Farm Environment, Farmer Knowledge and Technical Efficiency:
An Investigation Among Upland Corn Farmers in Bukidnon, Philippines

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Purisima G. Bayacag and Agnes C. Rola

Abstract

Using a panel data (1994-1999) of upland corn farmers' production and soil conservation practices, this paper investigates the influence of farmers' technical and ecological knowledge on their technical efficiency (TE). TE was derived from two types of translog production frontiers where the first equation did not include environmental factors as independent variables and the second did. In the first function, it was assumed that the farms faced the same environment thus, it measures production efficiency as influenced by both management and environment. In the second function, farms are assumed to face different environmental conditions, thus, measuring the technical efficiency due to crop management alone. The difference between the two efficiency measures of farms would then account for the influence of environmental factors.

To assess factors affecting technical efficiency ratings, an OLS function was estimated where the independent variables included farmer attributes including his/her ecological and technical knowledge ratings. The knowledge ratings were derived from the respondents' scores in a knowledge test conducted by the researchers in 1999.

Results of the study showed that on the average, the technical efficiency of farms with and without consideration of the environmental factors were 49.6 % and 45.2%, respectively. The difference of 4.4 % can be attributed to the influence of environment to production efficiency. Crop management accounts for 50.4% of technical inefficiencies. Farmers' TE was significantly explained by the following: a) average education of the farmer and her/his spouse; b) family labor force; c) distance of the farm from the national road; and d) the farmers' technical knowledge. The ecological knowledge of farmers did not yield significant results although this was found to be positively affecting TE.

I. INTRODUCTION

One of the areas that receive the greatest concern today is our upland. These lands are fragile in nature but because of population pressure, expansion and intensification of cultivation of these areas is inevitable. According to statistics, 56 percent of the 99 million hectares of the upland area in the Philippines is grown to grains and other annual crops (NSO, 1990).

Among the annual crops that dominate the upland area is corn. This is so because corn is important to the Philippine economy. It is next to rice as a staple food and a very important ingredient in the manufacturing and feed sectors. To help the corn industry, several programs to enhance its production were launched by the government. These programs serve as incentives to encourage upland farmers to intensify production even in erosion-prone areas. Today corn production has proliferated in our upland and this is seen to pose some environmental as well as economic concerns.

Corn has been associated with high rates of nutrient uptake and soil erosion that it is considered to be the chief contributor to land degradation in the uplands (David, 1988). Without enough conservation measures, continuous cultivation of the crop will reduce the productivity of the soil causing the volume of production to deviate from maximum yield that a technology could offer. If technical efficiency is defined to be the ability of the farmer to produce at the maximum output given quantities of inputs and technology (Aigner, Lovell and Schmidt, 1977, Farrel, 1957), then technical efficiency among upland corn farms can be attributed to; a) the managerial ability of the farmer to produce the crop, and b) the soil condition of the farm.

In order to maintain sustainable levels of production, the farmer must possess certain knowledge to match the technical aspect of production with soil conservation practices. It involves managing the land resource aside from the target crop in order to maintain the productive base of his farm over time. To accomplish this, the farmer must possess some agro-ecological knowledge - a knowledge that pertains to technical and environmental aspects of the production system that may influence his decision-making to balance both the economic and environmental risk of his farm. It is likewise shown elsewhere that agro-ecological knowledge of the farmer together with other factors will affect the production performance of the farm (Rola, 1998).

If we aim for sustainability of agriculture in our upland, we need to investigate the role of agro-ecological knowledge in technical efficiency of farms and further investigate what dominates inefficiency in upland corn farming - soil condition or management ability of farmer to grow the crop. These issues are addressed in this paper.

Location of the Study

The study site is the SANREM CRSP area in Lantapan, Bukidnon. Lantapan is a municipality about 15 kilometers south of Malaybalay City- the capital city of the province of Bukidnon. It has an average elevation of 1075 meters above sea level with land area of 31,820 hectares of which 41 percent are forested and remaining 53 percent being used for agricultural purposes (Lantapan MPDO, 1991).

The study area is classified into three ecozones based on land uses namely; "Kapatagan", "Kamaisan", and "Kasagbutan". The "Kapatagan" and "Kamaisan" ecozones are with elevations that ranges from 500 meters to 900 meters above sea level while the "Kasagbutan" is 1100 meters above sea level. The "Kapatagan' area is usually used for large scale commercial production of corn, sugar cane, and lowland rice. The "Kamaisan" ecozone is slightly sloping and permanently cultivated to corn. The "Kasagbutan" areas are characterized as mainly rolling to steeply sloping areas.

The study is mainly focused in the "Kamaisan" and "Kasagbutan" areas for purposes of comparing performance of farmers in areas permanently cultivated with corn and those areas that are rolling and steeply sloping. In the latter description, farmers usually shift from corn to vegetables or vegetables to corn depending on the market situation (Coxhead and Rola, 1998). The "Kamaisan" is composed of the following barangays; Poblacion, Balila, Baclayon, and Alanib. The"Kasagbutan” consists of Songco, Cawayan, Victory, Kibangay, and Basak. According to SANREM report (1998), one of the most important problems of farmers in the area is low and declining corn yields. Even farmers who regularly applied fertilizers whose farms suffered from soil erosion experienced a similar problem.

