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Technical Efficiency of Paddy Farms in MADA Granary Area: Application of Data Envelopment Analysis (DEA)

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Abstract: *A Cross-Sectional data obtained from a sample of 397 Paddy households via Multi-Stage and Simple Random Sampling techniques was estimated by employing Output Oriented Data Envelopment Analysis (DEA). Tobit model was used to ascertain factors of technical inefficiency. Estimates revealed that Paddy growers could increase their output levels by at least 13% through the adoption of best farm practices while remaining on the same levels of inputs. Factors significantly lessening the level of technical inefficiency are; education, MR219 seed variety, broadcasting planting method and machine harvesting method. The study determined existence of opportunity for improving paddy output through adoption of best farm practices and policy consideration for the significant determinants of technical efficiency.*
Keywords: *DEA, MADA, Paddy,Technical Efficiency, Tobit Model*

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I. Introduction

Paddy farming is one of the most important activities in Malaysian Agriculture sector. Paddy (rice) is a crucial part of everyday Malaysian diet. Thus according to [1], the crop enterprise was recently identified as the most important food crop in Malaysia for ensuring the nation`s food security. After oil palm and rubber, the most significant cultured crop in the country is Paddy, occupying land area of about 684,545 ha in 2012 [2]. It is mostly cultivated in the eight major designated producing areas called Granary Areas. The granary areas which cover over 200,000 hectares of the irrigated paddy land are found in Peninsular Malaysia. The mini granary areas with irrigation facilities totally about 28,000 hectares are also found all over the country. The granary Areas, which support main-season and off-season productions, provide about 72% of the rice production in the country [3]. Historically, Malaysia has never meet self-sufficiency level with respect to paddy production the highest level achieved was 92% (Table 1) during the third Malaysian plan [4]. The Ministry of Agriculture and Agro-based Industry, in an attempt to achieve higher self-sufficiency level and food security, adopted 4th National Agricultural Policy, which is now called the National Agro-food Policy 2011-2020. This policy is targeting at making the country to attain 85% self–sufficiency level in rice production by developing large scale paddy farming in Sabah and Sarawak through private sector investment and sector modernization (Table 1).

Table 1: Paddy National Production Self-Sufficiency Level (SSL) 1966 -2010 in Malaysia

Malaysian Plan	Period	SSL Targeted (%)	SSL Achieved (%)
1st Malaysia Plan	1966-1970	na	80
2nd Malaysia Plan	1971-1975	na	87
3rd Malaysia Plan	1976-1980	90	92
NAP 1	1984-1991	65	75.9
4th Malaysia Plan	1981-1985	65	76.5
5th Malaysia Plan	1986-1990	65	75
6th Malaysia Plan	1991-1995	65	76.3
NAP 2	1992-2010	65	65
7th Malaysia Plan	1996-2000	65	71
NAP 3	1998-2010	65	71
8th Malaysia Plan	2001-2005	65	71
9th Malaysia Plan	2006-2010	65	72
National Food Security Policy	2008	80 by 2010	72
New Economic Model	2010	85 by 2020	na
National Agro-Food Policy (or NAP 4)	2011-2020	70 by 2012	na

source: [4]. na: means not available

However, overall production of rice does not satisfy the country's need, the country thus the alternative was to importing from other countries to supplementshortfall between consumption and domestic production in the country (Fig 1).

