontier. There was 23% technical inefficiency at an aggregate level for upland rice production. This implied that output per farm can be increased on average by 23% under the existing technology without incurring any additional input. This result conforms to the study of Idiong (2007), who revealed that the mean efficiency level of rice farmers living in Nigeria was 77% implying that farmers were not fully technically efficient and there was remaining 23% for improving their efficiency.

Table 3. Frequency distribution of TE scores of upland rice farmers in Sarangani Province (2018)

| Range | Frequency | Percentage |
|---|---|---|
| 45 – 53 | 5 | 2 |
| 54 – 63 | 73 | 22 |
| 64 – 72 | 58 | 18 |
| 73 – 81 | 53 | 16 |
| 82 – 90 | 41 | 13 |
| 91 – 99 | 96 | 29 |
| Mean | 77 | |
| Standard Deviation | 15.6 | |
| Minimum TE | 45 | |
| Maximum TE | 99 | |

## 4. Conclusion and Recommendation

Included factors such as age, farming experience, sex, tribe, land tenure, education, household members, income of the farmer, number of extension visits, training and seminars attended, distance from the farm to market and type of beneficiary were not significant factors under inefficiency model. In other words, the included factors in the model do not affect the output of upland rice farmers. Also, upland rice farmers in Sarangani Province were not producing along the frontier since 23% was still needed for the improvement of their efficiency under the existing technology without incurring any additional input. Therefore, it is recommended that farmers should minimize the use of nitrogen application to avoid possible oversupply of nutrients and expand the utilization of labor, seeds, and phosphorus fertilizer to achieve a higher yield of upland rice. Mechanization practices anchored on the existing indigenous practices of upland rice farmers may be introduced by the LGU.

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