Resource use efficiency inpaddy productionin the salinity affected and the unaffected areas of Alappuzha District inKerala: An Economic Analysis

Abstract

Rice is one of the foremost and principal food crops in theworld, feeding more than four billion people primarily in Asia and India stands second in the production of rice after China with highest production. Even though rice is a staple food of Kerala, it occupies less than 7.7 per cent of the total cropped area. Kerala is known for its cultivation of paddy below the sea level. Salt water intrusion is the major problem in these areas. In this context, the present study aims to examine the efficiency of resource-use in paddy production in the salinity affected and the unaffected areas of Alappuzha District in Kerala. The study was based on the primary data collected from 50 rice farmers, *viz* 25 from salt water affected and 25 from unaffected areas andCobb Douglas production function was used to estimate the resource use efficiency. The study revealed that the inputs*viz.*, hired labour, manures and fertilizers, soil ameliorants, plant protection chemicals, machine and bullock labour power had a positive and significant effect on the rice yield in both salinity affected and unaffected areas. The returns to scale worked out for unaffected and affected farmers was 2.24 and 1.31 respectively. Chow test revealed that there is a significant difference in coefficients between the factors affecting yield of paddy among the salt water affected and the unaffected farmers.Marginal productivity analysis revealed that economic efficiency of all the variables except manures and fertilizers was more than one, indicating their sub-optimum usage and there exist the chances of improving the yield by the enhancedapplication of these inputs.

Keywords: Chow test, Cobb- Douglas production function, Marginal productivity analysis, Resource use efficiency, Salinity affected paddy

1. Introduction

Rice is a major food crop cultivated inKerala occupying 7.69 per cent of the total cultivated area followed bycoconut (30.3 %) and rubber (21.8 %). The area, production, productivity of paddy in Kerala in the year 2021-22 was 1.94 lakh ha, 5.59 lakh tonnesand 2884 kg/hectare, respectively (GOK- Economic Review, 2022). The three main rice growing seasons in the state are*Virippu*/ (First crop season), which starts in April-May and extends up to September-October,*Mundakan*/(second crop season), which starts in September-October and extends up to December-January and *Puncha*/(third crop season), starts in December-January and extends up to March-April (Economic Review, 2019). Mundakan crop is the main crop in the entirestate, while Puncha crop is leading in Alappuzha district. Palakkad, Alappuzha, Thrissur and Kottayam accounted for about 79 per cent of the total area and 82 per cent of total rice production in the state.Alappuzha has a share of 18.8 per centof area under paddy cultivation and it accounts to 36,506 ha in 2021-22 (Economic Review, 2022).

The major salt water affected ecosystems in the state are Pokkali, Kuttanad, Kaipadand Kole lands (Jayan and Nithya, 2010). In the districts located near coastal tracts of Kerala such as Ernakulam, Alappuzha, Kannur and Thrissur, hydromorphic saline soils are commonly observed. Estuaries and network of backwaters operate as pathways for seawater to enter these areas and cause salinity (Swarajayalakshmi, 2003). Inefficient use of scarce resources has a negative impact on food production as well as costs, resulting in low revenue among farmers (Khatun *et al.,* 2019). It is essential to know the conditions under which a farmer carries out the production process before estimating the efficiency. The allocation of resources varies with season and weather, which may result in unstable resource use efficiency (Khanal *et al.,* 2022).With limited inputs available, farmers need to be more responsive to prices in order to achieve optimum profits.Efficiency is an important concept of production economics, especially when inputs are constrained, and the chances for the adoption of better technologies are competitive at the same time (Suresh and Reddy, 2006; Gaddi *et al.*, 2002).Studies on the economics of salinity -affected paddy were rare in India as well as abroad, hence the present study was conducted with the overall objective of assessing and comparing the efficiency of rice production in saline and non-saline areas of Alappuzha district and to proposeimprovement measures.