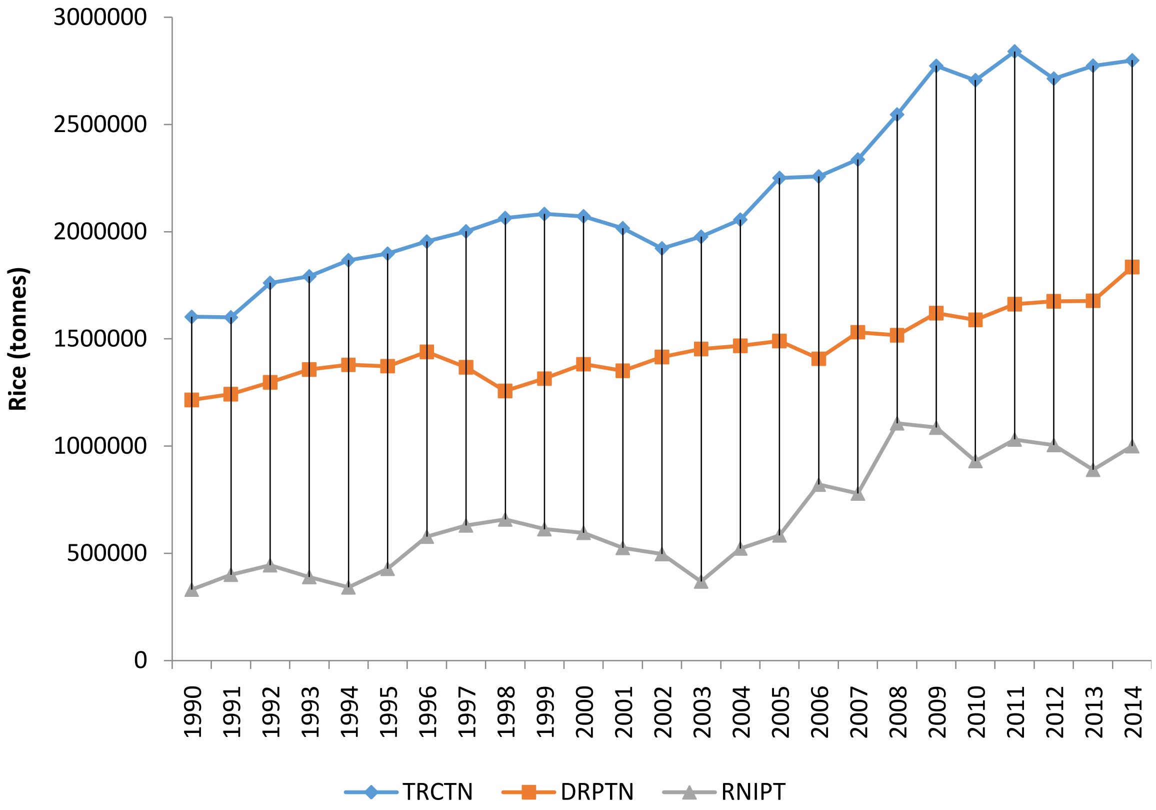

Figure 1: malaysia rice consumption, domestic production and net import, 1990-2014

Note:TRCTN (Total Rice Consumption); **DRPTN** (Domestic Rice Production); and, **RNIPT** (Rice Net Import).
Source: Time-series Data- Department of Statistics Malaysia (2015) and World Rice Statistics Online Query Facility-IRRI

Paddy farming in Malaysia is inherently operated with menace emanating from weeds, pests and diseases, inadequate supply of quality seed, extension support and intensive management practices. Others include limited opportunities for credit and the presence of technical inefficiency, which was identified by previous studies [5];[6] and [7] focusing on this sector as indispensable for sustainable paddy production. The ability of Paddy farmers to adopt new technology and achieve sustainable production depends on their level of technical efficiency, mostly determined by variable input and output quantity as well as level of fixed factors of production. Some farmers would operate optimally while others may operate on inefficient level. Determining farmer's technical efficiency and factors associated with inefficiency level and their magnitude constitute the empirical questions this study sought to answer. However, to assess the resource productivity of Paddy farmers is one of the prerequisites for increasing Paddy productivity in the study area. Therefore, the need for sustainability of Paddy production in MADA justifies this study.

II. Methodolgy

2.1 Study area

Muda Agricultural Development Authority (MADA) was the study area located in the north-west of peninsular Malaysia. MADA covers two Malaysian States that comprise Kedah and Perlis with a total area of 126,000 hectare which includes towns, forest and swamp areas. Area irrigated for paddy double cropping is 95,856 hectares of which 80.66% is located in the State of Kedah and 19.34% in the State of Perlis [8]. For easy administration MADA was divided into four regions and through the concept of area development the four regions was further divided into 27 localities (Fig 2). About 49,300 farmers are cultivating paddy in the study area either with state of sole ownership of land or renting [9]. MADA area accounts for 40% of national paddy production and 22% of paddy cultivation area in the country.

