EFFICIENCY OF THE AGROCHEMICAL INPUT USAGE IN THE PADDY FARMING SYSTEMS IN THE DRY ZONE OF SRI LANKA

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ABSTRACT

This paper assesses the technical efficiency of paddy production in one of the major irrigation schemes in Sri Lanka with special emphasis on the usage of agrochemical inputs and determinants of technical efficiency. The presence of technical inefficiency and its causality is investigated using a stochastic production frontier model. Data for the estimation was gathered from a farm household survey covering 225 households across five administrative units from 3 irrigation blocks for the cultivation season 2003/2004. The results of the production function show negative relationships between yield and the cost of pesticides indicating an over use of pesticides. The average technical efficiency was estimated to be 0.37. Among the determinants of inefficiency estimates considered, the importance of credit and extension services on improving efficiency of farmer stand out while the farmers come from neighbouring villages appear efficient than the farmers settled in the villages.

INTRODUCTION

The behavioral responses of the local peasantry to the high input farming package remain a researchable issue after several decades since the advent of the farming system to Sri Lanka even though it has been historically acclaimed that with adoption rates hovering around 90 percent, the Sri Lankan paddy farmer was set to reap the highest dividends of the green revolution technologies. The major issue in this regard for the agricultural economists and policy planners is to assess available means for the farmers to increase productivity under the given technology avoiding the costly and capital-intensive investments. The rural peasantry

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whether in paddy or in other field crop is essentially small-scale operators thus limiting the possibility of capital-intensive interventions. As such, the solution lies in the managerial capacity of the farmer to convert the available inputs into the highest outputs under the given technology and the efficiency of this conversion naturally depends on a wide spectrum of socio-economic variables in the context. The question remains whether the farmers are technically efficient in their resource allocation in the presence of a variety of circumstances in the rural farming.

Agricultural productivity revisited – Is technical efficiency a concern?

It is conventional wisdom in agricultural production that to achieve productivity growth, either technological innovation or the more efficient use of production technologies, or a balance of both, are required. In developing countries most new agricultural technologies have only been partially successful in improving productivity. This is often attributed, based on the seminal literature on this issue by T.W. Schultz, to a lack of ability or desire to adjust input levels by the producers resulting from the familiarity with traditional agricultural systems (Schultz's 'poor but efficient' hypothesis, 1964) or the presence of institutional constraints. These considerations suggest that, in some cases, there might exist a negative relationship between technical progress in 'conventional production technology' and realized efficiency. Whatever the exact case might be, if farmers are not efficiently using existing technology, then efforts designed to improve efficiency may be more cost-effective than introducing new technologies as a means of increasing agricultural productivity (Belbase and Grabowski 1985).

There is considerable agreement with the notion that an effective economic development strategy depends critically on promoting productivity and output growth in the agricultural sector, particularly with relation to small-scale producers. Consequently, many researchers and policymakers have focused their attention on the impact that the adoption of new technologies can have on increasing farm productivity and income (Hayami and Ruttan 1985; Schultz 1964). However, major technological gains stemming from the green revolution seem to have been largely exhausted across the developing world. This suggests that attention to productivity gains arising from a more efficient use of existing technology is justified (Bravo-Ureta and Pinheiro 1993). The presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, then empirical measures of efficiency are necessary in order to determine the magnitude of the gains that could be obtained by improving performance in agricultural production with a given technology.

The above overview holds true for the large smallholder dominated paddy sector in the developing countries. The literature on assessment of technical efficiency is replete with numerous attempts to investigate the production efficiency related to agricultural across the world. The determinance of technical efficiency is also deeply researched and the relative role played by numerous socio-economic variables has been addressed in different contexts. The efficiency measurement in rice farming has considerable literature in the developing countries. Generally, these studies estimate the single equation production frontier models using cross sectional or panel data. Stochastic frontiers are popularly estimated using maximum likelihood estimates. Most of the studies assume Cobb Douglas or Translog specifications at farm level. Apart from the production input related outcomes, the sources of efficiency differentials have been frequently highlighted. Many of the studies examine the factors behind the observation that some farmers are efficient than others and generally attribute the outcome to managerial and socio-economic variables. The managerial variables relate to the farmer's ability to choose the optimal farm input mix among seed type or rate, fertilizer and pesticide application and the selection of appropriate technology. Looking at the socio-economic picture, farm size, farmer's education, farmer's age and experience and the access to extension and credit are often highlighted in literature.