2. Methodology

2.1 Sampling and data collection

Alappuzha district was purposively selected for the micro level study as it is one of the majordistrict of Kerala cultivating paddy on a large area. Alappuzha stood second position with respect to area (38,623 ha), production (1,28,560 tonnes) and productivity (3041.18 kg/ha) of rice in Kerala (Economic Review, 2019). Moreover, salinity problems due to salt-water intrusion were frequently being reported from this district over the years due to its unique geographical characteristics and below Mean Sea Level (MSL) rice cultivation (MSSRF, 2007).Haripad block was purposively selected as it is one among the largest producers of rice among the 12 blocks in Alappuzha district and is facing serious threats of salt-water intrusion problems. Researches on salinity were mostly concentrated in other blocks and a research gap was felt in this area. For the present study paddy fields affected by salinity due to salt-water intrusion and unaffected from salt-water intrusion were carefully selected.Thewater salinity levels in the salt-water affected paddy fields and the unaffected fields was tested and it varied from 12.10 - 18.36 dS/m and 0.14 – 2.10 dS/m respectively (Kerala Centre for Pest Management, 2019). The method of sampling adopted was simple random sampling.The farmers in the study area werecategorised into two groups *viz.*, salt-water affected and unaffected. The farmers were selected based on the discussions with the officials of Department of Agriculture as well as *Padasekharasamithis* (paddy farmers group). Initially, a pilot study was conducted. For the main study, 25 farmers each from salinity-affected and unaffected fields were selected; thus, the total sample size of the study was 50. The data was collected throughformal interviews from February to March,2020.

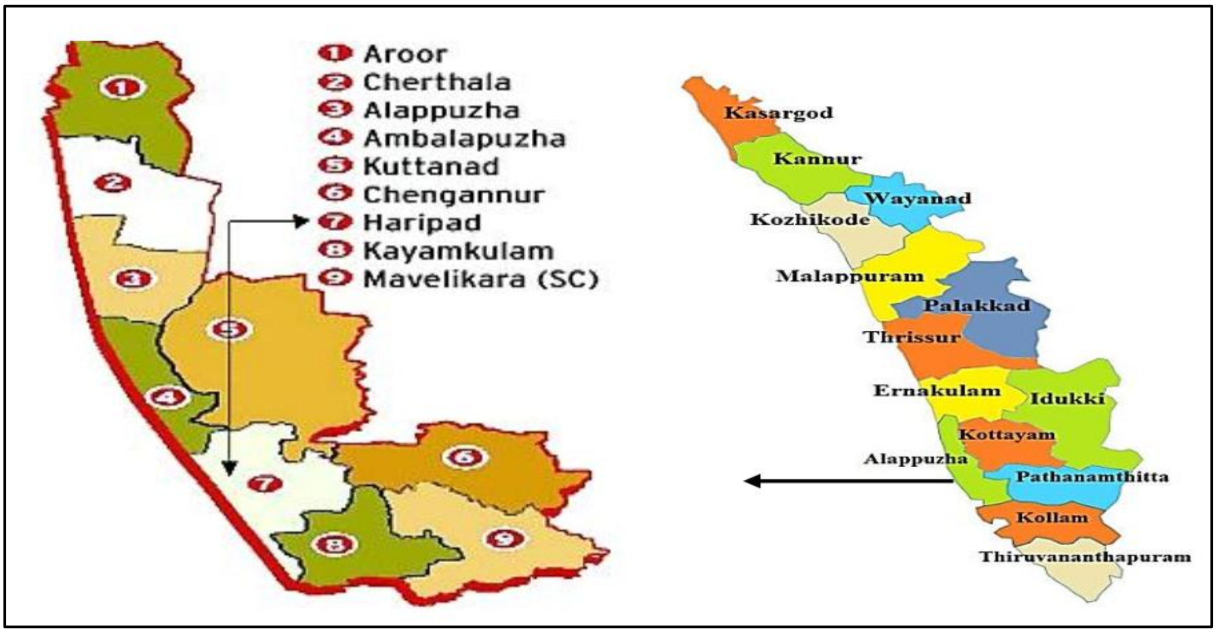

Figure.1 Political map of Alappuzha district (Source:https://alappuzha.nic.in/map-of-district/)

2.2 Production function analysis

To examine the resource use efficiency for rice cultivation, Cobb- Douglas production function was used. Efficiency studies help to explain the current performance and potential to boost the crop production to get desirable outputs (Karthik *et al.,* 2013). Among the different types of production functions, Cobb Douglas production function was chosen to examine the resource use efficiency in paddy production due to its relative advantage over other production functions(Thulasiram *et al.,* 2018).Its application in estimating the resource use efficiency in agriculturehas been proved by many researchers (Qamar, 2017; Rohith, 2018). It was used to assess how efficiently the scarce resources are allocated in the cultivation process of rice and also how various inputs and outputs produced in the selected locale are related to each other. The production function was fitted separately for paddy production ofthe salt-water affected farmers as well as forthe unaffected farmers. Physical quantities of the dependent variable and independent variables were taken for the regression analysis.Multicollinearity reduces the precision of the estimate coefficients, which in turn weakens the statistical power of regression model.Multicollinearity between the independent variables was checked by estimating the Variance Inflation Factor (VIF). Ordinary Least Squares (OLS) method was considered to estimate the factors influencing paddy production by taking production as dependent variable and the different inputs used as independent variables. The function was fitted separately for farmers from both salinity affected and non-affected areas.