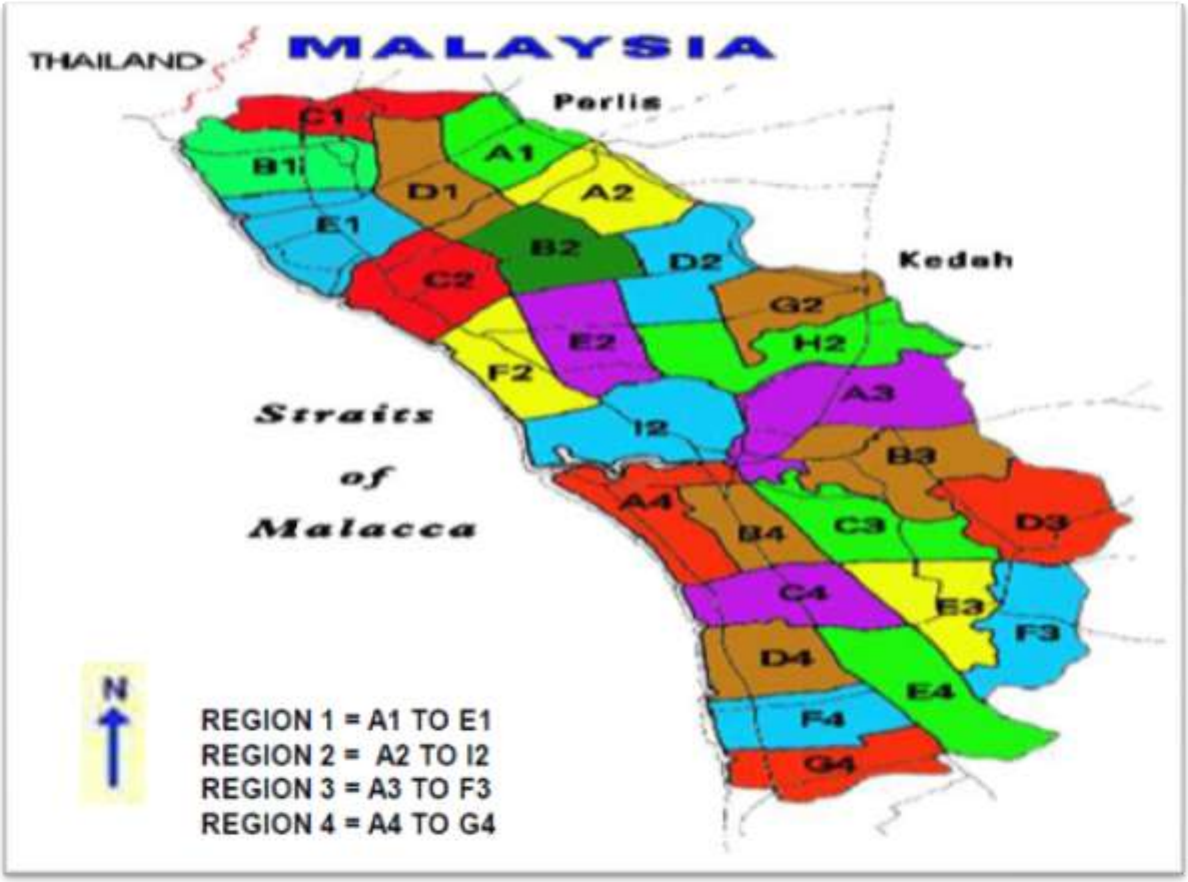

figure 2: study area source: [9]

2.2 Data collection

A structured questionnaire was used to collect primary quantitative input-output data and prices of input and output variables from a sample of 397 households. Information on socio-economic variables such as age, education, farming experience, extension contact, credit used, planting method, broadcasting method, use of high yield variety, agrochemicals and harvesting method were also collected.