Empirical evidence on technical efficiency in agriculture

For a number of years, many technical efficiency studies focused on farm size (Kalirajan and Shand, 1985; Chavas and Aliber, 1993). The premise that farm size had a significant impact on the production efficiency did not prove to be very promising, other factors have been progressively taken into consideration. The role of formal education in efficiency and productivity has been addressed in various studies (Azhar, 1991; Yaron, Dinar and Voet, 1992). The effects of nutrition on production or productivity have been focused by Strauss (1984). Institutional environment, such as labor and credit availabilities (Bera and Kelley, 1990) have also been investigated. According to a technical efficiency study for paddy farmers in Bangladesh by Rahman (2003), there are high levels of inefficiency in modern rice cultivation. The efficiency differences are explained largely by infrastructure, soil fertility, experience, extension services, tenancy and share of non-agricultural income. A study done by Dhungana (2004) addresses the issue of technical efficiency among a sample of Nepalese paddy farmers using data envelopment analysis and report the technical efficiency of 0.24. The inefficiency differences in this case are attributed to the variations in the 'use intensities' of resources such as seed, labour, fertilisers and mechanical power. Compass, T (2002) reports that farm size and access to rural credit as the crucial variables affecting the inefficiency in paddy production in certain regions of Vietnam. However, the causality of inefficiency in paddy farming appears to be mixed and case specific depending on the circumstances surrounding the various contexts that have been researched and there is evidence to believe that there are considerable levels of inefficiency even under irrigated conditions where high yielding varieties are been cultivated.

Few studies bear evidence to the fluctuating technical efficiency behaviour in the paddy sector in Sri Lanka. A recent study carried out in the dry zone of Sri Lanka by Gunaratne and Thiruchelvam (2002) focuses the issue of productive efficiency of the input use in paddy based farming systems coming under the Irrigation systems. This study highlights that with the increase of asset base, the farmers tend to become more efficient in major irrigation schemes while this observation was not true in the case of minor irrigation systems. The mean technical efficiency for the major irrigation schemes according to this study is 79% while the mean technical efficiency for the minor tank cultivated area was revealed to be 57% suggesting that the water availability plays a significant role in improving the input use efficiency in water-scarce areas.

With increasing attention towards the improvement of paddy productivity as a means of increasing the profitability of paddy cultivation, it is evident that there are considerable gaps in research in terms of estimation of efficiency and productivity with regard to contextual evidence from major paddy farming areas in Sri Lanka. This is not to imply that there is an absolute vacuum of research evidence but rather to emphasize need for productivity analysis in varying contexts that are encountered in the paddy cultivation scenario in the country. The variability in the circumstances could be explained taking geographical or agro-ecological elements which show considerable heterogeneity across the country, however, the emphasis in this particular study is the major irrigated paddy settlements in the dry zone of Sri Lanka. These are settlements containing mainly paddy tracts and irrigated to supplement the seasonal rainfall via major irrigation schemes, rendering the capacity to cultivate paddy in two seasons for the year. Even though analysis of technical efficiency is a fairly conventional theme in agricultural productivity analysis, it could still yield useful contextual evidence as the results of this study points out.

This paper analyzes the technical efficiency in paddy production in 5 selected villages of Mahaweli system H in Sri Lanka giving attention to the factors behind the determinants of the technical efficiency. The empirical application of this study is based on a total sample of 225 farmers representing 5 villages namely *Medellawa, Mullanatuwa, Kuratiyawa, Ihala-Kalankuttiya and Weliyawa* in block 304, 308 and 309 of Mahaweli system H using the data collected during *Maha* 2003/2004 cultivation season.

