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ANALYSIS OF AGRICULTURAL FARMS TECHNICAL EFFICIENCY OF COTTON PRODUCTION IN SELECTED DISTRICTS OF SOGHD OBLAST IN TAJIKISTAN: A NON-PARAMETRIC APPROACH

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ABSTRACT
The objective of this paper is to measure technical efficiency of farms in northern Tajikistan, and to identify determinants of in/efficiency. The total sample constituted 418 randomly selected farm households from three districts. Using VRS input-oriented approach in Data Envelopment Analysis and Tobit model, the study has found out that farm indebtedness and limited access to extension services negatively influence the efficiency level of farm households. As a result, policy intervention should consider the comparative advantages of districts.

KEY WORDS
Technical efficiency, data envelopment analysis, cotton, Tajikistan.

Agriculture is a mainstay of Tajikistan's economy. The share of agricultural sector in country's GDP is 23%, employing nearly 70 per cent of labour force. According to official statistics, only 4,1 million hectares or 30 per cent of the territory is suitable for agricultural production, out of which 800,000 hectares are arable. Due to low levels of precipitation, more than 85 per cent of arable lands are dependent on irrigation.

Pre-independence period of Tajikistan witnessed, similar to other former Soviet republics, a system where big collective farms were prevailing. In post-independence period the government envisaged several policies with an aim to improve the performance of the country's agricultural sector. Predominantly, land reforms were deemed to be important in the Poverty Reduction Strategy Paper, basically via State farms reorganization in to dehkan farms (peasant farms), which in turn have had an colossal impact on all sectors of the economy, mainly agriculture.

Referring to the Agency on Statistics under the President of the Republic of Tajikistan (AoS), as of 2021, former collective and state farms have been reorganized in to 179 005 privately owned *dehkan* farms. This implies that the reforms in the sector are still ongoing.

Due to its importance in the Tajik economy in terms of its contribution to GDP, employment and exports, and considering that three quarters of the population live in rural areas, the agricultural sector will continue to play a crucial role in economic growth and development of the country in the years to come. Considering this, several policy interventions have been undertaken by the Government of Tajikistan in order to enhance the performance of crop producing farms. However, still there are unsolved problems affecting agricultural sector performance. According to the Agricultural reform Program for the period of 2012-2020, weak banking system underdeveloped structure of agricultural inputs maintenance, absence of agricultural subsidization mechanism, insufficient agricultural products marketing and improper legal and regulatory framework were the main culprits of retarded agricultural sector development. It is also worth to note that until now there is no clear mechanism for harvest insurance as well agricultural leasing, which could serve as a driving force for sector's development.

Following agricultural sector reforms in the country and with the issue of poverty reduction on the table in recent years in compliance with Government decrees, 75 thousands hectares of land were distributed amongst population for agricultural production purposes

(Decree of the President of the Republic of Tajikistan number 342, “On the issuing of 50,000 hectares of land for citizens’ personal household farms” of October 9, 1995; Decree of the President of the Republic of Tajikistan number 874, “On the issuing of 25,000 hectares of land for citizens’ personal household farms” of December 1, 1997). Although land reform appeared to be having a positive effect on production (UNECE, 2004), newly established farms are lacking any of technical assets to improve their productiveness (Caccavale, 2005). Studies suggest that low level of technology, low level of inputs and low quality seeds are major deterring factors as far as crop production in Tajikistan is concerned (UNECE, 2004).

Currently, within the Agricultural sector of the country there are number of overarching strategic documents and more than 20 sectors short and long term state programs. The main overarching document in this context deemed to be, the Agricultural reform Program of the Republic of Tajikistan for the period of 2012-2020 steering the agricultural sector reforms. It considers main sector related priorities in the previous National development strategy of Tajikistan until 2015, the National development strategy for the period of up to 2030, mid - term development program for the period of 2016-2020.

Overall, within the period of last 15 years around 42 investment projects were implemented in agricultural sector. This means, nearly 20 thousand hectares of lands were reclaimed and improved, land area under perennial crops was expanded up to 54 thousand hectares and more than 100 thousand jobs were created.

Besides, referring to abovementioned, limited access to agricultural credits is considered to be as a main and important factor. Most of the farms, farm associations and cooperatives do not have in their possession sufficient financial resources to maintain the agricultural production process, whereas access to external financing sources is limited.