The Farmer Cooperators

Panel data of output levels and input use by farmers in the barangays described above were used in the analysis. In 1994, 191 respondents participated in the benchmark survey. In 1998, only 95 farmers remained in the panel. A subset of this or those who have planted corn at least once during the 6-year period (1994-1999) formed the panel for this study. Description of respondents is in Coxhead, 1995, and Rola and Coxhead, 1998, among other reports. The production year 1997 is not represented because production data were not available.

II. METHODOLOGY

Technical inefficiency is defined to be the failure to produce at maximum output (frontier production) given input quantities and technology and can be considered as a source of production losses. The literature is rich in the application of frontier functions in the estimation of technical efficiencies. Most of the applications of are in rice (Kalirajan and Shand, 1989, Battese and Coelli, 1992, Rola and Alejandrino, 1993, among others). In the case of upland corn farms, farmers follow more or less the same technology but are exposed to different soil environment. The failure to produce at the frontier in this case is generally attributed to: a) crop management of the farmer, and b) his/her degraded farm soil. Thus, the added challenge in estimating for technical inefficiencies among upland corn farmers is on the technique of disaggregating the effects of the different factors, especially the soil quality.

If we let $\mathbf{u^m}$ be the production loss due crop management and $\mathbf{u^s}$ as the production loss due soil degradation the total loss $\mathbf{u}_i$ which is equal to the deviation of the individual farm's production from the frontier is:

(1) $U_i = u^m + u^s$

Adopting the concept of Coelli, Perelman and Romano (1996), these two components can be estimated along the principle of technical efficiency.

A stochastic modified translog type production function (Fuss, McFadden and Mundlak, 1978) was utilized to generate the technical efficiency rating of individual farms, using panel data (following Cornwell et al. 1990, Kumbhakar, 1990). To measure $\mathbf{u^m}$ and $\mathbf{u^s}$ the following cases were considered.

Case A. In this model specification, it is assumed that the soil environment influences the shape of the production function and that the individual farmer is subjected to different soil conditions. In such a case, the soil factors are incorporated directly into the production function as independent variables. Hence, the deviation from the frontier is solely due to crop management ($\mathbf{u^m}$) and the function was expressed as:

$$
\begin{aligned}
(2)\ \ln y_{it} = {} & \alpha_o + \Sigma\alpha_l \ln x_{lit} + \Sigma\alpha_j \ln x_{jit} + 1/2\Sigma\Sigma\alpha_{lj} \ln x_{lit} \ln x_{jit} \\
& + \Sigma\alpha_{lk} E_{kit} \ln x_{lit} + \Sigma\alpha_{jk} E_{kit} \ln x_{jit} + \Sigma\beta_k E_{kit} + \varepsilon_{it}
\end{aligned}
$$

where: y_{it} = the output produced by the i^{th} farm during the t^{th} period;
$i = 1,2,3 \ldots n$ farms and $t=1,2,3,\ldots t$ periods

x_{lit} = the l^{th} input of the i^{th} farm during t^{th} period where
$l=1,2,3,\ldots L$ inputs

x_{jit} = the j^{th} input of the i^{th} farm during the t^{th} period
where $j=1,2,3,..J$ inputs

E_{kit}= the k^{th} factor that influence the soil properties of the
i^{th} farm during the t^{th} period where $k=1,2,3,\ldots K$ factors

$\varepsilon_{it} = v_{it} - u^m_{it}$ (composed error term)

v_{it} = random variable due to measurement error, random
shocks, and other statistical noise of the i^{th} farm during
the t^{th} period

u^m_{it} = technical inefficiency (production losses) due to managerial
performace of the i^{th} farm during the t^{th} period

Following Aigner, Lovell and Schmidt (1977), the random symmetric disturbance variable $\mathbf{v_{it}}$ is assumed to be identically and independently distributed as $N(0,\sigma_v^2)$. The $\mathbf{u^m_{it}}$ are non-negative technical inefficiency effects or production losses due to the managerial performance of the farmer which are assumed to be independently distributed and arise from the truncations (at zero) of the normal distribution with variance $\boldsymbol{\sigma_{um}^2}$.

Case B. In this model specification, it is assumed that the farms are subjected to the best soil environment in the area thus, the sources of production losses (technical inefficiency) are both from managerial and soil factors. The factors affecting soil properties had therefore direct influence on the degree of technical inefficiency $\mathbf{u_{it}}$ and not on the shape of the production technology. Thus, the production function is expressed as:

$$(3)\quad \ln y_{it} = \beta_o + \Sigma \beta_l \ln x_{lit} + \Sigma \beta_j \ln x_{jit} + 1/2\, \Sigma\Sigma\, \beta_{lj} \ln x_{lit} \ln x_{jit} + \varepsilon_{it}$$

where $\boldsymbol{\varepsilon_{it} = v_{it} - u_{it}}$ (composed error term)

v_{it} = random variable due to measurement error, random shocks, and the other statistical noise of the i^{th} farm during the t^{th} period.

u_{it} = technical inefficiency (production losses) due to managerial and soil environmental factors of the i^{th} farm during t^{th} period.