METHODS

The stochastic frontier co-efficient estimates of this model (Coelli, 1995) indicate the contribution of these variables on dependent variable (i.e. yield) in response to the increment of respective variables. Positive coefficients indicate the percentage increment in yield in response to one percent increment in respective independent variable. The inefficiency estimates used in the frontier production function estimate implies the contribution of these exogenous variables on inefficient usage of inputs. Depending on the co-efficient calculated for these exogenous variables, the inferences could be drawn. Negative co-efficient of an inefficient variable implies the reduction of inefficiency with the presence of the respective exogenous variable.

In this particular study the parameters of the production were selected based on their empirical validity and relative significance in the cropping system. They are namely; land extent measured by acres, cost on pesticides as the total cost per season by the household, fertilizer and machinery and labour quantified in a similar manner. The role of agrochemicals is emphasised as a critical variable in the production function given the fact that it has long been associated closely with the improvement of yields, especially after the adoption of green revolution farming package. The effectiveness of external agrochemical inputs in the farming model in terms of yield increase, economic viability and with regard to the environmental sustainability has long being debated and various attempts have been made to establish scientific relationships of reliable nature. The stochastic frontier model considers both inefficiency and random disturbances as reasons for production being not at the frontier. In estimating technical efficiencies with relation to paddy production, the data collected can be categorized into yield data, material cost items involved in paddy production such as fertilizer, pesticides and other exogenous variables that accounts for efficient use of inputs such as education level, age, exposure to extension services; credit bound relationships, type of land ownership etc. Technical efficiencies with respect to the selected villages are also analyzed using the stochastic frontier model based on the disaggregated data from each village.

Stochastic parametric frontier model

The stochastic parametric frontier model was first proposed by Aigner et al. (1977) and Meeusen and Ven den Broeck (1977) and a recent development of the parametric stochastic frontier approach (Coelli, 1995) is used to estimate efficiencies in production of paddy. The proposed model is as follows;

$Y_i = X_i \beta + \varepsilon_i$, Y_i refers to the output obtained by farm i, X_i is the vector of different inputs used and β is a vector of parameters to be estimated. The error term ε_i, includes two components in which one accounts for random effects (V_i) and other captures technical inefficiency (U_i). The error component Vi are assumed to be independently distributed as N $(0, \sigma^2 V)$, whereas this V_i captures the random variations in production due to factors such as random errors, errors in the observation and measuring of data. The error components Ui are non negative random variables ($U_i \leq 0$) which are assumed in capturing technical inefficiency.

The parameter γ, which replaces σ_v^2 and σ_u^2 with σ^2

So that $\sigma^2 = \sigma_v^2 + \sigma_u^2$

Thus, $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^{2)}$

The parameter γ, must lie between 0 and 1 and if the γ equals zero, the difference between farmers yield and efficient yield is entirely due to statistical noise. On the other hand γ=1 indicate the difference is entirely due to less than efficient use of technology (Coelli, 1995).

The model that will be used in the analysis is as follows.

$Y_{it} = \beta X_i + Z_i + \varepsilon_i$

$\varepsilon_{it} = V_{it} - U_i$

Y_{it} = Production of the i^{th} farmer

X_{it} = Inputs of the i^{th} farmer

β = Co-efficients of the above independent variables

ε_{it} = Composite error term

U_i represents the factors specific to farmers which contributed for their inefficiency of production.

Cost of pesticides[5], fertilizer, labour, machinery and the extent of land are considered as independent variables and inefficiency variable analysis was done using the two step procedure in which it first estimate relative efficiencies and then effects of exogenous variables on efficiency. The inefficiency variables considered in this analysis are the age of the farmer, education level, sole dependency on agriculture as the income generating source, access to extension services, credit bound/ mortgaged relationships, land ownership and type of settlement. Other than age of the farmer and education level, all the other inefficiency variables were considered as dummy variables in the analysis.