Algebraic form of Cobb-Douglas production function is represented as

$$Y = a\prod_{i=1}^{6}\left(X_i^{bi}\right)e$$

Fitted Cobb-Douglas production for this study was

$$Y = a\ X_1^{b1}\ X_2^{b2}\ X_3^{b3}\ X_4^{b4}\ X_5^{b5}\ X_6^{b6}\ e$$

Above fitted function can be written in its log-log form as

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + \ln e$$

Where,

Y = Quantity of output (kg)

a = Intercept

X_1 = Hired labour (man days)

X_2 = Family labour (man days)

X_3 = Quantity of manures and fertilizers (kg)

X_4 = Quantity of soil ameliorants (kg)

X_5 = Quantity of plant protection materials (kg)

X_6 = Machine and bullock power (hours)

b_1, b_2, b_3, b_4, b_5, b_6 = Regression coefficients of corresponding independent variables.

e = base of natural logarithm

VIF < 1 indicates no multicollinearity

VIF <5 indicates presence of negligible multicollinearity(Not enough to be overly concerned about).

VIF between 5-10 indicates high multicollinearity that may be problematic.

VIF > 10 confirms that the coefficients are poorly estimated due to multicollinearity.

2.3 Chow test

A Chow test was performed to get the parameter stability of the fitted regression models. For this production functions of salt water affected farmers, unaffected farmers and pooled function were used. F* was calculated by the given equation,

$$F^* = \frac{[\sum e_p^2 - (\sum e_1^2 + \sum e_2^2)]/K}{(\sum e_1^2 + \sum e_2^2)/(n_1 + n_2 - 2K)}$$

(Koutsoyiannis,1977)

Where,

$\sum e_p^2$= Sum of square of error term of pooled regression function of salinity affected and unaffected paddy farmers with ($n_1 + n_2 - 2K$) degrees of freedom

$\sum e_1^2$ = Sum of square of error term of regression function of salinity unaffected paddy farmers with ($n_1 - K$) degrees of freedom

$\sum e_2^2$ = Sum of square of error term of regression function of salinity affected farmers with (n_2-K) degrees of freedom

n_1 = Number of salinity unaffected farmers

n_2 = Number of salinity affected farmers

K = Number of regression coefficients including constant

H_0 : There is no significant difference in regression coefficients of the production functions of salt water unaffected and affected farmers

H_1 : The regression coefficients of the production functions of salt water unaffected and affected farmers differ significantly.

Compare the observed F* with the theoretical value of $F_{0.05}$ with $v_1 = K$ and $v_2 = (n_1 + n_2 - 2K)$ degrees of freedom.

If $F^* > F_{0.05}$, we reject nullhypothesis.ie we accept that the two functions differ significantly

If $F^* < F_{0.05}$, accept null hypothesis. *ie* there is significant difference between the two functions

2.4 Marginal Productivity Analysis

The ratio between Marginal Value Product (MVP) and Marginal Factor Cost (MFC)of each individual input gives the economic efficiency of resource use.

$$MPPi = b_i \times \frac{\bar{Y}}{\bar{X}i}$$

Where,

MPPi = Marginal Physical Product

$\bar{Y}$ = Geometric mean of production.

$\bar{X}_i$ = Geometric mean of the i^{th} independent variable.

b_i = Regression coefficient of the i^{th} independent variable.

The formula used for the MVP calculation was:

MVP of Xi = P y. $b_i \times \frac{\bar{Y}}{\bar{X}i}$

Where,

Py = per unit price of paddy

Allocative efficiency (K_i) is calculated by the formula:

$Ki = \frac{MVPi}{MFCi}$

Where,

K_i = Allocative efficiency of i^{th} resource.

MVP_i = Marginal Value Product of i^{th} resource.

MFC_i = Marginal Factor Cost of i^{th} resource

3. Results and Discussion

Resource use efficiency of paddy cultivation of salt water unaffected and affected farmers along with resource use efficiency of their pooled data estimated was furnished in tables 1, 2 and 3 respectively.