As in Case A the random symmetric disturbance variable $\mathbf{v_{it}}$ is assumed to be identically and independently distributed as $N(0,\sigma_v^2)$. The $\mathbf{u_{it}}$ are non-negative technical inefficiency effects or production losses due to managerial performance of the farmer and soil condition of his/her farm which are assumed to be independently distributed and arise from the truncation (at zero) of the normal distribution with variance σ_u^2. Other variables are defined as in Case A.

The unknown parameters of the two production functions (equations 2 and 3) were obtained simultaneously using the maximum likelihood estimation (MLE). This was done using the computer program FRONTIER Version 4.1 (Coelli, 1994). This program uses the parameterization $\boldsymbol{\delta^2 = \delta_v^2 + \delta_u^2}$ and $\boldsymbol{\gamma = \delta_u^2 / \delta}$ where $\boldsymbol{\gamma}$ must be between zero and one (Coelli, et al., 1996). In this case the individual technical inefficiencies $\mathbf{u^m_{it}}$ and $\mathbf{u_{it}}$ were computed as:

$$(4)\quad u^m_{it} = E[\exp(-u^m_{it})/ \varepsilon_{it} \qquad \text{and}$$

$$(5)\quad u_{it} = E[\exp(-u_{it})/ \varepsilon_{it}$$

After $\mathbf{u_{it}}$ and $\mathbf{u^m_{it}}$ were estimated in equations (4) and (5) the production loss due to soil condition ($\mathbf{u^s_{it}}$) was computed by subtracting $\mathbf{u^m_{it}}$ from $\mathbf{u_{it}}$. Thus,

$$(6)\quad u^s_{it} = u_{it} - u^m_{it}$$

A second stage regression was done between $\mathbf{u^m_{it}}$ and its determinants to understand if agro-ecological knowledge of the farmers influence the technical efficiency of the farms. Such regression analysis can be expressed in the following functional form:

(7) $u^m_{it} = \phi_o + \Sigma \phi_j z_{jit} + \varepsilon_{it}$

where: z_{jit} = the j^{th} factor that influence the managerial performance of the i^{th} farmer during the t^{th} period

ε_{it} = error term

Following Rola (1998), agro-ecological knowledge ratings were derived via a knowledge test developed and administered to the same farmer respondents as in the economics component of SANREM CRSP-SEA. The detailed questionnaire is in Bayacag (2001). To further determine the effect of agro-ecological knowledge, the average test score of the top 20% technically efficient farms was compared with the lowest 20 % farms using t-test. Average test score of top 20% farms with high soil conservation index was likewise compared with the 20 % of the farms with lowest soil conservation index also with the use of t-test.

Definition of Variables

To attain the objectives of study the following variables were fitted in the empirical models presented above.

Quantity of production ($\mathbf{y_{it}}$). This is the total quantity of shelled corn produced by the farmer in kilograms per hectare.

Inputs of Production ($\mathbf{x_I}$**'s and** $\mathbf{x_j}$**'s**).

1. Labor (**Lab**) - total pre-harvest labor rendered per hectare consisted of man-days, man-animal-days, and man-machine-days lump into one where one day is equivalent to 8-hours of work.
2. Lime (**Lim**) - is the total amount of lime applied in kilograms per hectare.
3. Seeds (**S**) - is the amount of seeds planted in kilograms per hectare.
4. Manure (**Mn**) – is the amount of compost, in kilograms per hectare. Manure is usually in the form of chicken dung bought by the farmer.
5. Fertilizer (**NPK**) - is the total amount of inorganic fertilizer in the form of nitrogen (N), phosphorous (P), and potassium (K) applied in kilograms per hectare.

Soil Environment Factors ($\mathbf{E_k}$).

1. Land Slope (**SLD**) – this is a dummy variable that represents the general slope of the farm. This variable is an important factor that influences the soil condition of the farm; i.e. the greater the slope the higher is the rate of erosion. Treating everything equal, farms with lower slopes are expected to be more productive than farms with

higher or steep slopes. In the empirical model this dummy variable is represented as follows:

SLD_1 = 1 for flat and slightly sloping (< 18 percent slope) farms, and

SLD_1 = 0 if otherwise

SLD_2 = 1 for steep/high slope farms (> 18 percent slope, and

SLD_2 = 0 if other wise

2. Slope Location (**LOCD**) - this is a dummy variable that represents the relative location of the farm in the sloping terrain. The slope location is another important determinant of the soil condition of the farms. All things equal, farms at the base are expected to be more fertile than farms at the side, top or shoulder of the slope because this portion of the slope receives the eroded soil. This dummy variable is expressed as follows:

$LOCD_1$ = 1 if the farm is located on the side portion of the hill and

$LOCD_1$ = 0 if otherwise

$LOCD_2$ = 1 if the slope location is mixed where some portion is on the side while the rest are either on the top or base of the hill.

$LOCD_2$ = 0 if otherwise

$LOCD_3$ = 1 if the farm is located at the shoulder and top of the hill and

$LOCD_3$ = 0 if otherwise

3. Ecozone (**EcoZ**) - this dummy variable represents the ecozone location of the farm. As previously mentioned, the study plots are in the "Kamaisan" and "Kasagbutan" ecozones. This variable is included to capture variation in climatic conditions like temperature and altitude between the two ecozones.

