Groundwater Use Efficiency of Micro Irrigation System in Jaffna Peninsula

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ABSTRACT

Besides being used for drinking, a large portion of fresh water is exhausted by way of irrigation. By adopting modern technology in irrigation, the squandering of fresh water in agriculture could be greatly minimized. Considering the peninsular Jaffna, unlike the rest of the dry zone it is solely dependent on groundwater and rain which recharges the groundwater and helps out with cultivation. The traditional irrigation methods carried out in the peninsula involve a great loss of water. Hence this research was carried out with the intention of assessing the economics of sprinkler irrigation against traditional basin irrigation for chilli in the Jaffna peninsula. Primary data were collected by a questionnaire survey within the framework of purposive random sampling technique. The sample consisted a total of 150 respondents and half of it belongs to traditional basin and the other half belongs to sprinkler. A stochastic frontier analysis was performed to obtain the technical efficiency of both irrigation systems. In addition, allocative efficiency and irrigation efficiency were also estimated. In comparison, the mean technical efficiency of the sprinkler is 99% as against basin at 62%. But for both systems, mean allocative efficiency was found to be less than one that is 0.145 for basin and 0.386 for sprinkler. This indicates that farmers are over utilizing groundwater for irrigation. Finally, a higher mean irrigation efficiency of 0.43 was estimated for the sprinkler and only 0.13 was estimated for the basin. This is suggesting that all chilli farmers are operating below the recommended physical water requirement and therefore technical level of output is lower than maximum. The frontier analysis indicates that comparatively sprinkler irrigation is more effective, advantageous and efficient than basin irrigation in all respects and at all times. From this fact, researchers recommend the use of sprinkler be extended to as many farmers as possible in the region.

INTRODUCTION

Due to drought and the scarcity of freshwater, the human population all over is desperately anxious to use the available water efficiently. Due to drought related famine every year a sizeable number of humans are perishing. Therefore, the responsibility of conservation and protection of available freshwater sources falls upon every human being. Besides being used for drinking, a large portion of freshwater is exhausted by way of irrigation. By using modern technology in irrigation the squandering of fresh water in agriculture is greatly minimized.

Most parts of the dry zone in Sri Lanka suffer from seasonal rainfall or year round severe water scarcities. Therefore, it is imperative that the Sri Lankan dry zone should deliberate more in conservation and optimum use of fresh water. Considering the peninsular Jaffna, unlike the rest of the dry zone it is fully dependent on ground-water and rain which recharges the ground-water and helps out with cultivation. However, Jaffna is characterized by Dry Zone and limited water resources which hinder the potential for considerable horizontal expansion of cropped areas. The people of the Jaffna district completely depend on the limited ground-water resource to meet all of their water requirements from the open dug wells. There are no streams or rivers in the Jaffna district. Unfortunately, the topography also does not permit the construction of reservoirs. This makes groundwater one of the scarce sources of water in the district. The traditional irrigation methods carried out in the peninsula involve a great loss of fresh water supply. The detrimental effect of too much water in soil is three fold. That encourages the growth of weeds and shrubs. It waters down the soil and takes the chemical impurities into the aquifers and contaminates the precious store of fresh water. In the process of drawing the excess water to surface, energy is lost, fuel is wasted and the environment is polluted. Thus the cost of production is enhanced transferring the burden to the consumer.

By using modern technology in irrigation the above mentioned disadvantages can be reduced to a minimum. Micro irrigation system is introduced primarily with the intention of saving water and increase the water use efficiency in agriculture andintroduced rather recently in peninsula. Micro Irrigation contains mainly drip and sprinkler irrigation methods. According to statistics of Department of Agriculture, Jaffna (2011) vegetable growers most commonly (nearly 98%) use basin irrigation system (BIS) while 1.3% use sprinkler irrigation system (SIS) and 0.3% farmers use drip irrigation system. Water is supplied at required intervals and quantities using pipelines, emitters and nozzles. Hence the conveyance and distribution losses are minimized which may result in higher water use efficiency under micro irrigation systems. The current research was conducted to assess the efficiency of the sprinkler against basin irrigation. The research involved four aspects,

-Estimating the technical efficiency of sprinkler and basin irrigation systems
- Estimating the Allocative Efficiency of sprinkler and basin irrigation systems
- Estimating the Irrigation Efficiency of sprinkler and basin irrigation systems
- Find out the important factors influencing the productivity of chilli cultivated under sprinkler and basin irrigation systems.