3.1 Resource use efficiency in paddy production by salt water unaffected rice farmers

Urea, Factamfos and Muriate of potash were thepopular fertilizers used among the farmers.Lime and dolomite were used as soil ameliorants in order to manage the soil acidity. Estimated resource use efficiency by using Cobb- Douglas production function for the paddy production by salt water unaffected farmers was presented in table 1.

Table 1. Estimated production function of rice cultivation by salt water unaffected rice farmers (N=25)

Particulars	**Coefficients**	**Standard Error**	**P value**	**VIF**
Intercept	0.335	1.908	0.862	
Quantity of hired labour	0.563**	0.226	0.023	4.75
Quantity of family labour	0.044	0.161	0.788	1.80
Quantity of manures and fertilizers	0.594***	0.202	0.009	4.40
Quantity of soil ameliorants	0.098**	0.038	0.020	2.02
Quantity of plant protection chemicals	0.285**	0.136	0.050	2.00
Quantity of machine and bullock power	0.640***	0.150	0.000	2.80
R^2	0.90			
Adjusted R^2	0.87			
Calculated F	27.33			
$\sum bi$	2.24			
No. of observations	25			

(** Significant at 5 per cent level, *** Significant at 1 per cent level)

The estimated Cobb-Douglas model is expressed below.

$$(\ln Y) = 0.355 + 0.563(\ln X_1) + 0.044(\ln X_2) + 0.594(\ln X_3) + 0.098(\ln X_4) + 0.285(\ln X_5) + 0.640(\ln X_6)$$

The obtained R^2 value ofsalt-water unaffected farmers was 0.90, which indicates that, 90 per cent of the changes in yield was explained by quantity of hired labour, family labour, manures and fertilizers, soil ameliorants, plant protection chemicals, machine and bullock power. Among the independent variables, quantity of manures and fertilizers, machine and bullock power significantly influenced the yield of paddy at 1 per cent level of significance. One percent increase in quantity usage of manures and fertilizers, machine and bullock power were found to enhance the yield of paddy by 0.59 and 0.64 per cent, respectively. Quantity of hired labour, soil ameliorants and plant protection chemicals were found to be significant at 5 per cent level of significance with positive coefficient and it indicated the vital role of these inputs in paddy yield. Quantity of family labour in the analysis was observed to be non-significant with positive coefficient and it was mainly due to the intensive hired labour requirement for various cultivation operations in Kerala (Raj *et al.*, 2020).

3.1.1 Returns to scale

$\sum bi$ value represents the returns to scale of the production function. It was observed from the analysis that, a simultaneous increase in all the independent variables by one per cent will increase the yield of paddy by 2.24 per cent. Therefore, the function had increasing returns to scale. The VIF value for independent variables was less than 5 indicating slight multicollinearity between the selected independent variables but not enough to be overly concerned about.

3.2 Resource use efficiency in rice production by salt water affected rice farmers

Results of resource use efficiency tabulated for salt water affected farmers were presented in table 2. The estimated Cobb-Douglas model for salt water affected farmers is given below.

$$(\ln Y) = 2.860 + 0.474(\ln X_1) + 0.094(\ln X_2) + 0.258(\ln X_3) + 0.174(\ln X_4) + 0.190(\ln X_5) + 0.123(\ln X_6)$$

R^2 value obtained for the salt-water affected farmers was 0.89 with an adjusted R^2 value of 0.86. The R^2 value thus represented that 89 per cent of variation in yield was explained by the independent variables used for analysis. The quantity of hired labour, manures and fertilizers were significant at 1 per cent level with coefficients 0.474 and 0.258 respectively. Quantity of plant protection chemicals has a positive coefficient and it was significantly influencing the yield of paddy at 5 per cent level of significance. One per cent increase in use of plant protection chemicals will result in 0.19 per cent increase in yield.

Quantity of soil ameliorants, machine and bullock power was observed to be significant at 10 per cent level of significance with positive coefficients and it indicated the vital role of these inputs in paddy yield. As in the case of unaffected farmers, family labour was found to be non-significant with positive coefficient for salinity affected farmers.

3.2.1 Returns to scale

$\sum bi$ value for the production function analysis was obtained 1.31, which indicatedincreasing returns to scale. Thus, a simultaneous increase in all the independent variables by one per cent will increase the yield of paddy by 1.31 per cent in the salt-water affected area. VIF was estimated to detect multicollinearity and it was within a range of 1.24 to 2.1 indicating negligible presence ofcorrelation between the independent variables.