Low productivity, as indicated in Caccavale (2005), is especially true for cotton production, where it needs massive inputs and it is often associated with big extensive fields. Though cotton is the dominant crop in the country’s agriculture, the share of food crops is increasing year by year. Such climatic conditions as hot dry summers in lowland and cool weather in the mountainous areas are providing favorable conditions to grow a wide range of crops. Nonetheless, irrigation systems are also poorly performing owing to several factors.

In our days, the understanding about the performance of agricultural farms is limited due to the fact that empirical studies conducted so far are insignificant. In other words, hitherto, the number of studies focusing on agricultural productivity and efficiency of cash and food crops producing farms is few. For instance, a research paper by Tashrifov (2005) sheds light on technical efficiency analysis of 34 cotton growing districts in Tajikistan, using panel data of 11 years covering the transition period 1992-2002, applying Translog Stochastic Frontier Production Function. The results of the study show that, technical efficiencies of cotton growing regions range from a minimum of 0.27 to a maximum of 1.00, with a mean efficiency being 0.814. It also demonstrates that around 68 per cent of cotton growing districts were having technical efficiency index of 0.80 and even greater.

On the other hand, a study conducted by CECI in 2006, with respect to Sughd Oblast cotton growing farms, was attempting to assess the comparison between three types of farms (large, medium and small) across seven cotton growing districts with an emphasis on technical efficiency and management related issues. Particularly, technical performances of farms with regard to cotton and non-cotton crops were examined, employing a frontier analysis. Based on the sample of 205 farms, this study reveals that factors like the proportion of cotton to total area and the manager’s knowledge have a significant impact on farm efficiency. Following on abovementioned study sample, Nkengne (2010) applied a Stochastic Frontier Production Function to estimate technical efficiency of cotton producing farms in northern Tajikistan and to define the optimal farm size, which is believed to be 53 to 56 hectares. The results of this study have discovered that the relationship between farm size and TE is more complex, meaning that the process of downsizing of the farms should be paid an appropriate attention.

Using VRS DEA Goibov et al (2010) estimated a technical efficiency of cash and food crops producing farms in three districts of Soghd oblast. An analysis of 303 randomly

selected farms revealed that on an average farms were performing at a 74 per cent efficiency level. Credit, age and gender were found to be main factors affecting farms efficiency.

In fact, the study of technical efficiency at the international level has been there since a fairly long time now. Various studies dealt with the productivity of the agricultural sector are suggesting that, taking an advantage of current scientific achievements and accordingly using factors of production, it is expected that efficiency could be increased by 2.5-3 times (Vakhidov et al., 2003; Umarov 2006).

Karimov (2014) in his study of factors affecting efficiency of 298 cotton producing farms in Uzbekistan, revealed that along with other factors, farmers' education, farm size, access to credit are deemed to have an impact on input use. The results of this study also suggest provision of extension services which in turn will enhance technical efficiency of farms.

A number of efficiency analyses in the Central Asian region were conducted so far. However, this study aims to fill the gap in the existing literature and contribute to the country's policy discussions which refer to resource use efficiency. The study uses DEA VRS (variables return to scale), to assess technical efficiency of farms in selected districts of Soghd oblast in finding ways to continue with the existing technology by improving the efficiency of less-efficient farms or opt for a new one.

As already discussed, one of the issues of agricultural production is whether a new technology is opted for or improving the efficiency of less-efficient farmers should be given priority given the current technology. Therefore, against the backdrop of the above-mentioned issues, the objectives of this study are to: 1) measure the technical efficiency level of farms in the study area, 2) find out if there is room to increase production and productivity by improving the technical efficiency of farms in these particular districts, 3) identify factors explaining difference in technical efficiency amongst cotton producing farms in the study area, and 4) suggest possible intervention mechanisms to bring about desired outcomes in improving the efficiency of less efficient farms.

CONCEPTUAL FRAMEWORK

As it was stated by Schultz (1964), resources are allocated efficiently in traditional agriculture, which is "poor but efficient" hypothesis. This hypothesis was further supported by Chennareddy (1967), who tested the hypothesis using production function to calculate ratio of marginal value product to marginal fertilizer cost in traditional agriculture of South India.