EcoZ = 1 if the farm is located in the "Kamaisan" ecozone and

EcoZ = 0 if otherwise

4. Soil Conservation Index (**SCindex**) = this variable is an index that captures the effects of soil conservation practices of the farmer. It takes into account both the method used and the number of years that the method is being used by the farmer. This is because different soil conservation methods differ in their effectiveness in conserving the soil. The duration of practicing the method is also a determinant of soil quality. This means that the real effects on the soil of a certain conservation practice can only be realized after some time.

The indexing was accomplished such that higher numbers were assigned to more effective conservation method while a point of 0.5 is given for every year of practicing a conservation method. To capture the combined effects of the conservation method and length of practice the two numbers were multiplied. Assignment of index numbers to different conservation practices are as follows:

no conservation practice = 0

semi-contour plowing = 1

mulching = 1

dibble planting = 1

leave grassy boundary = 1

contour hedgerows = 1.5

regular fallowing = 1.5

planting perennials on boundaries and steep slopes = 1

In cases where the farmer employed two or more methods, then the points of each method are added to come up with soil conservation index.

5. Soil Fertility (**SF**) - this is a dummy variable that represents the fertility condition of the soil as perceived by the farmer.

SF = 1 if the farmer perceived his farm soil is infertile and

SF = 0 if otherwise

6. Dummy Variables for Year of Observation (**Y**) - this variable is used to capture the yearly variation in climate and other forms of variation between years of observation. The values of these dummy variables are as follows:

Y_1 = 1 for 1994 observation

Y_1 = 0 if otherwise

Y_2 = 1 for 1995 observation

Y_2 = 0 if otherwise

Y_3 = 1 for 1996 observation

Y_3 = 0 if otherwise

Y_4 = 1 for 1998 observation

$Y_4 = 0$ if otherwise

The constant of the regression captures the effect of the 1999 production period.

The independent variable definitions of factors influencing technical efficiency in the OLS equation are as follows:

Age of Farmer- in years;

Average education of farmer and spouse- in years of schooling;

Farming years of farmer- a proxy for experience, in years,

Total family labor force- in number of family members involved in farming operation;

Tenure Dummy- 1 , secured tenure

0, otherwise

Total farm area-in hectare;

Area planted to corn- in hectare;

Technical knowledge- rating in the technical portion of the knowledge test (in %) conducted by researchers;

Ecological knowledge- rating in the ecological knowledge portion of the knowledge test (in %) conducted by the researchers;

Distance from the national road- distance of the farm from the main road, in meters.

III. DISCUSSION OF RESULTS

a. Demographic Characteristics of Sample Farmers

The average corn farmer in the study can be characterized to be 43 years old, a male, with a farming experience of 22 years. He attended formal schooling of about 5 to 6 years. He owns about 3 hectares of land but devoted only 1.27 hectares to corn. His average yield per hectare is 1442 kilograms and his farm is around 1,907 meters away from national road.

On the average the farmer's spouse is an elementary graduate and based on field observation, she is most knowledgeable about the farm activities and actively participates in decision - making process. Hand-in-hand with the wife, the farmer is helped by around one to two members of the family in tending his corn farm.

Farm practices in terms of input use are detailed in Bayacag (2001).

b. Technical efficiency estimates from alternative frontier production function specifications

The stochastic frontier production function model was estimated by MLE technique (Greene, 1980,Aigner, Lovell and Schmidt, 1977, Battese and Coelli, 1992, Battese and Coelli, 1995). The results of the Ordinary Least Squares (OLS) and Maximum Likelihood Estimate (MLE) with and without soil factors using FRONTIER Version 4.1 (Coelli, 1994) are presented in Table 2. Generally, the results seem to be well behaved in terms of expectations of the signs of the coefficients.

The technical efficiency ratings were derived from the MLE (following Jondrow, et al. 1982). As hypothesized, the average technical efficiency rating of farmers is higher when the soil factors are introduced into the production function. This is so because farmers are subjected to different soil environment so that source of inefficiency is solely from the managerial capability of the farmer in growing the crop. On the other hand, when soil factors are not included as regressors of the frontier production function, farmers are subjected to a more stringent condition of being compared to farms with best soil environment. In such a case, inefficiency is attributed to the managerial capability of the farmer and the soil environment of his farm.

Using equations (1) and (6), source of inefficiency among the upland corn farmers in the area can be decomposed on the average as follows: 4.31 percent is due to soil condition of their farms and 50.44 percent is due to crop management. Hence, the farmers were only on the average 45.25 percent efficient in their production. These observations imply that there is some potential source of yield gain in corn production in the uplands. This is through improving the crop management of the farmers and, and to a lesser extent, improving the soil condition of the farms.

The results also show that 99.99 percent of the variation in production was due to inefficiency reasons and only 0.01 percent is attributed to random errors when soil factors are included in the production function. However, when the soil-related variables are absent, only 95.05 percent of the variation in production is explained by inefficiency reasons and 4.95 percent is due to random errors. This result implies that Case A - a model with soil factors is a better model to explain the technical efficiency as a measure of the management ability of farmers. The purpose of generating Case B model - a production function without the soil factors is to enable one to estimate the inefficiency or production losses due to soil conditions, and to determine the significant variables that influence production if farmers are compared one having the best soil and best management practices.

c. Implications of OLS and MLE (frontier) production function estimates

The focus of discussion in this part of the paper is to understand the differences in coefficients of Case A and Case B models in explaining technical efficiency of farms. The OLS regression (please refer back to Table 2) is the average production function; it reflects the production performance of the average farmers. The MLE on other hand, is the frontier production function; it represents best practice in the area.