Table 2. Estimated production function of rice cultivation of salt water affected rice farmers (N=25)

Particulars	**Coefficients**	**Standard Error**	**P value**	**VIF**
Intercept	2.860	0.596	0.000	
Quantity of hired labour	0.474***	0.103	0.000	2.10
Quantity of family labour	0.094	0.068	0.186	1.44
Quantity of manures andfertilizers	0.258***	0.079	0.004	1.44
Quantity of soil ameliorants	0.174*	0.087	0.060	1.89
Quantity of plant protection chemicals	0.190**	0.089	0.046	1.44
Quantity of machine and bullockpower	0.123*	0.066	0.078	1.24
R^2	0.89			
Adjusted R^2	0.86			
Calculated F	25.16			
$\sum bi$	1.311			
No. of observations	25			

(* Significant at 10 per cent level, ** Significant at 5 per cent level, *** Significant at 1 per cent level)

3.3 Resource use efficiency in paddy production fromthe pooled data

The estimated Cobb-Douglas model for salt water affected farmers is given below.

$(\ln Y) = 3.404 + 0.213(\ln X_1) + 0.314(\ln X_2) + 0.271(\ln X_3) + 0.010(\ln X_4) + 0.383(\ln X_5) + 0.450(\ln X_6)$

Results of production function analysis of pooled data of the salt water affected farmers and the unaffected farmers were shown in table 3.

Table 3. Estimated production function of pooled data of rice farmers (N=50)

Particulars	Coefficients	Standard Error	P value	VIF
Intercept	3.404	0.894	0.000	
Quantity of hired labour	0.213*	0.122	0.088	1.51
Quantity of family labour	0.314***	0.111	0.007	1.26
Quantity of manures andfertilizers	0.271**	0.100	0.010	1.24
Quantity of soil ameliorants	0.010	0.032	0.763	1.61
Quantity of plant protection chemicals	0.383***	0.108	0.001	1.24
Quantity of machine and bullockpower	0.450***	0.104	0.000	1.45
R^2	0.70			
Adjusted R^2	0.66			
Calculated F	17.04			
$\sum bi$	1.64			
No. of observations	50			

(* Significant at 10 per cent level, ** Significant at 5 per cent level, *** Significant at 1 per cent level)

The R^2 value obtained 0.70 with an adjusted R^2value of 0.66 explaining that 70 per cent of variation in yield was explained by the independent variables used for the analysis. The quantity of family labour, plant protection chemicals, machine and bullock power were significant at 1 per cent level with coefficients 0.314, 0.383 and 0.450 respectively. Quantity of manures and fertilizers was significantly influencing the yield at 5 per cent level. One per cent increase in use of manures and fertilizer resulted in 0.27 per cent increase in yield of paddy. Quantity of hired labour was observed to be significant at 10 per cent level of significance with a positive coefficient 0.213. Coefficient of soil ameliorants was positive and non-significant.

3.3.1 Returns to scale

The returns to scale ($\sum bi$) for the production function analysis was found to be 1.64, which indicated an increasing returns to scale of overall paddy farmers in the area. Thus a simultaneous increase in all the independent variables by one per cent will increase the yield of paddy by 1.64 per cent in the selected area in Alappuzha district. VIF was estimated in order to check multicollinearity and observed values lie within a range of 1.24 to 1.51 indicating negligible presence of multicollinearity among the independent variables.

Similar studies conducted by Suresh and Reddy (2006), Kalpalatha and Reddy (2018) on the resource use efficiency in rice revealed that the quantity of human labour, manures and fertilizers and plant protection chemicals used have a positive and significant effect on rice production and the findings of current study are in agreement with these results.

3.4 Impact of salinity on rice production

Chow test was used to examine the existence of significant difference inregressioncoefficients of independent variables used in the regression analysis of rice production by the salt water unaffected and the affected farmers.The results of chow test were given in table 4.F* calculated from the Chow test was 5.14, which was compared with the table value of F at 5 per cent level of significance with $v_1 = K$and $v_2 = (n_1 + n_2 - 2K)$ degrees of freedom. The $F_{0.05}$ at v_1 = 7 and v_2 = 36 degrees of freedom was found to be 2.28 and hence the null hypothesis was rejected and concluded that there is significant difference in coefficients between the salt water unaffected and the affected farmers. The reason behind the significant difference in coefficients wasmainly by the impact of salinity on rice production.A similar study conducted by Radhika (2014) revealed that the relative production of paddy and the profitability from saline affected Kaipad area of Kannur district was much less than thatof the non-saline areas.

Table 4. Results of Chow test showing significant difference in coefficients

F*	F-tab	Decision	Remark
5.14	2.28	If F* > $F_{0.05}$; then there is a significant difference in coefficients between salt water unaffected and affected farmers	The two production functions differ significantly between the salt water affected and unaffected area.