With the main purpose of maintaining productive efficiency of farms in mind, restructuring production organizations in East Germany and to see whether newly created ones are more efficient than former big state enterprises via application of parametric and non-parametric techniques, a study by Mathias and Swinnen (2001) found that family farms are technically efficient than collective and state farms (LSO's). On the other hand, Clayton (1980), in her study on productivity of Soviet agriculture, provides an example of input factor importance, where sum of inputs (such as land, labour, livestock, machinery, fertilizer) were around 0.97 indicating constant returns to scale.

The efficiency measurement of production of farms mainly stems from Farrell's (1957) eminent work. Within the theoretical framework, he defined for measurement of productive efficiency. He indicates that a firm or a decision making unit (DMU) is considered technically efficient if it is on best practice frontier based on minimum set of input requirements, which is also referred to as cost minimization. It is worth to note that whilst defining approaches to measure technical efficiency he was referring to non-parametric approach.

Studies carried out on measuring efficiency were categorized into two groups, namely parametric and non-parametric, advantages and drawbacks of which were discussed by Forsund et al., (1980) Later, an ample reviews of the two approaches were provided by Bjurek et al., (1990), Lovell (1993), Greene (1993), and Ali and Seiford (1993). The former approach assumes a specific functional form for the frontier, whereas later do not. The parametric, statistical approach uses econometric techniques to estimate either stochastic or deterministic frontier functions (Hollingsworth et al., 1998). However, the disadvantages of the parametric approaches are the need to assume a functional form for the frontier and on

the distribution of efficiency. Correspondingly, Coelli (1995), denoted about the two advantages of the nonparametric approach, in other words DEA. Being a deterministic, first it doesn't require an assumption of functional form for the frontier, which could bypass unnecessary restrictions about functional form that can disrupt the analysis and distort efficiency measures (Fraser and Cordina, 1999). And secondly, as per inefficiency term distribution, it doesn't require a specific assumption.

In this study, however, the technical efficiency of cash and food crops producing farms were measured using non-parametric technique, which involves Data Envelopment Analysis. Being a linear programming tool, Data Envelopment Analysis generates a boundary for the farms performing on a best-practice basis. The first DEA model was developed by Charnes, et al (1978). On one hand, there is no requirement in DEA to specify precise functional form for the analysis of a production process, due to its characteristic of being non-parametric. This adaptability property turns out DEA to be more convenient when it is not possible to ascertain the form where set of various inputs are used to have certain output beforehand. On the other hand, DEA allows managing more than one input as well as output at the same time. This is, in fact, the advantage of this particular technique to maximize virtually the input and output, thus defining the weighted sums of the input and output vectors of the crop producing farms. Further, based on the model either under CRS or VRS, DEA sets apart the technical (in) efficiency. Taking into account that in actual fact farmers in study area are not operating at an optimal scale, for example due to various land size, constraints on inputs, the CRS DEA model(Coelli, et al.,1998) could not be an appropriate tool to carry out efficiency analysis. Therefore, the VRS DEA model, which was later introduced by Banker, et al (1984) is used in our study knowing that farmers in the study area vary in their size and perform at different scales.

Following Fare,et al (1985) and Coelli, et al (1998), method of estimating a VRS DEA model can be represented as:

$$\text{Min } \theta,\lambda \ \theta$$

$$\text{Subject to: } -y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0, \text{ eq. (1)}$$

Where: θ = technical efficiency score the value of which lies between 0 and 1. The farm is assumed to be on the frontier, if the value of θ is equal to 1. This explains that the farm is fully technically efficient. N1 is Nx1 vector of weights on the vector λ, showing the linear combination of peer performers of the i-th farm. The value of θ is availed for each and every farm via solving the linear programming problem N-times. Subsequently, the scale efficiency of i-th farm could be measured, that is the ratio of CRS by VRS DEA.

The estimation of the technical efficiency scores in this study was done by using the DEAP version 2.1 (Coelli, 1996) software.

Because efficiency measures range between 0 and 1, following Maddala (1999), the two- limit Tobit model is employed to identify factors, which are assumed to affect efficiency of crop producing farms, and expressed as:

$$y_j^* = \beta_0 + \Sigma \beta_m X_{jm} + \varepsilon_j, \ \varepsilon_j \sim IN[0, \sigma^2]$$

$$\begin{cases} 1 & \text{if } y_j^* \geq 1 \\ y_j^* & \text{if } 0 < y_j^* < 1 \end{cases}$$

Where: yj* is denoted as latent variable of farm j's efficiency, Xjm as vector of explanatory variables m(m = 1,…,k) for farm j; and εj is an error term which is independently and normally distributed, with mean zero and a constant variance (σ2).