Case A.

Labor employed both by average and best practice farmers are both significant in linear and squared terms, but with negative squared term. This means that although labor has a positive effect in linear terms, this effect maybe offset by the negative effect of the squared term. In such case, assuming other inputs are constant, there is a certain level of labor employment beyond which will lead to a decrease in production.

Seed input is another significant variable that positively influences the level of production of both the best practice and average farmers. This is significant in squared term; meaning that amount of seed input is underutilized by the farmers. Additional rate of seeding is required to increase the production level of the farmer. The higher coefficient of the OLS equation implies that all else equal, any addition to the rate of seeding will provide the ordinary farmers a higher additional output than efficient farmers. In this case, the average farmers should increase their seeding rate per hectare for better output.

The amount of inorganic fertilizer (NPK) is another significant variable that influences the production level of farmers. The result of this variable is quite interesting because it differs between the ordinary and best practice farmers, between ecozones, and between different geophysical conditions of the farms.

The OLS results show that NPK is still inadequately used by average farmers as shown by the significant positive coefficient of the squared NPK term. It can also be noted that the coefficient of interaction of $LOCD_1$ and NPK yielded significant negative results. With the assumption that $LOCD_1$ is equal to one for farm at the side of the hill or slope then this would mean that all else equal, production of farms at the said location were less responsive to NPK application relative to farms located at other slope locations. This is a clear indication that such farms may have been rendered infertile due to erosion. Eroded soils are usually acidic and hard that no amount of inorganic fertilizer such as NPK could increase its productivity. Most nutrients and elements are only available to the plant when the soil pH is more or less neutral and the soil structure must be loamy to favor good rooting system for the plant.

Another observation with the OLS is the positive and significant coefficient of the interaction term between NPK and ecozone dummy. This result explains that farms in the "Kamaisan" area are more responsive to NPK than farms in the "Kasagbutan" area. This means that additional application of NPK in the said area will result to higher yields as compared to the "Kasagbutan" area.

The MLE coefficients describing best practice, exhibit somewhat different; this may imply that best practice farms respond differently to NPK input. Unlike the average farms, best practice farms respond negatively to squared NPK term. This observation implies that efficient farms are using NPK exceedingly, such that any additional application will lead to a decrease in production. The coefficient of variety dummy and NPK interaction term is also significant but positive. With our assumption that variety dummy has a value of one for hybrid corn, then the result implies that hybrid corn is more responsive to NPK than open-pollinated varieties. This result is consistent with the common knowledge that hybrid corn needs more NPK fertilizer to realize good levels of production.

The other significant variable coefficient in the MLE is the negative interaction of manure and NPK. This indicates that the two inputs are substitutes. The MLE coefficient of the interaction term of the SLD_2 and NPK is negative and significant. The value of SLD_2 is assumed to be one for farm with high slopes, so that the negative coefficient would mean that these farms are less responsive to NPK compared to farms with mixed slopes and farms which are flat or slightly sloping. This is an indication that steep-sloped farms have depleted nutrients in the soils and that additional application of NPK will no longer lead to increased productivity. It was previously mentioned that eroded soils are hard, acidic and depleted of other nutrients/elements (aside from NPK) needed by the plant.

Similarly, the $LOCD_1$ and NPK interaction term in the MLE had significant and negative results which is the same result obtained in the OLS equation. $LOCD_1$ was assumed to be equal to one for farm at the side of the hill so that with the same explanation as above these farms are relatively less responsive to NPK than those found in other slope location. As also found in the average farms results, the best practice farms in "Kamaisan" area were more responsive to NPK than in the "Kasagbutan" area.

Manure is another significant input among the best practice farmers, but measured in the squared term of the MLE, and was not found to be significant in the OLS. The positive squared term coefficient implies that even best farmers may still need more of organic source of fertilizer to increase their production. Although the "Kamaisan" area was less responsive to manure, it is conventional wisdom in the upland areas that manure is a superior source of fertilizer and a good soil conditioner.

Results of the MLE also show that SLD_1, $LOCD_3$, and ecozone dummy are significant for best practice farms while SF dummy and soil conservation index (Scindex) are significant for both best practice and average farms. The positive coefficient of the SLD_1 implies that farms belonging to this characteristic were more productive than those with mixed and steep slopes. Meanwhile, the negative and significant coefficient of $LOCD_3$ means a lesser productive farm and these are the farms with slope location at the top and shoulder of a hill. Soils on these locations are more infertile and acidic relative to the soil in the base and side slopes.