METHODOLOGY

Study area

Jaffna District is predominantly an agricultural area. Crops such as red onion, chillies, potatoes, tobacco, vegetables, banana and grapes are cultivated for commercial purpose. About 65411 families and 30000 farm labourers are involved in agriculture. About 19,261 agro wells and 2433 ditches are being used for agricultural purpose. Well drained and highly productive calcic red yellow latasol and red yellow latasol types of soils are mainly found around the peninsula (Jaffna District Statistical Hand Book, 2010). It consist a total of seven Agrarian Service Centres. Vlikamam region was chosen for this research due to the intensive nature of agriculture practiced in this area. Groundwater source in the region is the largest and utilized for both agriculture and household purposes.

Method of sampling and data collection

Purposive random sampling method was used to select the sample for this study. The survey was administered to 156 farming families representing seven Agrarian Service Centres. At least 10% of the population from each agrarian division was randomly selected as a sample for the research. For a better comparison and to minimize the influence of the external factors the researchers have chosen the sample farmers those who have been cultivating a similar chilli variety of MI-2 and having the same soil of calcic red yellow latasol. A structured questionnaire was prepared based on the objectives of the research and pretested with few selected farmers. After checking the applicability of the questionnaire it was administered to the sampled farmers. The sample consisted a total of 156 respondents and half of it belongs to traditional basin and the other half belongs to sprinkler. Secondary data were mainly collected from Department of Meteorology and Department of Agriculture. Finally, the data were sent through a data cleaning process and the outliers were removed from the sample. Thus the final data set consisted of 150 samples.

Theoretical framework and the model

Model specification developed by Battese and Coelli (1995) was adopted and the Frontier (4.1c) developed by Coelli (1994) was used for the analysis.

Technical efficiency (TE)

Efficiency of a firm consists of two components. Technical efficiency, which reflects the ability of firm to obtain maximal output from given set of inputs and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices (Farrell, 1957). To account for technical efficiency the error term has two components (V_i and U_i), as defined in equation (4). The problem of separation of these was solved by Jendrew*et al.*(1982) using the expectations of Ui, conditional upon $e_i = Vi - Ui$ to predict the technical efficiency. They have derived the equation 1.

$$f(Ui/e_i) = -\gamma e_i + \sigma_A\{\frac{\varphi(\gamma e_i/\sigma_A}{1-(\gamma e_i/\sigma_A}\}(1)$$

Where $\sigma_A = \sqrt{\gamma}\ (1-\gamma)\sigma^2\ and\ \varphi$ are the standard normal density functions of a random variable.When the dependent variable is the log of output for instant cobb-douglus form predictor of the technical efficiency of the i[th] firm could then be caluated using TEi=exp(-E[Ui/ei].When the dependent variable is logged, Battese and Coelli (1988 and 1995) specified the Equation 2 in estimating the technical efficiency.

$$\text{TEi=exp(-E[Ui/ei]} = \frac{1-\varphi(\sigma_A-\gamma e_i/\sigma_A)}{1-\varphi(\gamma e_i-\sigma_A)}\ \exp(\gamma e_i - \sigma_A^2/2) \qquad (2)$$

Gunaratne *et al.* (2004) also adopted the same methodology in the technical efficiency estimation of micro irrigation system in low country dry zone of Sri Lanka.

