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Impacts of Climate Change on Productivity and Efficiency Paddy Farms: Empirical Evidence on Tidal Swamp Land South Kalimantan Province – Indonesia

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Abstract

The purpose of this article is to evaluate the impact of climate change on productivity and technical efficiency paddy farms in tidal swamp land. The analysis showed Impact on productivity have not good because negative. Technical efficiency analysis uses frontier production function. The analysis showed the farmers in tidal swamp land have good efficiency, with an average of 78%. The local paddy varieties production in tidal swamp lands, positively and significantly, affected by land use, fertilizer; labor and climate. The number of seeds had no significant effect. Production factor that found significantly influence the farmers technical efficiency is education. Age and farm business experience had no real effect.

Keywords: Tidal Swamp Land, Paddy Farms, Productivity, and Technical Efficiency

1. Introduction

Food agriculture sector is increasingly under pressure due to climate change due to global warming anomalies (Crosson, 1997; Finger and Schmid; 2007; Nelson, et al 2009). Indonesia national data indicate the period 1998 - 2009 average has been a drought each year in an area of 268 470 ha of agricultural land. In the same period there has been inundated with an average acreage per year 295,000 ha, which 93,800 ha experiencing puso (Irianto, 2010). If the household farmers manage rice farming in wetlands, they is easily exposed by the effects of climate change. Wetlands areas are alternative that could be developed to address the increasing need for food, population and land-uses each year. The swamp land area in Indonesia reached 39 million ha, scattered on the larger islands such as the island of Sumatra, Kalimantan; Sulawesi and Papua (MoA, 2001).

In South Kalimantan; tidal land become an important efforts to achieve the target of rice production to increase farmers' income. Farmers require adaptation in order to maintain productivity gains or avoid declining production in the era of climate change. One thing could be done is to use production factors of rice farming that can be measured by technical efficiency. The technical efficiency is one component of the overall economic efficiency (Lau and Yotopoulus, 1971). However, it can be said a new farm economically efficient if the efficiency of the technique have been achieved. Achieving high efficiency techniques is essential in order to enhance competition and farm profits, including rice farming in the tidal area.

The purpose of this article are to (a) describe the development and changes in rice production productivity due to climate change, (b) describes whether the productivity factors have been allocated in quantity dosage technically efficient and comparing the results with some previous studies.

2. Method

2.1. Theoretical Framework

Economically, productivity describes the ratio between output and input (Mohanty (1998) in Rutkauskas and Paulaviciene (2005); Samuelson and Nordhaus (1995)). Furthermore, Olaoye (1985) stated that productivity is a concept that can be viewed from two dimensions, namely the Total Factor Production (TFP) and partial productivity. Partial productivity is the average production of a production factor that measured as quotient of total production and total production factor used. Total factor productivity or multi-factor productivity index is defined as the ratio output to total factor production index (in Sayaka Otsuka, 1995).

Chamber (1988) states the total factor productivity is a measure the ability of all production factors as an integral factor in the overall production output (aggregate output). Formulation of total factor productivity can be determined by the production function approach. If the production function is defined as: Q = AF (L, K), where A is a parameter called technology index or productivity, the productivity index is formulated as (Nadiri, 1970):

$$\text{Total factor productivity index: } A = \frac{Q}{F(L,K)}, \text{ or } A = \frac{Q}{(aL+bK)} \quad (1)$$

where Q, L, and K, respectively are aggregate level of output, labor input and capital: a and b are a weight adjustment.

Increased productivity can be caused by five different relationships between input and output (Misterik, 1992; Tangen, 2005):

1. Output and input increases, but proportionately increased input smaller than increased output;
2. Output increases with the same input;
3. Output increases with reduced input;
4. Same output with reduced input;
5. Output decreases with more reduced input.

The success of a rice farming can be approximated by efficiency principle (Defourny; Lovell and N'Gho; 1990; Battese and Colli, 1992; Coelli TJ 1995). The Economic basic principle is efficiency in producing maximum output value with limited input (s), or produce a certain output or input by using the lowest possible cost. Efficiency in of economic theory terms can be viewed from two aspects, namely in the technical sense (technical efficiency) and in economic terms (price or allocative efficiency). Technical efficiency implies the achievement of the maximum output quantity that can be generated from a particular use of a number production factors. The greater output quantity produced, relative to inputs quantity used, the higher technical efficiency level achieved by input (Yotopoulus and Nugent, 1976). Technical efficiency achievement can be achieved through the physical productivity maximization of production factors.