2.3 Sampling Techniques and Sample size

The registers of the participating paddy farmers from MADA granary authority constituted a sampling frame. The four regions were taken as the sampling units as a first stage of sampling. At the second stage localities were randomly selected from each region to represent the region. The final stage covered random choice of paddy farmers in every locality selected making a total of 397 respondents. [10] provides a simplified formula to calculate sample sizes. Therefore, following the formula in calculating sample size as proposed by[10], this study arrived at its sample size based on the population of paddy farm households available in the study area during the period of the study. [10] formula is specified as follows:

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where n = sample size, N = population size and e = level of precision.
The sample size for Localities used was determined as:
N = 27, e = 0.05 (95% confidence interval). Therefore:
$n = 27/1+27(0.05)^2$
= 25 localities.
The total sample size of paddy farming households used was determined as:
N = 49,300, e = 0.05 (95% confidence interval). Therefore:
$n = 49{,}300/1+49{,}300(0.05)^2$

= 397 farm households in all.
The sample size for the two states (Perlis and Kedah) in the study area was also determined based on the relative concentration of paddy farms as follows:
Perlis sample size:
n = 10,383/49,300 x 397 = 84 farmers.
Kedah sample size:
n = 38,917/49,300 x 397 = 313 farmers.

2.4 Data analysis

The study employed Output Oriented Data Envelopment Analysis (DEA soft were version 2.1) to estimate technical efficiency and output/inputs slack variables and Tobit regression model to identify determinants of technical inefficiency while descriptive statistics was also used to describe the estimated results.

2.5 Theoretical framework

Data Envelopment Analysis (DEA) is an alternative non-parametric method of measuring efficiency that uses mathematical programming rather than regression. There are two efficiency measures in DEA that is input-oriented efficiency and output-oriented efficiency. According to [11], DEA constructs a piece-wise linear surface by employing least inputs of paddy farms, if input-oriented efficiency analysis is applied. On the other hand if output-oriented efficiency analysis is applied, a piece wise linear surface is constructed by focusing on the maximum outputs of paddy farms. DEA can either be Constant Return to Scale (CRS) or Variable Return to Scale (VRS). CRS implies that a proportionate change in inputs leads to an equal proportionate change in outputs while VRS implies a proportionate change in inputs leads to more than proportionate change in outputs: Increasing Return to Scale (IRS) or less than proportionate change in outputs: Decreasing Return to Scale (DRS).

Paddy farmers in the study area were found to experience variations in agricultural production occasioned by factors such as financial constraints, fluctuating inputs prices, unreliable labour supply, pest and diseases etc. Since there is no reason to assume constant return to scale (CRS) exists in the production of paddy at the farm level, the use variable return to scale (VRS) was assumed appropriate in order to account for these variations. Technical efficiency was estimated based on output-orientation where farmer produces maximum output given a level of inputs and determines the maximum proportional increase in output produced with inputs level held fixed. With DEA the performance of a farm is evaluated in terms of its ability to either decrease usage of an input or expand the output level subject to restrictions imposed by the best observed practices [12].

Solving an output-oriented equation with VRS of DEA model as developed by [13], the relative efficiency score for each DMU assuming that there were n DMUs each with m inputs and s outputs was obtained as follows:

$$\text{Max } \sum_{t=1}^{s} V_t Y_t \quad (2)$$

$$\text{Max TE} = \frac{\sum_t^s V_t Y_{tp}}{\sum_{r=1}^m U_r X_{rp}} \quad (3)$$

Subject to:

$$\frac{\sum_t^s V_t Y_{ti}}{\sum_{r=1}^m U_r X_{ri}} \leq 1 \quad (4)$$

$V_t, U_r \geq 0$ For any t, r

Where: t = 1 to s, r = 1 to m, i = 1 to n, v_t = weight given to output t, u_r = weight given to input r, Y_{ti} = amount of output t produced by farm iandx_{ri}= amount of input r used by farm i.