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[5] The term pesticides includes weedicides, insecticides and fungicides

DATA

The data was collected under the ongoing project 'Managing Agrochemicals in Multiuse Aquatic Systems' (MAMAS). The enumeration was carried out in five villages namely *Kuratiyawa, Ihala-Kalankuttiya, Medellawa, Mullanatuwa and Weliyawa* in the 'Mahaweli' System H (located in Irrigation Blocks 304, 308, and 309 which are served by the Left Bank Main Channel of the *KalaWewa* reservoir. A total sample of 225 farmers was randomly selected from the five villages. This sample approximates to 30% of the total village population. The sample distribution is as follows.

Table 1: Sample representation in the study site

Village	Population of farm households	Studied Sample
Kuratiyawa	221	67
Ihala Kalankuttiya	96	31
Medellawa	183	50
Mullanatuwa	148	43
Weliyawa	104	34
Total	752	225

RESULTS AND DISCUSSION

Descriptive analysis

Since this is a settlement area, a large variation of land holdings was not observed. This is mainly the allocation of 2.5 ac of lowland and 0.5 ac of highland. However the cultivation extents varied based on the seasonality of rainfall. During times of water scarcity, the farmers follow a traditional land sharing system named "*Bethma*", inherited for generations in order to share the arable, irrigable land which is closer to the water source. Practice of cultivation requires farmers to shift to the plots to which water was distributed in that particular season.

Even though the 'Maha' Season is the main paddy cultivation season year in the dry zone of Sri Lanka, the drought conditions in the particular season when the research was carried out lead to deviation from the expected outcomes in terms of yield and productivity.

The study focused on farmers who cultivated paddy extensively as the first income generating source. The considered yield includes harvest that is being sold, kept for farm use such as seed paddy and the portion reserved for home consumption. The results revealed an average paddy yield of 1213.52 kg/ac which is lower than the average paddy yield (1857 kg/ac) obtained by farmers in Anurdhapura district[6] in *Maha* 2003/2004 season (Department of Agriculture, 2004).

The labour cost component includes the total labour used for farming which is the total of family labour, exchanged labour and hired labour. Exchanged labour was quite prominent where farmers used as a strategy of reducing cost of production. As shown in table 2 labour cost was 17,124 which is higher compared to the average of *Anuradhapura* district which is Rs. 10,038 (Department of Agriculture, 2004). Average expenditure on pesticides for the Paddy production is Rs 2367.

Interestingly, farmers used a portion of their previous season harvest as seed paddy to cultivate. Therefore the expenditure on seeds was intentionally omitted from this analysis, because all most all the farmers' inclination in using seed paddy produced in their fields, hence no cost was associated with obtaining seed paddy.

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[6] A paddy cultivating District located nearby to the research site

Table 2: Descriptive analysis of the paddy cultivation *Maha* 2003/2004

	Paddy Yield (Kg/ac)	**Pesticide Cost (Rs)**	**Fertilizer Cost (Rs)**	**Extent (Ac)**	**Labour Cost (Rs)**	**Machinery Cost (Rs)**
Average	1213.52	2367.96	5196.09	2.14	17124.07	5451.81
Std. Deviation	1045.67	1949.25	4628.42	0.99	9912.13	3762.12

Estimates for parameters of stochastic frontier production function

Maximum likelihood estimates of the stochastic frontier are presented in table 4 and 5. As shown in table 4, the extent cultivated, fertilizer cost and machinery costs showed positive values of 0.68, 0.01 and 0.01 respectively. Costs associated with pesticides and labour showed negative values of 0.1 and 0.001 respectively. Costs on fertilizer and costs on pesticides were only parameters which were significant at 5 percent level. Negative value for the co-efficient of pesticide as an input implies, as result of one percent increment on cost of pesticides would result in reduction of paddy yield by 0.1 percent. This can be explained by the interesting observation of overuse of pesticides by the farmers in anticipation of the risk of crop losses due to pests, a common practice by the paddy farmers throughout the Dry Zone.