The a farming technique efficiency has several definitions. One definition commonly used is the ratio between the production of farm observations with output (production) of production function frontier (Battese and Coelli; 1991). In econometrics, Technical Efficiency of a Farm Business, TERi, is defined as ratio the farm production average at i^{th}, ui is positive, as well as at the level of a particular input (xi) with average production ui = 0. Technical efficiency measures the extent a farmer transform inputs into outputs at level and economic and specific technological factors. This means, two farmers who use same number and type of inputs and technologies could produce different output. Most of the difference is due to diversity found in almost all life aspects. Others caused by individual characteristics and public policy factors. Ortega et al. (2002) says the factors such as extensive farming, management, demographic characteristics and producers have contributed to differences in the technical efficiency level among farmers.

Technical efficiency can be measured using frontier production function. This function describes the technical position of potential output that could be achieved by a business cropping (rice or other crops) with a number specific production factors (Lau and Yotopaulus, 1971; Battese, 1992). Rice cropping in tidal wetlands or other planting efforts did not achieve the maximum output based on existing technology level and quality inputs. The actual output quantity produced will be under frontier function. Indexes of technical efficiency is measured by comparing the planting effort between production level (output) that can actually achieved (y) with the production level (output) potential "frontier" (y1) using X input. Cropping effort to reach a perfect technical efficiency will get index of one (Battese and Tesserma, 1993; Battese, 1992; Kumbhaker, S. C & Heshmati, A.; 1995 and GE Battese and TJ Coelli, 1996).

2.2. Data and Sampling Techniques

The research was conducted at tidal wetlands agro ecosystem in Banjar district. This district selected purposively because the rice tidal land at that area was the largest in South Kalimantan. In addition, the farmers are human resources in agriculture that have hereditary managing rice farming in tidal land.

The sampling technique used is multi-stage sampling. The first phase purposively selected two districts, namely Aluh Aluh and Beruntung Baru Subdistrict. In the second stage, for each subdistrict, three villages randomly selected from all six village. Furthermore, the third stage, at each village, farmer selected as respondent using random sampling proportion. The entire sample farmers as the primary data source was 180 respondents.

2.3. Data analysis and hypothesis

Data analysis used is stochastic frontier production function analysis. Stochastic frontier model is an extension of the original deterministic models to measure the effects of unpredicted effect (stochastic effects) within the production limits. This study uses stochastic frontier production function from Cobb-Douglas (CD). In production function, factors that directly affect the quantity of products produced are dominant production factors used in the business. These factors are land, seed, fertilizer urea, inorganic fertilizers besides urea, drugs (chemicals) and labor. By entering the independent variables into the equation, then the model equation in estimating the frontier production function frontier of rice farming in the tidal area can be written as follows:

$$Ln\ Y = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 \quad +dD + v_i - u_i \tag{2}$$

where:

Y : tidal land rice production (kw)

X_1 : land area (hectares)

X_2 : seed (kg)

X_3 : fertilizer (kg)

X_4 : pesticides / drugs (lt)

X_5 : Manpower (HOK)

D : dummy, where D = 1 for land affected by climate, and D = 2 for land is not affected

β_0 : intercept

β_j : coefficient of parameter estimators, i = 1,2,3, ...

$v_i - u_i$: error term (ui) technical inefficiency effects in the model.

The expected coefficients value: β1, β2, β3, β4, β5 > 0. Significant positive coefficient means with the increasing inputs such as land, seed, fertilizer, pesticides and labor is expected to increase rice production.

Technical efficiency analysis can be measured using the following formula:

$$TE_i = \frac{Y_i}{Y_i^*} \tag{3}$$

where:

TE_i = Technical efficiency achieved at i^{th} observation

Y_i = Current rice output in milled dry rice (kg)

Y_i * = Output limit (potential) of land rice plant in milled dry rice (kg)

Where TEi is the technical efficiency of i^{th} farmers, ie $0 \leq 1 \leq TEi$. The technical efficiency value is inversely related to technical inefficiency effects value and only used for functions that have a certain number of outputs and inputs (cross section data).