Analysis was done using STATA 15.1.

METHODS OF RESEARCH

The data used in this study were collected from the sample survey of farms located in three districts of Soghd oblast in Tajikistan. Data collection at farm level was conducted during the period February-April, 2019. Being located in Fergana valley, unlike southern part of the country, the main feature of Soghd oblast is its focus on production of cash crops, namely cotton. It is the region with around 2753100 inhabitants (in 2020), which is making 28,9 per cent of total country's population. The three districts of Soghd oblast, namely Bobojon Gafurov, Jabbor Rasulov and Spitamen amongst other 9 cotton producing districts were chosen intentionally with relatively more number of newly established dehkan farms which is continuing up today. The underlying purpose behind selecting these three districts and to conduct technical efficiency analysis is based on the statistical data on productivity (yield per hectar, etc.) obtained from the official statistics. Abovementioned was complemented with extensive discussions with key stakeholders, like key specialists from the ministry of Agriculture, districts agricultural, statistical and land committees. Secondary data obtained prior and after the survey conducted, are including all aspects of agricultural sector within these districts.

The main focus on choosing the farms located within these three districts was to represent water distribution for agricultural production, differences in land use and environmental issues. Most notably, the northern part of the country is characterized by the decreasing productivity rates of food crops production, where productivity rates for cash crops, namely cotton remains unchanged. Looking at the country statistics, though there is a little difference between country and Soghd oblast productivity rates (i.e. yield per hectare), there are big differences in productivity rates amongst districts within the northern oblast. For instance, considering cotton case in Spitamen, Jabbor Rasulov and Bobojon Gafurov districts, an average yield per hectare for cotton in 2010 were 1.65, 1.81 and 1.81 tons per hectare respectively. Similarly, in 2019 these rates have been changed to 2.26, 2.28 and 2,16 tons/ha respectively.

In order to obtain the list of farms operating in these particular locations for further sampling and selection of farms, departments of Agriculture in three districts were approached. Followed by sample selection process, questionnaires were administered to 418 farms in abovementioned districts.

Six inputs including, land, labor, fertilizer, seeds, machinery, irrigation costs and one output were used in this study. The variables having an impact on the efficiency of farms are assumed to be age, extension contact, credit access and farm indebtedness.

RESULTS AND DISCUSSION

Efficiency analysis of cash and food crops in three districts of Northern Tajikistan was done at two levels: aggregate and crop levels. Herein, an assumption was to have a picture of farms technical efficiency (TE) in specific crops production they are engaged in. This is due to consideration of the fact that some farms across these districts are or could be efficient in growing one or another crop so that one could think of comparative advantage of districts in specific crop production. At an aggregate level, an attempt was made to calculate overall technical efficiency of farms within three districts.

Amongst the five estimated coefficients, two are highly significant at $p<0.01$ and one is significant at $p<0.10$. Average operational land under cotton across surveyed farms is around 6,45 hectares. Therefore it was decided to consider land area above six hectares as an independent variable affecting technical efficiency of farms. Hence, the negative sign for the land under cotton shows that going above existing average operational land which is 6

hectares affect negatively technical efficiency of farms. The estimated coefficient for the variable indicating availability of extension services has a negative sign. This implies that the technical inefficiency of farms diminishes when extension services are availed in the study area. Owen et al (2001) in their analysis found out that farmers' access to extension services could increase the value of the agricultural output by 15 per cent. As it was pointed in a number of studies (Müller, 1974, Parikh *et al*., 1995, Kalirajan and Flinn, 1994), the result of three districts analysis shows that farm indebtedness which is a result of credits taken in previous years is likely to affect technical efficiency of crop production. This has a lot to do with the types and the timing for the input credits farmers receive. It is expected to observe such results, because due to delays in obtaining inputs, farms are not able to start planting in time.