Allocative Efficiency (AE)

Allocative efficiency also called price efficiency, refers to economic optimum conditions and focuses on the adjustment of inputs and outputs to relative prices (Ellis, 1992). The classical production function distinguishes the inputoutput relationship into three stages. In the first stage, marginal physical product (MPP) exceeds average physical product (APP). In the second stage, APP exceeds MPP but MPP is positive. In the third stage, MPP is negative. Economic optimality conditions indicate that an input (x_i) should be used at some point in stage 2, where the production is increasing but at adecreasing rate (Debetrin, 1986). At this stage, a farmer is allocatively efficient if production inputs are allocated according to their relative prices (Torkamani and Hardaker, 1996). The condition of optimum use of input x_i as predicted by the theory of equilibrium in factor markets under profit maximization the marginal value product (MVP) equals the price of the input (Pi). If MVP is lower than Pi the resource is over-utilized and lowering the quantity used at the current price will increase the MVP and restore optimality. On the other hand, if MVP is greater than Pi the resource is under-utilized and using more of it will bring additional gains to the producer. A measure of allocative efficiency (AE) is givenin Equation 3.

$$AE=MVPi / Pi \qquad (3)$$

Allocative efficiency is only achieved when the quantity of input used satisfies the condition of AE = 1 (Beattieand Taylor, 1993). Inefficiencies in water use arise when the actual MVP of water is less or greater than the attainable expected MVP for current input and output prices under profit maximization conditions. Farm specific water allocative efficiency would then be defined by how close individual groundwater use is to the optimal level. This of course, provides an indication of how efficient a farmer is in terms of water allocation to a particular crop. Specially, it indicates how the achieved water MVP compares to the optimal MVP. The relevant production function was specified in the Cobb-Douglas form which is widely used (Moore *et al.*, 1994).

$$lnY = \beta 0 \sum_{i=1}^{k} \beta i \; lnXi - Vi - Ui \quad (4)$$

Where *Y* is the crop output and *Xi* is the input used for the production for instant number of labour unit, extent of land, amount of water used, amount of agrochemicals (Urea, and TSP), amount of seed used etc. *Vi* is the random variable. *Ui*is non-negative random variable which is assumed to account for the inefficiency in production.

Here the cost of irrigation was calculated as follows. In peninsula, lift irrigation method is dual water pumps worked by power or fuel. The subsidized unit value for power consumption for farming is Rs.19.50. The numbers of hours multiplied by this unit value give the cost of power supply and in case of fuel considering the horsepower of the pump the value of fuel consumed would give irrigation cost. In both cases however labour cost has to be added.

Irrigation Efficiency

The third concept used in this study is irrigation efficiency. It is defined as the ratio of effective water which means the amount of water actually utilized by crop to the water applied to the crop (Lynne *et al.*, 1987). A computational formula is stated by Norman *et al.*, (1996) as in Equation 5.

$$IE = Id / Is \quad (5)$$

where,

I_d is the estimated crop water demand at the field level in m^3.

I_s is the irrigation supply in m^3.

Efficiency values usually fall between zero and one, where values close to one are the most efficient. In general, any value below or above one would suggest water use inefficiency. The irrigation efficiency is found by the formula indicated in Equation 5. Crop water demandis the crop water requirement (CWR). Irrigating a crop according to its water requirement is the best way to increase irrigation efficiency. Accordingly, the relationship between crop and environmental factors is shown by the Penmann-Monteith formula, which can be used to determine the crop water requirement.

$$ETcrop = Kc \; X \; ETo \quad (6)$$

ETcrop – crop evapotranspiration, this is considered as the CWR.

ET_o– Potential evapotranspiration. *Kc* - Crop coefficient

The ET_0 was calculated from the FAO Penmann-Monteith's equation. For this calculation the required variables for instance location, ambient temperature, humidity, radiation wind velocity etc. data were obtained from the Meteorological Department, Jaffna. According to FAO standards, the crop coefficient of chilli has been fixed at 1.05. The rainfall of cultivation period should be subtracted from crop evapotranspiration in order to obtain irrigation requirement. Therefore, the CWR is found by the Equation 7.

$$CWR = (Kc \times ETo) - Rain\ fall \qquad (7)$$

Since the farmers who adopted the sprinkler method of irrigation were few in number, the researchers had to limit themselves to the study of sprinkler irrigation against basin irrigation under the supervision of the same farmer or they studied the two methods in adjoining farmers. Thus the available material was greatly limited.