The ecozone dummy also had significant but negative coefficient. Corn farms in "Kamaisan" are less productive compared to the "Kasagbutan" area. This observation is consistent with the findings of Rola and Tagarino (1996), where they found that that hybrid corn performed better in the "Kasagbutan" area. Furthermore, the "Kamaisan" area is characterized as continuously growing corn while the Kasagbutan" is composed of farms shifting from corn to vegetable and vice versa. According to reports of farmers, corn perform better if grown alternately with vegetable. They perceive this to be due to the availability of fertilizer residue from the vegetable crop. These farmer perceptions could possibly explain the above finding. Besides, the soil and type of climate also differ in the two ecozones. Eighty-nine percent (89%) of the farmers in the "Kamaisan" area reported that their soil was infertile or acidic while only 63 percent of the farmers in "Kasagbutan" area reported the same.

The soil conservation index (Scindex) exhibited positive and significant coefficient as expected. Farms with more conservation measures or have better conservation measures and adopted some conservation technique for a longer period of time are more productive.

Farmers' perception about the fertility condition of his farm was also a significant variable. The negative coefficient implies that farms perceived to have poor and infertile soil are less productive than those fertile ones. This is an evidence that farmers were aware of the soil condition of their farms.

The year dummies showed that production performance of best farmers in 1994 was relatively lower compared to 1999 production. Production performance in 1998, however, was not significantly different from 1999 production. Results likewise showed that best practice farmers had better production in 1995 and 1996 relative to 1999.

Case B.

If we subject farmers to the best soil condition in the area, the OLS and MLE results would be different from that of Case A (please refer back to Table 2). In the case of labor variable, the Case B is similar to the Case A result.

Seed and fertilizer NPK are significant and positive in squared term. In this case, production can still be increased through more use of NPK, as well as increasing the seeding rate per hectare. A caution must be observed, however. The coefficient of NPK and manure interaction term is significant and negative which means that manure can be a substitute to inorganic NPK. To make production more responsive to NPK, then lime must also be applied as shown by the significant and positive coefficient of NPK and lime interaction term. It can be noted that lime alone will yield negative effects in production. This is to be expected as lime alone without the other necessary elements is useless. The role of lime is to check the soil pH or acidity. Most nutrients and elements needed by the plant are only available for use when the soil is more or less neutral in acidity. In the absence of important macro and micro nutrients, the effect of lime to plant growth will not be realized.

A similar trend is observed for year dummies in both Case B and Case A. Production in 1994 and 1998 are significantly lower than the production in 1999. Production in 1995 and 1996 are not significantly different from 1999.

d. Determinants of technical efficiency

To determine the factors that influence technical efficiency aside from the differences in environmental conditions, the efficiency rating of individual farms using Case A model (with environmental factors) of production function was further regressed with variables which are hypothesized to have some effects on technical efficiency. It can be recalled that the efficiency ratings of this model is free from soil condition effects and that the efficiency rating will solely be due to the crop management or managerial ability of the farmer. The results of the OLS regression are summarized in Table 3. The adjusted R^2 value is low but the F-value of the model is highly significant. Among the independent variables that were considered, the following had significant coefficients: average education of the farmer and his spouse, family labor force, technical knowledge, and distance of farms from the national road.

The agro-ecological knowledge of the farmer is categorized into ecological and technical knowledge. This is to determine aspects of agro-ecological knowledge that exert greater influence on technical efficiency. Results show that only the technical or crop management knowledge of the farmers had significant coefficient. Ecological knowledge had a positive but insignificant effect.

The average educational attainment of the farmer and his spouse measured as the average number years that the farmer and his wife spent in formal schooling is another important factor that influenced technical efficiency. In most studies, education has been found to explain technical efficiency (Kalirajan and Shand, 1985, Lockheed, Jamison and Lau, 1980, Phillips, 1994, among others). Such observation suggests that educational attainment of spouse and not of the farmer alone are also potential source of improving technical efficiency in corn farming. This is true because it has been observed during the interview of farmers that wives were also knowledgeable of the different farming activities and participated actively in decision-making. In fact, this led the study to use such variable instead of the educational attainment of the farmer alone as being cited in most literature.

The number of family members aside from the farmer and his wife involved as full time work force in the farm is another determinant of technical efficiency. The positive result suggests that the greater the number of family members involved in the farm activities the more efficient is the farm. This can be explained by the fact that the readily available family labor will provide the timely execution of important farm activities such as fertilization and weeding, thus, contributing to higher yields. Besides, most farmers are financially constrained and thus, the availability of family labor will ease hiring labor. This observation supports the hypothesis that access to the source and timely supply of inputs is positively related to technical efficiency.

The distance of the farm from the national road is another factor that influenced technical efficiency of farms. The coefficient of this variable is significant and negative (Table 3). This result implies that farms far from the national road are less efficient compared to farms that are near and accessible by transportation facilities. In areas like our study site, accessibility of farms to the transport facilities is quite important. High cost of input procurement will most likely deprive them of using some of the necessary farm inputs like fertilizer. In such case, farms that are remote and far from the national road will not be as privileged and as efficient compared to their counterparts that are readily accessible by transportation facilities. This is another proof of the hypothesis that access to source and timely delivery of inputs will increase technical efficiency of farms.

e. Agro-ecological knowledge of best practice and average farmers

To further analyze the relationship of agro-ecological knowledge and technical efficiency, a cross tabulation was made between the average test scores of top 20% and lowest 20% of farmers, in terms of technical efficiency rating and their technical and ecological knowledge scores. If the top 20% farmers are considered best practice and the lowest 20% as average farmers, then results in Table 4 reveal that the former had significantly better test scores than the latter. Average test scores in technical or crop management knowledge was 69.20 percent for best practice farmers while average score of average farmers was 58.80 %. There is a significant difference of 10.4 %.