2.6 DEA frontier production function specification

To analyse the technical efficiency of paddy farmers in the study area, this study used output oriented DEA as designed by [14] and adopted by [15] to determine how much input mix the farmers would have to change to achieve the output level hat coincides with the best practice frontier. According to [15], DEA is a relative measure of efficiency where the general problem is given as:

$$\text{Max TE} = \frac{\sum_r^s D_r Y_{ro}}{\sum_{r=1}^m T_i X_{io}} = \frac{K}{K^*} \quad (5)$$

Subject to:

$$\frac{\sum_{r=1}^s D_r Y_{rj}}{\sum_{r=1}^m T_i X_{ij}} \leq 1 \quad (6)$$

j = 1, ... n; v_r, u_i = 0; r = 1, ...,s; i = 1,.....,m and X_{ij} and Y_{rj} respectively are the quantities of the i-th input and r-th output of the j-th farm. T_i and D_r are input and output weights individually. At maximized ratio it would not be greater than one by constraint. The variables of Data Envelopment model are described upon below:
Y_{rj} = Quantity of Paddy output obtained by j-th farmer measured in Kg/ha,X_{ij} = Inputs quantity: Seed (Kg/ha), Fertilizer (Kg/ha), Agrochemicals (Lt/ha) and Labour (Man days/ha). All DMUs with a score of 1 were regarded as being technically efficient (fully or 100% efficient), while all other DMUs with scores of less than 1 or 100% were rated as being technically inefficient.

2.7 Technical inefficiency model specification

After generating technical efficiency scores of every sampled farm by using Data Envelopment Analysis (DEA) model, analysis is continued by investigating the factors influencing technical inefficiency. To determine the effects of these factors Tobit regression model was chosen for the analysis. Following [16]specification, Tobit regression model for this study is specified as follows:

$$u_j = \beta_0 + \beta_1 Age_j + \beta_2 Edu_j + \beta_3 Mst_j + \beta_4 Hhs_j + \beta_5 Exp_j + \beta_6 Ext_j + \beta_7 Cre_j + \beta_8 Loc_j + \beta_9 Lct_j + \beta_{10} MR219_j + \beta_{11} MR220CL2_j + \beta_{12} Plt_j + \beta_{13} Bdt_j + \beta_{14} Agc_j + \beta_{15} Hvt_j + \epsilon_j (7)$$

Where$u_j$represents the inefficiency score of j-th farm obtained from equ.5 (TI = 1- TE) before running Tobit regression. β_0, $\beta_{1\text{-}15}$ are estimated parameters of inefficiency factors,$_j$represent an error term of j farm which is assumed to be independent and normally distributed. Age = Farmer`s age (year), Edu = Level of education (years), Mst = Marital status (married = 1, single =0), Hhs = Household size (number), Exp = Farming experience (year), Ext = Access to extension contact (number), Cre = Credit usage (access =1, no access = 0), Loc = Farm location (Perlis = 1, Kedah = 0), Lct = Land cultivation technology (tractor = 1, others = 0), MR219 = Improve seed variety (MR219 = 1, others = 0), MR220CL2 = Improve seed variety (MR220CL2 = 1, others = 0), Plt = Planting tech. (broadcasting = 1, transplanting = 0), Bdt = Broadcasting tech. (machine = 1, manual = 0), Agc = agrochemical use (used = 1, not used = 0) and Hvt = Harvesting tech. (machine = 1, others = 0).

III. Results

3.1 Technical Efficiency Estimates of Paddy Farmers

Result in Fig 3 reveals overall technical efficiency level in the study area and technical efficiency levels achieved by each State in the study area.