Finally to calculate the amounts of water delivered by sprinkler and basin, initially the suction head and delivery head were summed up to obtain the total head. Having obtained the total head and using the horse power of the relevant pump the amount of water delivered in gallons/minute is obtained. Multiplying this figure by a given factor (4.53) the quantity of water used for irrigation can be calculated in M^3/minute. This calculated amount multiplied by the time lapse for a single delivery will give the net volume of water exhausted for a single irrigation. Be it sprinkler or basin this method can be used to obtain the volume of water used for a single irrigation.

RESULTS AND DISCUSSION

Efficiency Measures

Calculated technical, allocative and irrigation efficiency measures are presented in Table 1.

Table 1: Summary of efficiency estimations

Chilli	Technical efficiencies	Allocative efficiencies	Irrigation efficiencies
Basin	62%	0.145	0.13
Sprinkler	99%	0.386	0.43

In comparison that technical efficiency of the sprinkler is 99% as against basin at 62%, allocative efficiency is 38.6%for sprinkler and 14.5%for basin. Further, irrigation efficiency is 43% for sprinkler and 13% for basin. Efficiency measures indicate a great deal of water use inefficiencies. In overall, the results reveal that famers are under utilizing groundwater and have been using ground water more extensively for irrigation. In summary, comparatively sprinkler irrigation is being operated quite efficiently and helping to conserve groundwater.

Technical Efficiency

The technical efficiency is reflecting the ability of a farm to obtain maximum output from a given set of input; and is 99% for sprinkler and 62% for basin.

Table 2: Distribution of Technical Efficiencies

Technical Efficiency	Number of Chilli Farmers	
	Basin	Sprinkler
0--9	0	0
10--19	0	0
20--29	1	0
30--39	2	0
40--49	5	0
50--59	18	0
60--69	29	0
70--79	17	0
80--89	3	0
90--100	0	75

The distributions of technical efficiencies depicted in Table 2. The frequency distribution of the technical efficiency in the Table 2 indicates that all the farmers under sprinkler irrigation technical efficiencies range between 90-100%. But majority of the farmers under traditional irrigation system falls in the range of 50-79%.

Table 3 gives the ordinary least square (OLS) and maximum likelihood estimates (MLE) for the Cobb-Douglas stochastic frontier production function estimates for chilli under basin irrigation system. Under MLE the extent of land cultivated, and women labour hours were the inputs that significantly affected the value of output for chilli under basin irrigation system. Here the estimated coefficients represent partial production elasticities (Gujarati, 2003). This implies that1% increment of the inputs, extent of land cultivated and women labour hours will increase the value of output by 0.978 % and 0.899 % respectively. The mean technical efficiency of the farmers was estimated to be 62%, which indicates that the value of output could be increased by 38%, without increasing the input levels. The γ is estimated to be 0.521, which indicate that majority of the error variance is due to inefficiency error Ui and not to the random error Vi. This indicates that inefficiency effects are substantial contribution in the analysis (Coelli *et al.*, 2005).

Table 3: OLS and ML Estimates for parameters of Stochastic Frontier (Cobb-Douglas Model) for chilli under Basin irrigation system

**Significant at 10% level, **Significant at 5% level and ***Significant and 1% level*

Variable	Coefficient OLS	Coefficient MLE	Standard Error OLS	Standard Error MLE	t-ratio OLS	t-ratio MLE
Constant	1.591	1.998	1.671	1.597	0.952	1.251
Land	0.955***	0.978***	0.342	0.326	2.791	2.992
Seed	0.025	2.900	0.061	0.059	0.408	0.487
Men labour	-0.198	-0.163	0.124	0.129	-0.016	-1.264
Women labour	0.336**	0.326**	0.158	0.151	2.122	2.157
Fertilizer-Urea	0.023	0.011	0.145	0.134	0.163	0.086
Fertilizer-T.S.P	0.088	0.077	0.132	0.124	0.667	0.619
Water	-0.301	-0.306	0.162	0.155	-0.018	-1.975
σ^2	0.672	0.899**		0.391		2.299
γ		0.521		0.401		1.299
log likelihood function	-87.315	-87.158				
LR test		0.312				

The Table 4 bellow gives the ordinary least square (OLS) and maximum likelihood estimates (MLE) for the Cobb-Douglas stochastic frontier production function estimates for chilli under sprinkler irrigation system. Under MLE the men labour hours, women labour hours and amount of water were the inputs that significantly affected the value of output for chilli under sprinkler irrigation system. This implies that 1% increment of the inputs, men labour hours, women labour hours and amount of water will increase the value of output by 0.18%, 0.386 percent and 0.164% respectively.