In terms of ecological knowledge, the best practice farmers average a superior score of 85.78 % while the average farmers got an average score of 78.02%. The difference of 7.76% is also statistically significant. It can be noted from the results that overall average test score of farmers in ecological aspects is better than in the technical or crop management aspect of the test. This is an indication that farmers are aware of the basic ecological aspects of their farms. For instance, they seem to understand the fertility condition of their farms as was mentioned earlier. The presence of SANREM and other concerned groups had contributed to such level of awareness. This was according to farmer respondents that we interviewed. On the other hand, the inferior performance in technical or crop management aspect further means that farmers need more training and information to improve their knowledge in crop management. Different varieties would need different management strategies, and farmers have to learn these.

Likewise the knowledge test scores were cross tabulated with soil conservation index scores. Results of this analysis are consistent with expectation that farmers with high soil conservation index had significantly better ecological knowledge than those with poor conservation index (see Table 5). Average test score of farmers with high soil conservation index was 82.24% while those with low soil conservation index was 79.31%. It can be recalled from the previous discussion that farmers with better soil conservation methods are more productive. To increase the productivity of our upland corn farms, information and relevant training to improve the ecological knowledge of farmers is needed. This could then promote adoption of better conservation methods among the farmers.

IV. CONCLUSION

This paper advances the empirical work in technical efficiency analysis in two ways. First is the recognition that environmental factors affect technical efficiency ratings. Hence, analysis centered on the estimation of the magnitude of effect of these factors in technical efficiency indices. Second is the measurement of the impact of farmer’ technical and ecological knowledge on their technical efficiency scores. While results suggest that environmental factors affect TE to a lesser extent than crop management practices of farmers; the extent of technical knowledge is a significant source of inefficiency, the magnitude of which is about the same level as the formal education of the farmer and spouse.

It was also revealed by the study results that best practice farmers have higher technical and ecological knowledge than average farmers; and farmers with high soil conservation index had generally higher technical and ecological knowledge than farmers with low soil conservation index.

These results are important to consider in our aim for a sustainable corn production in fragile environments such as the uplands. The above analyses suggest that crop management technique is indeed the one major source of inefficiency in the uplands. But crop management techniques can be improved through strategic information. For instance, would farmers know the corresponding crop care for new corn varieties? Do farmers realize that the different locales along the steep slopes may need different types of soil conservation techniques and soil care? Do farmers understand balanced fertilization?

Answers to the above questions may be difficult and upland farmers may even not have the access to the sources of the new information. It is then appropriate for extension delivery services of government as well as private sector dealers of seeds and other inputs, to recognize these farmer needs. For sustainability in corn production could only be realized if farmers recognize the limits of their production environment. Such limits are obvious if farmers understand the interaction of technology and the environment. This understanding implies a high level of technical efficiency.

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Table 1. Demographic profile of sample upland corn farmers, Lantapan, Bukidnon, Philippines, 1994-1999.

Variables	Average	Percent(%)
Age	43.34 years	
Sex:		
Male		98%
Female		2%
Farmers' educational attainment	Grade VI	
Average educ. of farmer and spouse	Grade VI	
No. of years in corn farming	22.38 years	
Family labor force	1-2 persons	
Total farm area	2.93 hectares	
Area planted to corn	1.27 hectares	
Farm tenure:		
Owners and near owners		85%
Tenants and lease holders		15%
Distance of farm from nat'l. road	1,907.40 meters	
No. of observations (n)	208	

Table 2. Production function estimates of upland corn farms in Lantapan, Bukidnon, 1994-1999.

Independent Variables	Case B -Without Environmental Factors		Case A - With Environmental Factors	
	OLS	MLE	OLS	MLE
ln constant	2.7457^{**}	5.0566^{***}	2.8902^{**}	5.1831^{***}
	(1.5972)	(1.2401)	(1.1503)	(0.3448)
ln labor	1.5065^{**}	0.8314^{*}	1.1643^{*}	0.5787^{***}
	(0.7636)	(0.6047)	(0.7212)	0.1896)
ln lime	-0.4792^{**}	-0.4486^{**}	-0.1954^{ns}	-0.1401^{ns}
	(0.2311)	(0.1948)	(0.2242)	(0.1340)
1/2 $\ln^2$labor	-0.3159^{**}	-0.1590^{ns}	$-.2618^{*}$	-0.0739^{*}
	(0.1836)	(0.1476)	(0.1733)	(0.0505)
1/2 $\ln^2$seed	0.1661^{**}	0.1649^{***}	0.1434^{**}	0.0497^{***}
	(0.0769)	(0.0554)	(0.0742)	(0.0199)
1/2 $\ln^2$NPK	0.0303^{***}	0.0266^{***}	0.0269^{*}	-0.0117^{*}
	(0.0164)	(0.0075)	(0.0175)	(0.0074)
1/2 $\ln^2$ Mn	0.1180^{**}	0.1005^{**}	0.0478^{ns}	0.0393^{*}
	(0.0574)	(0.0481)	(0.0558)	(0.0262)
var x lnNPK	-0.0635^{ns}	$-.0365^{ns}$	-0.0340^{ns}	0.0723^{***}
	(0.1014)	(0.0727)	(0.0963)	(0.0309)
lnMn x lnNPK	-0.0961^{**}	-0.0846^{***}	-0.0221^{ns}	-0.0389^{**}
	(0.0425)	(0.0360)	(0.0428)	(0.0201)
lnlim x lnNPK	0.1076^{**}	0.0939^{**}	0.0376^{ns}	0.0320^{ns}
	(0.0504)	(0.0431)	(0.0493)	(0.0312)
var dummy	1.0255^{***}	0.7512^{***}	0.4555^{ns}	0.1058^{ns}