Technical efficiency method in this study refer to technical inefficiency effects model developed by Battese and Coelli (1995) in Coelli (1996). Ui variables used to measure technical inefficiency effects, are assumed independent and the distribution truncated normal with N (μi, σ2).

This study used the following equation to determine the parameter distributions value (μi) of technical inefficiency effects:

$$\mu i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 \quad +w_{it} \tag{4}$$

where:

μi : technical inefficiency effects

Z1 : Farmers age (years)

Z2 : Farmer formal education (years)

Z3 : Farmer experience (years)

Coefficient expected: $\delta 0 \geq 0$, $\delta 1 > 0$, $\delta 2$, $\delta 3$, $\delta 4 < 0$

The research hypothesis is the production factors allocated by farmers in tidal wetlands rice farming are technically inefficient. Hypothesis testing is based on production function estimation with partial testing. Hypothesis testing is done with the following conditions:

H0: ki = 1

Hi: ki ≠ 1

Hypothesis testing is done via t test. If Ho is rejected, it means that the use of i^{th} production factors was not efficient.

3. Results and Discussion

3. 1. Technical Efficiency (TER) Rice Tidal

Frontier production function coefficient can be used to determine the level of total productivity / technical efficiency (TER), is measured by comparing the actual production achieved farmers with yield potential, the production estimates of frontier production function. TER values become proxy management factor in tidal rice farming. The higher TER value that can be achieved by farmers, the better management conducted by farmers in combining the production factor. TER maximum value that can be achieved by a farmer is one, which is equal to the achieved of maximum production potential, estimated by the frontier production function.

The calculation results of technical efficiency level of each sample farmers reveals that the average TER is 0.78. The highest TER value is 0996 and the lowest is 0,483. These results indicate the majority of farmers are relatively well in achieving TER. Efficiency rate 78 percent gives sense that average farmer can achieve at least 78 percent of potential output from sacrificed combination inputs. It will also mean that there is little opportunity to increase rice production in the study area.

3.2. The function of the actual rice production farming in land Tidal

Using same variables as in the frontier production function analysis can make actual production function. Actual production function consists of the production function without management variables and functions with production management variable.

Estimation regression models of Cobb Douglas function is used to determine the effect production factors usage on rice production. Production factor included in the model are land (X1), seeds (X2), urea (X3), pesticides and other drugs (X4), and labor (X5) and dummy D for climate variable. The F and R^2 values are used to look at the overall effect of the production factor to rice production level. Meanwhile, the t test is used to see the influence of each production factor. Regression analysis of rice production factor was conducted by OLS and MLE, as shown by Tables 1 and 2.

Table 1. Regression analysis of production factor on rice production using OLS

Input Variable	Parameter Estimation	Deviation Standard	t_{rasio}
Land (X_1)	0.682	0.048	14.03
Seed (X_2)	0.009	0.010	0.939
Fertilizer (X_3)	0.039	0.008	4.774
Pesticide (X_4)	0.016	0.009	1.872
Labor (X_5)	0,017	0,006	2.593
Land (X_1)	-0.236	0.066	-3.603
F_{value} = 176.82 R^2_{adj} = 0.8550			

Based on Table 1, simultaneously, the input has most significant effect on rice production ($F_{value} > F_{table}$). Coefficient (R^2) for estimation of this function is 0.8550 or 85.50%. These results indicate that the performance excellence of the production function can be used to estimate the relationship between rice production to production factor. Value of 85.50% means the production function is adequate to describe the relationship. In addition, it also means the value of the tidal rice crop production is influenced by the production factor with amounted to 85.50%, the rest is influenced by other factors than production factor incorporated into the model.

Partial regression analysis was used to see the influence of each factor on rice production. Table 1 shows the results of partial regression analysis for land, fertilizer, pesticides and labor as well as the effects of climate. T_{value} is greater than t_{table}. Therefore, H0 is rejected. In other words, partially, land, fertilizer, pesticides and labor significantly influence the rice production level. Other factors indicate t_{value} smaller than t_{table}. It was concluded the production factor is partially has significant effect on the rice production level. For pesticides and other drugs; coefficient values are negative. This implies that farmers actually must reduce the use of pesticides or chemical drugs in order can optimize rice production in tidal land. Climatic influences is illustrated from the test results.