Table 4: OLS and ML estimates for parameters of stochastic frontier (Cobb-Douglas Model) for chilli under Sprinkler irrigation system.

Variable	Coefficient		Standard Error		t-ratio	
	OLS	MLE	OLS	MLE	OLS	MLE
Constant	3.661**	3.668	1.758	2.242	2.081	1.635
Land	-0.098	-9.857	0.260	0.214	-0.378	-0.459
Seed	0.107	0.107	0.134	0.119	0.800	0.898
Men labour	0.18**	0.18**	0.085	0.081	2.209	2.225
Women labour	0.386***	0.386***	0.109	0.100	3.518	3.833
Fertilizer -urea	-0.815	-0.081	0.150	0.136	-0.542	-0.596
Fertilizer -T.S.P	-0.037	-0.037	0.101	0.093	-0.371	-0.403
Water	0.164*	0.164**	0.087	0.082	1.884	2.005
σ^2	0.335	0.3***		0.056		5.345
γ		0.000		0.126		0.002
log likelihood function	-61.268	-61.268				
LR test		3.968				

**Significant at 10% level, **Significant at 5% level and ***Significant and 1% level*

Analysis revealed that extent of land has a positive correlation with the output under basin irrigation.But it is not so with the sprinkler. The numeral revelation is that when the extent of land increases by 1% the increase in production is 0.95% at 1% significant level. Arbitrarily it cannot be said that increase in land usage results in increased productivity. Becausethe availability of land is scarce and expensive. Increase of land and the input must go in tandem. But it cannot be conclusively stated that increase of land and increase input does not as a rule bring about profitability. Because expanding beyond a limit renders the production unwieldy and enters the diseconomies of scale. So the line of thought should be to extract maximum from the available land. The solution being the sprinkler form of irrigation. In chilli cultivation under basin irrigation, female labour has a considerable impact on yield. It has a positive sign and found to be significant at 5% level. Mostly women labour is used for weeding and harvesting in chilli cultivation. Women labour is significant at 5% level. In micro irrigation the female labour is substitute for men labour by farmers. Female labours are hired for low wage and is easy available than men labour. Results show that irrigation water is significant determinant of crop yield. The coefficient of irrigation water quantity is an elasticity measure. It also indicates the first derivative of marginal productivity of water with respect to output. It means that a unit change in quantity of water will affect the yield negatively for basin. Water is significant at 10% level. In chilli, the amount of water used is as above the recommended level. Total chilli cultivation labour hours per season of sprinkler irrigation are less than basin irrigation. Adoption of sprinkler irrigation will reduce the labour hours and irrigation cost. In basin irrigation, duration of irrigation is very high. It increases the electricity bill payment or the fuel expenditure. Also irrigation is done manually. Therefore, irrigation labour cost is also high for basin irrigation technique. Weeding is done both manually and chemically. Hired labours are used for manual weeding. Under sprinkler irrigation technique, weeding consumes more women days than basin irrigation technique. Moreover, from the collected data the researchers found that sprinkler irrigation lowers the pesticide application by 3%. Application of water is also low. Therefore, sprinkler irrigation is cost effective and environmentally friendly irrigation technique. The Frontier analysis indicates that sprinkler irrigation has far more effective advantages and efficiency than basin irrigation in all aspects and at all times. Cumulatively, the inference is that the technical efficiency of the sprinkler is superior to basin irrigation. From this fact, researchers recommend the use of sprinkler be extended to as many farmers as possible. Suggesting the use of sprinkler irrigation to the farmer at large it is recommended that he be given special credit facility for the equipment or that he be charged a nominal subsidiary value. This approach will encourage farmers to access the equipment to their advantage.