Table 1 – Variables and definitions

Variable name	Variable description	Variable measurement
Age	Age of the household head	Measured in years
ExtCont	Extension Contact	A dummy variable having a value of "1" if farmers have extension contact at least once during the cropping season and "0" otherwise
Credit	Credit receive	A dummy variable having a value of "1" if farmers have received a credit during the cropping season and "0" otherwise
Farmindbt	Farm indebtedness	A dummy variable having a value of "1" if farms are indebted and "0" otherwise
COTAREA6	Operational area under crops, namely cotton	A dummy variable having value of '1' if crop area (land size) is above 6 hectares and '0' if less than 6 hectares

Table 2 – District Level determinants of crop production TE (N=418), Tobit model

Variables	Coefficient	St. Error	Significance
Age	-0.01328	0.0170	0.436
Extension Contact	-0.1073	0.0174	0.000
Credit	-0.0211	0.0229	0.356
Farm indebtedness	-0.0379	0.0228	0.097
Cotton area above 6 ha	-0.0564	0.0191	0.003
Constant	1.0005	0.0173	0.000

Source: Author's calculation.

During the period of 1996-2007, the prices for agricultural inputs were usually set by these marketing intermediaries unilaterally and higher than the actual retail price in the market. On the other hand, as per study conducted by Action Against Hunger in 2003 (AAH), in selected districts of southern Tajikistan, although kolkhozes/sovkhozes has been restructured in to dehkan farms, their debt have been transferred to the new farms according to their size in hectares. Farm indebtedness is mainly due to long term liabilities like input credits provided by financial(marketing) intermediaries as well as current liabilities like wage arrears, water use fees and taxes. Basically these marketing intermediaries were operating since 1996, based on the government decree (Ashurov, 2002).

With regard to variation of technical efficiency scores across districts, figure 1 given below paints an interesting picture. The average measures of the technical efficiency of the farms of three districts are 83.6, 95.9 and 85 percent for Spitamen, Jabbor Rasulov and Bobojon Gafurov districts, respectively. This implies that the average technical inefficiencies at district level stand at 16.4, 4.1 and 15 percent, respectively that, on average, farmers across three districts should reduce their input use. As can be observed from the figure and from the average efficiency scores indicated above, Jabbor Rasulov district is out-performing other districts. On the contrary, Spitamen district seem to be performing relatively poorly.

More specifically, according to the figure above, on average, nearly 76.9 percent of farms in Jabbor Rasulov were performing close to 100 per cent efficiency level. 45.7 per cent of rams in Spitamen district performing at 75-85 percent efficiency scale, against 23 percent of Bobojon Gafurov districts farmers, performing between 85 and 95 percent efficiency category. Only 24.5 percent of the Bobojon Gafurov district farms and 29.7 percent of Spitamen district farms are performing close to 100 percent efficiency level. On average, total efficiency score for three districts is 0.8715, which means farms are performing at 87

per cent efficiency scale. The results reported above for the districts are somehow confirmed with that of the efficiency measurement study conducted by CECI in 2006. It has been conducted for selected cotton growing districts of the northern Tajikistan, and the estimated technical efficiency score was 0.88 at maximum.

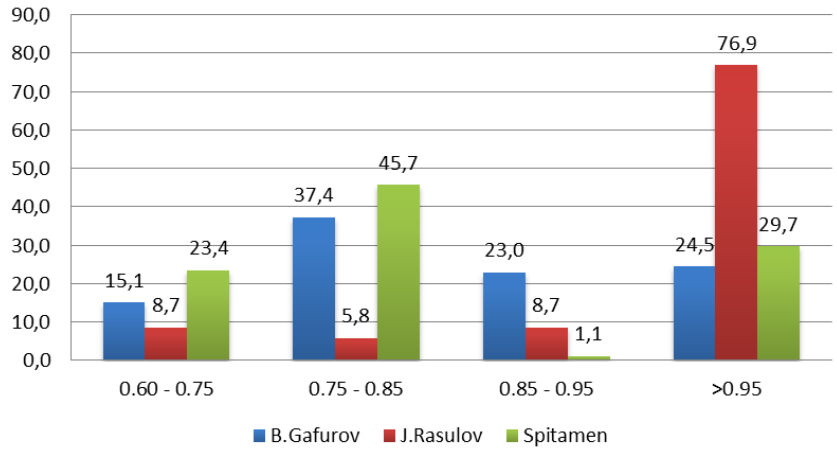

Figure 1 – District level Efficiency distribution; Source: survey data, 2019

Since the districts are differing in their efficiency levels and further back up the arguments given above as regards differences in technical efficiency scores across districts, one-way ANOVA was conducted. Results suggest that mean technical efficiency score differences amongst the three districts are indeed statistically significant (Table 3).