	(0.3963)	(0.2883)	(0.3842)	(0.1187)
1994 dummy	$-.5035^{**}$	-0.0432^{***}	0.1006^{ns}	$-.2223^{***}$
	(0.2458)	(0.1854)	(0.2544)	(0.0939)
1995 dummy	-0.0630^{ns}	0.1801^{ns}	0.2760^{ns}	0.2592^{**}
	(0.2279)	(0.1642)	(0.2201)	(0.1134)
1996 dummy	0.1522^{ns}	0.1865^{ns}	0.5840^{***}	0.2240^{**}
	(0.2448)	(0.1862)	(0.2450)	(0.1009)
1998 dummy	-1.1557^{***}	-0.5323^{***}	-0.8072^{***}	0.0805^{ns}
	(0.2268)	(0.1862)	(0.2244)	(0.0678)
SLD$_1$			0.2352^{NS}	0.2598^{**}
			(0.2280)	(0.1195)
LOCD$_2$			-0.2466^{*}	-0.0537^{NS}
			(0.1876)	(0.0575)
LOCD$_3$			-0.1370^{ns}	-0.4080^{***}
			(0.2121)	(0.0458)
SF			-0.2460^{*}	-0.1752^{***}
			((0.1503)	(0.0670)
Scindex			0.0968^{***}	0.0964^{***}
			(0.0166)	(0.0083)
EcoZ dummy			-0.3268^{ns}	-0.3662^{***}
			(0.2557)	(0.0537)
SLD$_2$ x lnNPK			-0.0517^{ns}	-0.0606^{**}
			(0.0667)	(0.0270)

LOCD$_1$xlnNPK			-0.1205**	-0.0563**
			(0.0600)	(0.0265)
lnNPK x EcoZ			0.1500**	0.1361***
			(0.0730)	(0.0199)
LOCD$_3$ x lnMn			-0.2063^{ns}	0.1046^{ns}
			(0.1839)	(0.0902)
EcoZ x lnMn			-0.1474*	-0.6574*
			(0.1127)	(0.0484)
σ^2	0.9902	2.0613***	0.8516	1.8840***
		(0.2545)		(0.1696)
γ		0.9505***		0.9999***
		(0.0224)		(0.0000)
log-likelihood		-257.6560		-217.2534
Ave. Tech. Eff.		45.25%		49.56%

Notes:

Dependent Variable: ln y where y = corn output in kilogram per hectare.

Level of significance: * ------- 10 %

** ------- 5%

*** ------ 1%

ns ------ not significant

Values inside the parenthesis are standard errors

Table 3. OLS estimates of the determinants of technical efficiency among upland corn farms in Lantapan, Bukidnon, 1994-1999.

Dependent Variables	Estimated Coefficients
Constant	-0.2105^{ns}
	(0.2495)
Age of the farmer	$-.00024^{ns}$
	(0.0022)
Ave. education of farmer & spouse	0.0152^{**}
	(0.0075)
Farming years	-0.0035^{ns}
	(0.0222)
Total family labor force	0.0371^{*}
	(0.0198)
Tenure dummy	0.0350^{ns}
	(0.0451)
Total farm area	0.0107^{ns}
	(0.0075)
Area planted to corn	0.0304^{ns}
	(0.0075)
Technical knowledge	0.0091^{***}
	(0.0022)
Ecological knowledge	0.0021^{ns}
	(0.0029)

Dist. of farm from nat'l. road	-0.00002**
	(0.00001)
Adjusted R^2	0.1424
F Value	4.4376***

Notes:

Dependent Variable: Technical Efficiency ratings of farms (in percent)

Level of Significance: * --------- 10%
** --------- 5%
*** -------- 1%
ns -------- not significant

Values inside the parenthesis are standard errors.

Table 4. Agro-ecological knowledge test scores of best practice and average upland corn farmers, Lantapan, Bukidnon, Philippines, 1999.

Type of Knowledge	Best Practice Farmers	Average Farmers	t-probabilities and level of significance	Overall average
technical knowledge	69.20%	58.80%	0.0040 (***)	63.14 %
ecological knowledge	85.78%	78.02%	0.0170 (**)	81.35%

Table 5. Average agro-ecological knowledge test scores of farmers with high and low soil conservation index.

Type of knowledge	Farmers with High Soil Conservation Index	Farmers with Low Soil Conservation index	t-probabilities and level of significance	Overall average
technical knowledge	63.25%	60.08%	0.1090 (n.s.)	63.14%
ecological knowledge	82.23%	79.31%	0.0680 (*)	81.35%

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