3.5 Marginal productivity analysis

Marginal Value Product (MVP) of each inputs were worked out from the corresponding geometric means and regression coefficients. Allocative efficiency explains how resources in a farm are efficiently utilized in terms of economic aspects and is examined by the value of K. The results of marginal productivity analysis done for salt water unaffected area were given in table 5.The K value obtained for each independent variable from the analysis showed that, all variables except manures and fertilizers were having a K value of more than one. Which indicates the suboptimal or underutilization of resources by farmers in salt water unaffected area. An optimal utilization of resources can improve the allocative efficiency and hence production of paddy in the area. K value for quantity of manures and fertilizers was 0.61. Thus, it represents the overutilization of manures and fertilizers by the farmers. From the study it was observed that farmers in the salt water unaffected area applied manures and fertilizers on the basis of their indigenous technical knowledge and did not practice anysoil based nutrient analysis in their fields.

Likewise for unaffected farmers, the K value obtained for all variables except manures and fertilizers were having a value more than one. It indicates the underutilization of these resources by farmers in salt water affected area. K value for quantity of manures and fertilizers were obtained 0.90. This represents the current levelof usage of manures and fertilizersby the farmers was economically optimum and there is little scope for its reduced use to improve the allocative/economic efficiency. The results of marginal productivity analysis done for salt water affected area was given in table 6.

Table 5. Economic efficiency of input use for paddy production by salt water unaffected farmers

S No.	Particular	Geometric mean	MVP	MFC	MVP/MFC=K
1	Yield	4617.88			
2	Quantity of hired labour	30.98	1346.78	725.27	1.86
3	Quantity of family labour	6.36	11004.2	716.22	15.36
4	Quantity of manures and fertilizers	510.56	10.72	17.54	0.61
5	Quantity of soil ameliorants	267.74	275.99	5.44	50.77
6	Quantity of plant protection chemicals	6.06	2012.01	1206.11	1.67
7	Quantity of machine and bullock power	11.17	3180.65	1251.51	2.54

Table 6. Economic efficiency of input use for paddy production by salt water affected farmers

S No.	Particular	Geometric mean	MVP	MFC	MVP/MFC=K
1	Yield	4526.04			
2	Quantity of hired labour	43.95	7937.75	680.01	11.67
3	Quantity of family labour	6.20	9316.42	703.74	13.24
4	Quantity of manures and fertilizers	809.87	14.11	15.68	0.90

5	Quantity of soil ameliorants	731.88	42.94	5.50	7.81
6	Quantity of plant protection chemicals	8.33	2546.85	1140.45	2.23
7	Quantity of machine and bullock power	13.44	1720.99	1303.69	1.32

Efficiency of resources varies from place to place due to the changes in fertilizers used, availability of inputs, financial conditions and extent of adoption of agricultural operations. A similar study on resource use efficiency of rice production carried out by Devi and Singh (2014) in the state of Manipur revealed that the allocative efficiency worked out for all the inputs was less than one, except for fertilizer. This revealed the over utilization of other inputs and under-utilization of fertilizer in the area. And results of the current study run contrary to this study.The under utilization of resources in the study area were mainly due to the high costs of inputs.

4. Conclusions

The resource-use efficiency of rice production from salinity affected as well as unaffected areas of Alappuzha districthas been estimated separately by Cobb-Douglas productionfunction and economic efficiency byusing marginal productivity analysis.It revealed that most of the inputs used in paddy production in the area had positive and significant effect on the rice yield in both the affected and the unaffected areas.Chow test revealed that the production functions differ significantly between the salt water affected and the unaffected area. Economic efficiency of all the variables except manures and fertilizers was more than one, indicating the sub-optimum usage. And there exist chances of improving the yield by the additional application of those inputs.

In order to practice optimum levels of input use, the farmers have to be educated or trained with respect to the economic efficiency of inputs. Soil test based fertilizer application can be recommended for encouraging application of exact doses of manures, fertilisers as well as soil ameliorants.Timely construction and proper maintenance of bunds are the most efficient measures to refrain salt-water intrusion to the farmer's fields. Opening and closing of Thottapally spillway and Thannermukkom bund have a major role in maintaining the salt-water intrusion in Alappuzha district. The conflicting needs by paddy farmers and by fish farmers in the case of operation of bunds needs to be addressed properly. Institutional measures may be made more effective which is the most important factor to address this issue.

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