Further analysis show the results of stochastic frontier production function estimation using five factors and a dummy variable. Estimation results illustrate best practice of farmer respondents in existing technology level. Estimation performed by the MLE model.

Table 2. Regression analysis of production factor on rice production by MLE

Variable	Parameter	Estimation Value	Standard Deviation	t-ratio
Constant	β_0	0.40369960E+01	0.45858550E+00	0.88031480E+01
Land (X_1)	β_1	0.82217909E+00	0.78677654E-01	0.10449969E+02
Seed (X_2)	β_2	0.20348054E-02	0.83820643E-02	0.24275707E+00
Fertilizer (X_3)	β_3	0.48218304E-01	0.28079498E-02	0.17172068E+02
Pesticide (X_4)	β_4	0.86844790E-02	0.11916408E-01	0.72878327E+00
Labor (X_5)	β_5	0.13266464E-01	0.56975671E-02	0.23284437E+01
Climate Dummy (X6)	B_6	-0.58709886E-01	0.13080067E+00	-0.44885003E+00

Factors that significantly influence production limit of farmers respondents is same as obtained in an average production function. This illustrates that the production function of average farmer respondents had approached the frontier production function. Production factor of seeds and fertilizer at average production function does not affect on the respondent farmers production. In the stochastic frontier production function, these factors are still not affect the production boundary (frontier) of local varieties rice farmers. Technical efficiency is analyzed using stochastic frontier production function model, using output side approach. Technical efficiency distribution model can be seen in Table 3.

Table 3. Technical efficiency distribution of farmer respondents

Technical Efficiency	Index Efficiency	
	(Total)	(%)
40-50	12	6,667
50-60	18	10,000
60-70	36	20,000
70-80	24	13,333
80-90	36	20,000
>90	54	30,000
Total	180	100
Average	0,78	
Minimum	4,83	
Maximum	9,96	

According to Lau and Yotopoulos (1971) and Farrell (1957), the efficiency index value is categorized efficient if the value is 1.0 (a). By tracing the technical efficiency distribution value per individual farmer respondents, it was found the farmers who have a 1.0 grade for technical efficiency is only 1 farmers (1.25%) and the rest

(98.75%) had a near efficient technical efficiency. Table 3 shows the average technical efficiency is 0.78.

Technical inefficiency effects model of stochastic frontier production function is used to determine the factors that affect technical efficiency level of farmer respondents. The results of the estimation of technical inefficiency effects model are presented in Table 4.

Table 4. Parameter estimation of Stochastic frontier production function technical effect

Variable	Parameter	Estimation Value	t-ratio
(Constant)	δ_0	-0,0656	-0,3231
Age	δ_1	0,0019	0,6508
Education	δ_2	-0,0134	-1,1498
Experience	δ_3	-0,0026	-1,0112

Table 4 shows the significant factors in explaining technical inefficiency in production process of the respondent farmers, at $\alpha = 5\%$, is membership in farmer groups. Until $\alpha = 10\%$ level, age, education and farm business experience of local rice varieties had no significant effect on technical inefficiency level of farmer respondents

4.Conclusions And Recommendations

4.1. Conclusion

a. The level of technical efficiency calculation for each sample farmer shows the TER average value achieved is 0.78, the highest TER value is 0.996 and the lowest was 0.48. These results indicate nearly all farmers achieve maximum TER value. 78 percent efficiency rate gives the sense that average farmer can achieve at least 99 percent of potential production combinations from production input sacrificed.
b. The use of land, fertilizer, pesticides, labor and climate have positive impact to local rice varieties production in tidal land. The number of seeds had no significant effect.
c. Technically, local varieties rice farmers in the study area is nearly efficient. Membership in farmer groups is a factor which significantly affect the farmer technical efficiency. Age, education and farm business experience do not have significant effect. At the prevailing prices of inputs level, farmers in the study area has not been efficient allocatively and economically.

4.2. Recommendations

Policies that are more focused on farm size, cultivation techniques and the use of production factor through better management can improve the technical efficiency. Management at the level "on-farm" variable is very important in determining the success of the rice-based farming systems in tidal lands, in climate anomalies era. Therefore, the training and education for farmers to encourage farmers adaptation must proceed. Extension program also become a priority for Food Security Agency. In effort to strengthen peasant household economy, the technical aspects of this research should be linked to aspects of consumption and labor allocation.

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