Allocative Efficiency (AE)

AE measures indicate a great deal of inefficiency in both sprinkler irrigation and basin irrigation. But for both systems mean allocative efficiency was found to be less than one that is 0.145 for basin and 0.386 for sprinkler. This means that in both cases, farmers are over utilizing groundwater for irrigation. Also this less than one AE values indicates that the returns to water, as assessed by the value of marginal product lowers the unit cost of the input (groundwater). This is in keeping with findings of Omezzine and Zaibet (1998) and Vijitha and Thiruchchelvam (2010) who says smaller farms use water more extensively than do larger farms. This conclusion applies perfectly to the peninsula farmers as the researchers have found out average land extents are limited to 4.39 lachchems with the standard deviation of 2.34.

In basin irrigation, average AE is equals 0.14 which indicates that farmers are over utilizing irrigation water. Lowering the quantity used at the current price will increase the MVP and restore optimality.On average, AE is 0.38 which indicates that farmers are over-utilizing groundwater in sprinkler irrigation also. This value indicates that the returns to water, as assessed by the value of marginal product, reduce the unit cost of the input (water). Results show that 95% farmers belong to less than one category. Out of seventy-five, seventy-one farmers belong to less than one category. Table 5 explains different category of AE of both sprinkler irrigation and basin irrigation.

Table 5: Frequency of Allocative Efficiency (AE) measures for chilli

AE	>3	2-3	1-2	0-1
Basin	0	0	2	73
Sprinkler	*0*	*1*	*3*	*71*

The AE for both sprinkler and basin are less than one. This indicates that both methods are used excessively. Over utilization though found in both methods is far more visible in basin irrigation (0.145) than sprinkler (0.306) method. This is due to trends in the cheap acquiring of water and two the indifference of the cultivator to environmental pollution. This means that apart from disbursing the technical knowhow to the farming community it is imperative that they be given an understanding of the importance of the optimum use of fresh water. It would be in vain to impart technical knowhow to farming community while they are ignorant of the damages cost to the environment. It is recommended that the farmers be given all the elements involved in a package that they may implement the parameters to maximum effect.

Irrigation Efficiency (IE)

Further IE would be 0.43 sprinkler and 0.13 basin. This is suggesting that all chilli farmers are operating below the recommended physical water requirement and therefore technical level of output is lower than maximum. In basin irrigation, the loss of water is staggering due to seepage. This means more water has to be run to overcome the effect of transportation losses. This in turn results in energy loss, enhanced cost of production and contribution to the environmental pollution. It has to be mentioned that unnecessary weed growth was seen to be in competition with the desired crop. Again the cost of production increases due to weed clearing and the use of agrochemicals, especially weedicide pollute both the top soil and ground water. Table 6 depicts the frequency of farmers of irrigation efficiency measures.

Table 6: The frequency of irrigation efficiency measures for chilli.

IE	<10	10-30	31-50	>50	>70
Basin	75	0	0	0	0
Sprinkler	71	3	1	0	0

All farmers are having below 10% of irrigation efficiency in basin irrigation. In sprinkler irrigation, out of seventy-five, only four farmers are having above 10% IE. These results show that adopting sprinkler irrigation is increasing the efficiency measures to some extent in Jaffna district.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated water use efficiency in agriculture in the Jaffna peninsula. It focuses essentially on technical, allocative and irrigation efficiency for individual farms using sprinkler irrigation for chilli cultivation. Results indicate reduction in technical and economic inefficiencies due to over utilization of water. Further, in this study, all costs are farm specific and calculated individually for each farm. The higher the unit cost of groundwater extraction, the lower the value of allocative efficiency. Hence it can be concluded that lower AE values are the result of higher water unit cost. Irrigation efficiency measures are all less than one suggesting that farmers are operating below the recommended physical water requirement and therefore technical level of output is lower than maximum. On average, less than one AE measures indicates that farmers are over-utilizing groundwater. The results of the frontier analysis show the extent of land significant for chilli under basin irrigation at 1% level. In addition, labour and water are significance for chilli. This study shows that comparatively groundwater is conserved in micro irrigation system than in traditional system. Water is used inefficiently in basin irrigation system. From the data collected from the field researchers observed that in micro irrigation system comparatively less amount of water and agrochemicals have been used, but in basin irrigation system more amount of water and agrochemicals are used inefficiently and they lead to contamination of ground water. In traditional irrigation method, more water is wasted as leaching and depletion. In basin irrigation system, amount of fertilizer and labour requirements are higher than in micro irrigation method. Comparing the basin irrigation and sprinkler irrigation, results show that less energy is utilized and cost of production decreased in sprinkler irrigation than in basin irrigation.