Table 3 – Anova results of mean technical efficiency scores across districts

n/n	N	mean	Std.dev	Minimum	Maximum
Bobojon Gafurov	139	.8506	.10392	.64	1.00
Jabbor Rasulov	104	.9590	.08999	.69	1.00
Spitamen	175	.8362	.11227	.65	1.00
Total	418	.8715	.11581	.64	1.00
n/n	Sum of squares	df	Mean of the squares	F	Significance
Between groups	1.075	2	.537	49.363	.000
Within groups	4.518	415	.011		
Total	5.592	417			

As the table given above indicates, Jabbor Rasulov is performing very well followed by Bobojon Gafurov and Spitamen, in the order of mention.

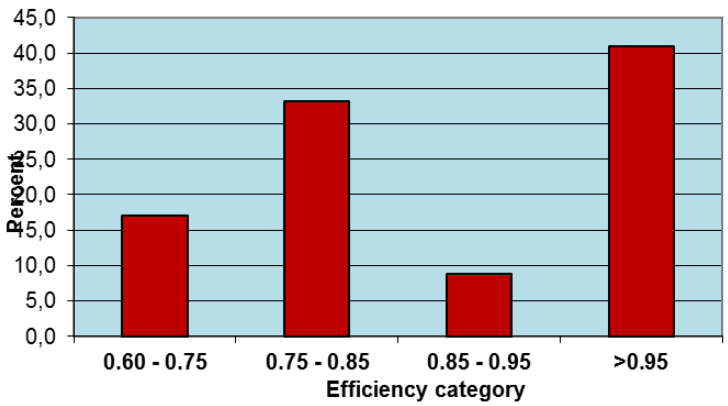

Figure 2 – Efficiency distribution of cotton production; Source: survey data, 2019

According to the results shown in table 3, comparatively to other districts, Jabbor Rasulov district is considered to be more efficient in crop production. Spitamen district, for instance, is observed to be relatively less-efficient in crop production.

Crop level results. The number of cotton producers in Spitamen, Jabbor Rasulov and Bobojon Gafurov districts are 175, 104 and 139 respectively. Thus, under VRS, the minimum efficiency rate of the cotton growing farms is 64% and the maximum is 100%. The mean efficiency is 87,1%. Average size of the land under cotton in Spitamen district is 8.35 hectares, in Jabbor Rasulov 2,95 hectares and 6,6 hectares in Bobojon Gafurov district.

The reason behind indicated operational land size is due to an ongoing land reforms where, number of farms being still reorganized into a smaller size farms. According to the Agency on Statistics, as of 2019, the share of land under cotton out of total agricultural land in Spitamen district is 30.2, in Jabbor Rasulov district 25.5 and in Bobojon Gafurov 20 per cent respectively. More than 40% of cotton growing farms covered by this study are performing above 95% efficiency level. 33,3 per cent of farms found to be efficient between the range of 75-85 per cent. Only about 17 % of the farms performance falls between 60-75%.

CONCLUSION

The purpose of this paper was to use an input-oriented DEA model to estimate technical efficiency of cotton producing farms, and second farm specific characteristics having an impact on the efficiency were estimated running a two-limit Tobit model.

Results indicate that district level farm technical efficiency scores are estimated to be 83.6, 95.9 and 85 percent, for Spitamen, Jabbor Rasulov and Bobojon Gafurov districts. This shows that there is a room to improve the efficiency levels of farms in the study area as well as in the country. Coming to crop-specific district level efficiency, Jabbor Rasulov district is reported to be the most efficient in cotton production amongst other two districts.

Inefficiencies observed at district level are mainly due to the farm indebtedness and existence of extension contacts in the area. Operational land under cotton above 6 hectares is also found to have an impact on the efficiency of farms. Age and credit received in the last financial year were not found to be significant factors in explaining efficiency in the study area.

Concerning the policy on the ground, it has to be targeted to the needs of farm specificities and peculiarities of the districts, considering comparative advantage of the districts in various crops production. Farm level extension services and maintaining appropriate access to credit facilities are the issues to be addressed.

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