Table 4: Maximum likelihood estimates for *Maha* 2003/2004 season

Variables	**Parameter description**	**Co-efficient**	**Standard-error**	**t-Ratio**
Bo	Intercept	8.95**	0.55	16.16
β_1	Extent	0.68**	0.034	19.59
β_2	Pesticide Cost	- 0.1**	0.031	3.45
β_3	Fertilizer Cost	0.01**	0.004	2.66
β_4	Labor Cost	- 0.001	0.007	- 0.2
β_5	Machinery Cost	0.01	0.048	0.25

* Significant at 5% probability level ** Significant at 10% probability level

The γ parameter as proposed by Bateese and Corra (1977) must lie between 0 and 1. As proposed by them, the difference between farmers yield and efficient yield is entirely due to less than efficient use of technology since the γ value of the frontier is 0.99.

Table 5: Inefficiency estimates for *Maha* 2003/2004 season

Variables	Parameter description	Co-efficient	Standard-error	t-Ratio
δ_1	Education Level (D1=1 Upto??? Primary education, D1=0 otherwise	- 0.067	.0226	- 0.29
δ_2	Age of Farmers	- 0.007	0.016	-0.46
δ_3	Farming is the only Income Generation Activity (D2=1 Yes D2=0 Otherwise)	0.78	0.721	1.09
δ_4	Credit Bound or not (D3=1 Credit bound, D3=0 Otherwise)	- 2.1**	0.741	-2.83
δ_5	Mortgaged or not (D4=1 Yes, D4=0 Otherwise)	- 1.43*	0.755	-1.9
δ_6	Extension Services Available (D5=1 Yes, D5=0 Otherwise)	- 2.65**	0.814	-3.25
δ_7	Settler/non settler (D6=1 Settler, D6=0 Otherwise)	0.62*	0.344	1.8
δ_8	Land Ownership (D7=1 Owned, D7=0 Otherwise)	1.02**	0.340	2.99

Table 6: Model estimates for *Maha* 2003/2004 season

	Co-efficient	Standard-error	t-Ratio
σ^2	6.327	0.956	6.613
γ	0.999	0.371	0.268 E+08

* Significant at 5% probability level
** Significant at 10% probability level

Variation of technical efficiency

All the farmers in the sample are categorized in the Figure 2 based on the technical efficiency categories and the lowest decile dominates the distribution with above 35 percent of the farmers displaying technical efficiency values less than 10 percent. This outcome, however, deviates greatly from the usual farmer behavior for the considered cultivating season due to the heavy yield losses encountered as a result of drought conditions. Still for all the other categories, the classification display significant variation with farmers distributed in more or less equally among all technical efficiency categories. This result again reinforces the empirical evidence from most developing country paddy cultivating environments where considerable variation of technical efficiency can be observed among farmers in a given region.