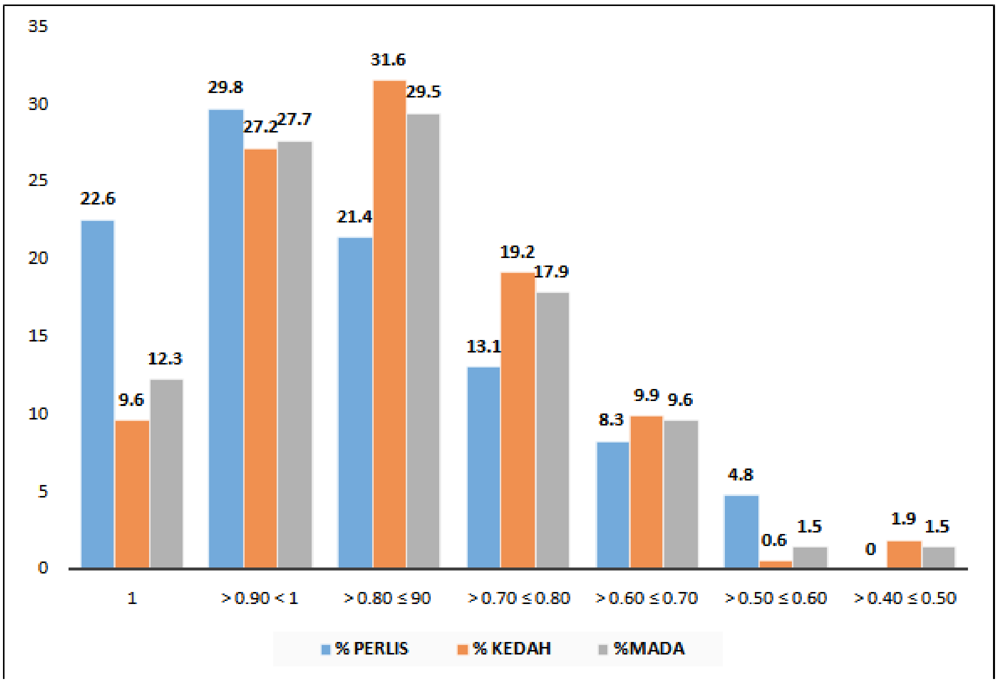

figure 3: technical efficiency distribution for states and over the study area

Note: mean, minimum, maximum and standard deviation for Perlis, Kedah and MADA are: 0.903, 0.867, 0.871, 0.638, 0.411, 0.411, 1, 1, 1 and 0.079, 0.138, 0.127.

On the overall performance the technical efficiency of the surveyed paddy farms range from 0.403 to 1. Moreover, mean technical efficiency of the study areahave been calculated to be 0.871 (87.1%). Majority of the surveyed paddy farmers (more than 87%) achieved greater than 0.70 to 1 output oriented technical efficiency out of which more than 12% were found to be at the frontier level. Furthermore, more than 12% obtained 0.403 to 0.70 output oriented technical efficiency. It was observed that Perlis State has mean technical efficiency level of 0.903 (90.3%) and Kedah State was calculated to have 0.867 (86.7%).

3.2 Parameter Estimates of Technical Inefficiency Model

The farmers` socioeconomic, institutional and technological factors were modelled and estimated using Tobit model available in Stata12 software as determinants of inefficiency to understand how these factors influence the level of inefficiency of the paddy farmers in the study area. All estimated coefficients of inefficiency model analysed were presented in Table 2.

Table 21: Tobit Regression Model Estimates for Determinants of Inefficiency Effects.

Variable	Parameter	Coefficient	Standard Error	P-Value
Constant	δ_0	0.094	0.111	0.400
Age	δ_1	0.015	0.010	0.135
Education	δ_2	- 0.010*	0.006	0.085
Marital Status	δ_3	0.084	0.125	0.500
House hold Size	δ_4	0.005	0.005	0.275
Farming Experience	δ_5	- 0.0003	0.0009	0.705
Extension Visit	δ_6	- 0.0004	0.001	0.778
Credit Access	δ_7	- 0.115	0.126	0.361
Location (State)	δ_8	- 0.139	0.105	0.185
Land Cultivation Tech.	δ_9	0.0002	0.0007	0.738
MR219 Seed Variety	δ_{10}	-0.500**	0.203	0.014
MR220CL2 Seed Var.	δ_{11}	- 0.087	0.174	0.616
Planting Tech.	δ_{12}	- 0.051**	0.022	0.021
Broadcasting Tech.	δ_{13}	- 0.008	0.020	0.741
Agrochem. Tech use	δ_{14}	0.021	0.261	0.936
Harvesting Tech.	δ_{15}	- 0.001***	0.0003	0.008

Note: *, ** and *** denote significance at 10% and 5% and 1% level respectively.