The efficiency of micro irrigation system also has to be increased by providing proper technical training and regular inspection and also doing a mass propaganda regarding the water conservation and advantage of ground in Jaffna district. Economic optimality is however socially preferred as it provides higher returns to water resources. From this fact, researchers recommend the use of sprinkler be extended to as many farmers as possible. Awareness of micro irrigation system should be conveyed to farming population and provide proper extension services in order to adopt micro irrigation system.

REFERENCES

Annual Statistics (2011). Annual Statistics of Department of Agriculture, Jaffna.

Beattie, B.R., and Taylor, C.R. (1993).The economics of production, Krieger publishing Company, Malobar, Florida.

Battese, G.E and Coeli, J.T (1988).Prediction of firm-level technical efficiencies with the generalized frontier production function and Panel data.*Journal of Econometrics,* 38: 387-399

Battese, G.E and Coelli, J.T. (1995).A model for technical efficiency in a stochastic frontier production function for panel data. *Empirical Economist*. 20: 325-332.

Coelli, J.T. (1994). A guide to Frontier version 4.1: A computer program for Stochastic Frontier Production and Cost function Estimation. Department of Econometrics, University of New England, Australia.

Coelli,J T., Pradada Rao, D.S. , Christopher J. O'Donnell and Battes, E.G. (2005). An Introduction to Efficiency and Productivity Analysis, Second Edition, Springer publication.

Debertin, D.L. (1986). Agricultural Production Economics.First Edition.Macmillan publishers.

Ellis, F. (1992).Agricultural Policies in developing countries, Cambridge University Press, Cambridge.

Farrell, M.J. (1957). Measurement of productive efficiency.*Journal of the royal statistical society*. 120(3): 253-281.

Gujarati, D. (2003).Basic Econometrics. Third Edition, McGraw-Hill International.

Gunaratne, L.H.P, Krishanth, M, Ekanayake, E.M.T. and Gunawardenae, E.R.N. (2004). An Economic Evaluation of Micro Irrigation Systems in Low country Dry zone, Proceedings of the Water Professionals' Day Symposium, Geo-Informatics Society of Sri Lanka, pp 1-12.

Jaffna District Annual Statistical Hand Book, (2010). Published by the JaffnaSecretariat.

Lynne, G.D., Anaman, K.,Kiber,C.F. (1987). Irrigation Efficiency: Economic interpretation, *Journal of irrigation and drainage*, 113(3), 317-333.

Moore, M.R, Gollehon, N,R, and Carey, M.B.(1994). Multicrop production decisions in western irrigatedagriculture: the role of water price. American*Journal of Agricultural Economics*, 76:859–74.

Norman, W.R., Al-Ghafri, A., Shayya, W.H.(1996). Water use performance and comparative costs among surface and traditional irrigation systems. Northern Oman Symposium on Water and Arab Gulf Development: Problems and Policies, Exeter University.

Omezzine, A. and Zaibet, L. (1998).Management of modern irrigation systems in Oman: Allocative vs. Irrigation efficiency. *Journal of Agricultural Water Management*. 37: (1998) 99-107.

Torkamani, J., Hardaker, J.B.(1996). A study of economic efficiency of Iranian farmers in Ramjerd district: An application of stochastic programming. *Journal of Agricultural Economics*,14:73-83.

Vijitha, K and Thiruchchelvam,S., (2010). Technical and Economic Efficiency of ground water use in agriculture in Jaffna peninsula. Proceedings of the Water Professionals' Day Symposium, Geo-Informatics Society of Sri Lanka, pp 105-114.