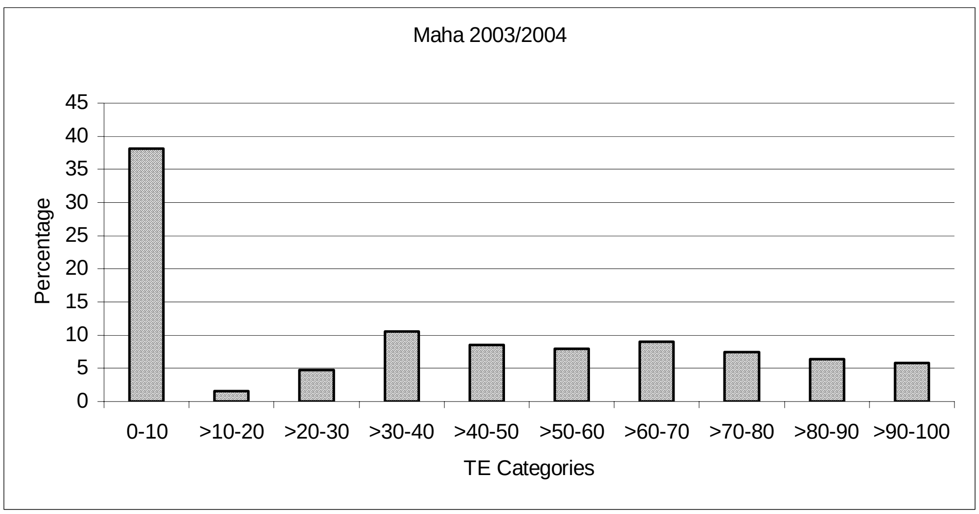

Figure 2: Summary estimates of technical efficiency in *Maha* 2003/ 2004 season

The inefficiency effects in this particular instance reinforce other empirical evidence from the developing country agriculture. The positive roles of credit and extension services emerge as significant factors behind the technical efficiency of the farmers. The education and age of the farmer remains insignificant even though the direction of the coefficients is in accordance with the past literature on the behavior of these variables. Interestingly, the issue of differentiation of the household income generation fails to produce a significant outcome. The ability to mortgage appear to be a positive factor in improving the efficiency of the farmers and this result can be explained by the close association of mortgaging with the raising of required capital for farm expenses.

The most striking outcomes that can be highlighted in this particular case study are the impact of land ownership and the issue of being a settled member of the irrigation scheme. Since the initial distribution of farm lands to farmers few decades back, the composition of the peasantry has undergone conspicuous change. The more successful farmers have diversified their farms and acquired land from the not-so-successful farmers on informal agreements given the fact that the most of the land titled under major irrigation schemes are non-tradable by law. In this particular site, it was observed that successful farmers from surrounding areas have come to farm on the land within the site, and as such the farmers in these instances have been both non-settlers and non-owners of the land plots considered. These 'outside' farmers have the added incentive to cultivate efficiently since paddy farming in their eyes is an enterprise undertaken to generate profit or surpluses.

Estimation of Separate Technical efficiencies for individual villages

Data were analyzed separately for the villages to obtain an idea about the technical efficiency differences among farmers in different villages within the research site. It should be noted that using data for each village the model was estimated separately in addition to the above analysis, which was conducted on the pooled sample, the aim being to assess the individual village performances in terms of mean technical efficiency values. The farmers in *Kuratiyawa* showed the highest mean technical efficiency (66.4) compared to other villages. This higher efficiency could largely be attributed to the presence of an irrigation tank within this village buffering the drought impact during the cultivation. The capacity of the village tanks in the cascade system could be crucial towards the success of paddy cultivation in a given village especially during seasons of water scarcity. *Ihala-Kalankuttiya* and *Mullanatuwa* showed a technical efficiency value closer to 50 percent (see figure 3). Results showed a lower mean technical efficiency in production of paddy by the farmers in *Medellaw,* the village which was greatly affected by the drought conditions prevailing owing to its disadvantageous location within the cascade system. It was observed that highest percentage (44.5 percent) of farmers in *Kuratiyawa* village belongs to high (more than 80) technical efficiency group. It should be noted that overall technical efficiency of the total sample was significantly affected by the greater farmer population in *Kuratiyawa.*