Factors of education, extension visit, credit access, farming experience, region, seed varieties (MR219 and MR220CL2), planting technology, broadcasting technology, and harvesting technology are having negative signs, implying that these factors reduces technical inefficiency as expected. Furthermore, variables of education, MR219 seed variety, planting technology and harvesting technology are the factors significantly affected technical inefficiency.

3.3 Output and Input Slacks

The primary objective of this section is to investigate the relationship between the farm output and the inputs given the assumption of a specific technology and to estimate the slack input variables in terms of their excess use in the production process. Output oriented DEA function of technical efficiency seeks a proportionate increase in its output level given its input usage while remaining on the same production frontier. Input slack which is otherwise termed as input excess is the surplus quantity of any input that can be taken away and still produce the same quantity of output while when output slack is zero means that outputs were not optimized and vice-versa.

Estimates of the DEA model generate together the radial Farrell technical efficiency scores & radial slacks to provide an accurate clue of a DEA analysis.

3.4 Output slacks

Table 3 reports State and overall output and input slacks from DEA model for the surveyed paddy farms of the study area. Result in the table shows that, the values of output are all zeros, revealing that there are no slacks in the output. This by implication means that the outputs were not optimized.

Table 3: Output and Input Slacks of the Production Model

Input/output Variable	Slacks		
	Perlis	Kedah	MADA
Output			
Paddy grains produced (kg/ha)	0	0	0
Inputs			
Seed (kg/ha)	0.324	0.511	0.748
Fertilizer (kg/ha)	1.826	3.363	3.591
Labour (Man days/ha)	0.838	1.011	1.073
Agrochemicals (Lt/ha)	0.128	0.244	0.192

3.5 Input slacks

A slack variable represents excess inputs or amount of any of the input used which could be reduced and still produce the same output. Input slacks were experienced in MADA granary area. The mean quantity of seed planted, the fertilizer used, the labour used in Man days and the agrochemicals applied in the entire paddy production process in the study area had slacks (Table 3). On the average seed, fertilizer, labour and agrochemicals had slacks of 0.748, 3.591, 1.073& 0.192 correspondingly. These understood inputs might be lessened by those units and still produce the observed output. It also indicates that these inputs were not efficiently used in the production process. On the other hand the farms were drastically unproductive in their input application by the said units. The surveyed farms were underutilizing their resources and not optimizing their outputs.

IV. Discussion

The results of technical efficiency levels of Paddy farmers in the study area appeared to correspond with those findings by [15]who realised that majority of the Poultry egg producers in Ogun State, Nigeria are comparatively technical efficient in their resources allocation, with mean technical efficiency being 87.3 percent. [17]estimated mean technical efficiency of Cotton farmers in Texas under variable returns to scale to be 88.6 percent. [18]also estimated an average technical efficiency of 72 percent for sorghum production in Adamawa State, Nigeria. However, the finding of this study seem to be dissimilar with study of [19]who estimated a mean technical efficiency of sorghum production in Zambia to be 34 percent. [20]also estimated technical efficiency of sorghum production in Borno State, Nigeria to be averaging 37 percent. Likewise [21]found the average technical efficiency of sorghum production in Kenya to be 41 percent.

The finding from the study indicates that in the study area as a whole there is potential to increase the level of output by more than 12% through the adoption of best farm practices without increasing the level of inputs. The variation in the mean technical efficiency level of the States shows that DMUs in Perlis State are more efficient (90.3% technical efficiency level) than their counterpart in Kedah State (86.7% technical efficiency level). However, the coefficient of variations between the DMUs indicates that more variation exist among the farms in Kedah (0.138) State than between the DMUs in Perlis State (0.079) which implies that more extension knowledge in the study area should be geared to Kedah State.