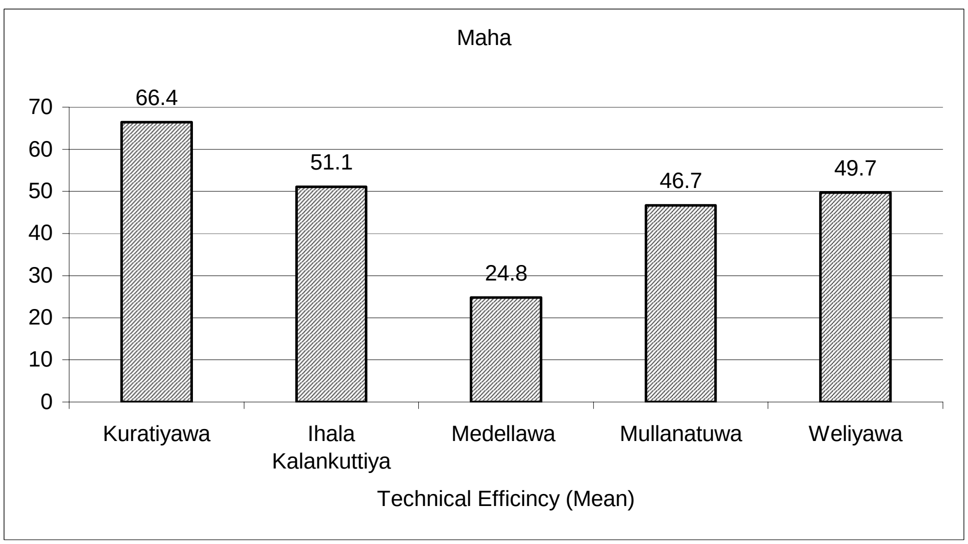

Figure 3: Mean technical efficiencies in *Maha* 2003/2004 season

The disaggregated analysis for the individual villages elicit certain important considerations with regard to the reliability of pooling the even slightly heterogeneous circumstances in the stochastic frontier analysis, especially with regard to agricultural productivity analysis. In this instance, with village separation the frontier performance display considerable disparity which obviously gets overshadowed by the frontier performance in the pooled analysis.

A further remark warrants attention at this juncture in terms of the ‘differential’ response to a common drought impact by the adjoining villages as well as by the farmers in each village as evident from the mean technical efficiency results for the villages. Can this be attributed to the differential entrepreneurial capacity or the managerial ability of the farmers to avert external shocks. These characteristics in farmers certainly play a crucial role in their response to unforeseen circumstances which could be very disastrous as it is n the case of droughts. The underlying observation, however, is the vast heterogeneity of behavioural reactions by the farmers in the considered context , an element which is obscured by the apparent uniformity in paddy farming environment. It is quite just to add that any remedial measure to improve the circumstances of the farming livelihoods and productivity should take this aspect into consideration in order to be pragmatically valid.

CONCLUSIONS AND POLICY IMPLICATIONS

According to the analysis, the mean technical efficiency between the five villages selected is 0.37. It is important to consider this technical efficiency value with respect to the drought impacts experienced by the farmers in the site. Even after taking into account unexpected drought impact, the variation of technical efficiency across the farmer population and the production function and inefficiency parameter results highlight certain conspicuous elements in the considered farming environment. The overuse of agrochemicals mainly pesticides emerge from the production function estimates. As expected exposure to extension services also showed a negative co-efficient implying the role of extension services in improving efficiency in farming. The neglect of the government extension series lately seems to have had considerable impact on the farm behaviour according to the above results. The need for viable alternatives to the fill the vacuum created needs greater policy attention. The positive role of credit access as a beneficial element towards improving technical efficiency holds true for this analysis reinforcing numerous findings to this effect from various farming contexts in developing countries.

A remarkable behavioural element of entrepreneurial land acquisition by successful farmers from outside the village gets highlighted in the results pertaining to the determinance of inefficiency. These farmers who acquire lands from unsuccessful farmers on informal agreements display higher technical efficiency and prove the case for liberalizing the user rights of paddy lands in the dry zone in favour of a more efficient production climate by successful farmers. In other words, the ownership and settlement right proves a disincentive to the efficient performance of paddy production.

The context of the study plays an important role since the measurement of efficiency could fundamentally be based on a spatial disaggregation or a temporal classification. Alternatively, it could be a classification based on the functional differences of a certain farming system i.e. the level of intensity in the farming system, the objective of the activity such as the commercial versus subsistence motive. The final interpretation depends heavily on the nature of the selected context and generalization based on such case specific data could be far from logical.

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