From the determinants of technical inefficiency, the finding is synonymous with [22]; [23]who found that high level of education increases chances of using improve and sophisticated technology and techniques. [24]also reported that years of experience reduced farmers' inefficiency. Moreover, variables of age, marital status, household size, land cultivation technology and agrochemicals have indicated positive effects to technical inefficiency. This also agrees with [25]who reported family size to have negative consequences on farmer's productivity where he said in a condition where the family size is large and only a small proportion of farm labour is derived from it, then the inefficiency effect is expected to be grater.

The presence of input slacks means that more output could be produced with the same quantity of inputs then what is being achieved. The input slacks were all positive. Positive slack by implication means that a linear combination can produce at least much of every output using no more of any input [26]; [21]. From the result agrochemicals has the least input slack which implies that agrochemicals is more efficiently utilized than other inputs while fertilizer is the most under-utilized input. However in comparism Perlis State is more efficient in inputs utilization than Kedah State and this could be the reason why Perlis DMUs is more technical efficient than Kedah DMUs. The finding is synonymous with the study of [21]where they estimated input slacks of 0.02, 0.22 and 8.85 for land, seed and labour respectively in Kenyan sorghum production.

V. Conlusions

The study was undertaken to provide an assessment of technical efficiency among the Paddy farmers. The study found that many sampled Paddy producers were technically inefficient. They were found operating on a mean technical efficiency level of 87% with some producers operating in as low as 41% technical efficiency level while only 69.5% of them were operating above 80% technical efficiency level. The study also found that Paddy farmers in the study area were not optimizing their Paddy outputs mainly due to the fact that the inputs used for Paddy production were underutilized. Fertilizer was the most underutilized resource compared with other inputs used. Finally the study concluded that, there is a great potential for enhancing Paddy production through improved efficiency of available resources. The improvement could be undertaken through taking care of significant factors that either undesirably or desirably affect the stages of technical inefficiency in the study area through policy formulation.

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APPENDIX

Tobit Model Estimates of Determinants of Technical Inefficiency effects

Dependent Variable: INEFF
Method: ML - Censored Normal (TOBIT) (Quadratic hill climbing)
Date: 08/19/15 Time: 15:21
Sample: 1 397
Included observations: 397
Left censoring (value) at zero
Convergence achieved after 4 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.094041	0.111443	0.843844	0.3988
AGE	0.014541	0.009739	1.493059	0.1354
EDU	-0.010405	0.006043	-1.721863	0.0851
MSTATUS	0.084259	0.125023	0.673949	0.5003
HHSIZE	0.005277	0.004834	1.091650	0.2750
FEXPER	-0.000334	0.000880	-0.378981	0.7047

EXTVISIT	-0.000345	0.001222	-0.281895	0.7780
CACESS	-0.114675	0.125497	-0.913769	0.3608
LOCATION	-0.139117	0.104940	-1.325685	0.1849
LCULTTECH	0.000222	0.000664	0.334696	0.7379
MR219	-0.500433	0.202775	-2.467920	0.0136
MR220CL2	-0.087363	0.174054	-0.501932	0.6157
PLTTECHN	-0.051017	0.022178	-2.300352	0.0214
BCTTECHN	-0.007453	0.020358	-0.366093	0.7143
ACHEMTECHN	0.021124	0.261360	0.080825	0.9356
HARVTECHN	-0.000813	0.000308	-2.643072	0.0082
	Error Distribution			
SCALE:C(17)	0.172448	0.006453	26.72401	0.0000
Mean dependent var	0.187150	S.D. dependent var		0.166663
S.E. of regression	0.165776	Akaike info criterion		-0.381228
Sum squared resid	10.52552	Schwarz criterion		-0.211591
Log likelihood	93.24562	Hannan-Quinn criter.		-0.314050
Avg. log likelihood	0.233114			
Left censored obs	32	Right censored obs		0
Uncensored obs	345	Total obs		397

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