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An Economic Analysis of Ground-Water Use for Agriculture in the Jaffna District

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ABSTRACT. Heavy withdrawal of ground-water has been identified as a serious problem affecting ground-water quality, threatening agricultural productivity and thereby the income of the farmers in the Jaffna district. A two stage mathematical model was developed to determine the optimal use of water throughout the irrigation season and to suggest an optimal cropping pattern and suitable policy changes required to improve ground-water use in the Valigamam region of the Jaffna district. In the first stage, ground-water recharge and crop water requirements were estimated for ten years from 1971 to 1980. The information generated from the hydrologic models was entered into a linear programming model in a dynamic form at the second stage, with other resource constraints. Economic data from 1980 to 1989 were used in the economic analysis for five Agrarian Service Centre (ASC) areas in the Valigamam region.

The results of this study show that water was over utilized in Nallur, Keerimalai and Tholpuram, but under utilized in Puttur and Uduvil ASC areas. The results of the optimization exercises reveal the need to increase institutional credit and for family labour to be fully utilized for a higher return. Significant changes were noted in the mixed cropping of the average optimal plans over the existing plans at all recharge levels. This suggests potentials for increasing the total cropped area and net returns, particularly, in the Puttur and Uduvil ASC areas. This leads to 26% more intensive use of land and 14% income increase from agriculture, and the effective utilization of water in the whole study area. The findings will be useful to policy makers and administrators in promoting and implementing development plans in the study area.

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INTRODUCTION

The future of irrigated agriculture in many parts of developing countries is uncertain due to impending water scarcity and escalating irrigation costs. Agriculture must be prepared to respond to this era of limited, high cost water by becoming more efficient in its use.

Considerable research efforts have focused on the development and improvement of surface irrigation, and less attention has been given to ground-water in many developing countries (Toulmin and Tiffen, 1987). In this context, this paper focuses on the efficient use of ground-water for agricultural development in the northern part of Sri Lanka.

The problem

Water scarcity has been a major problem for agricultural development in the Jaffna district. Farmers in this district practice intensive agriculture, and depend wholly on ground-water for irrigation. Several studies conducted in the study area by several researchers (Gunasekeram, 1977; Elankumaran, 1986 and Nadanasabapathy, 1987) have indicated that the rising demand for ground water, particularly for agriculture, has resulted in salinity at an alarming rate. The lower level of output and income over the years may be attributed to the deterioration of ground-water (Thiruchelvam and Abeygunawardena, 1990).

Study objectives

The general objective of this study was to develop and apply a model to allocate a finite water supply throughout the irrigation season in the Valigamam region of the Jaffna district. The specific objectives of this study were to:

a. Estimate the available water for agriculture and the irrigation requirements for major crops grown in the ASC areas in the Valigamam region,

b. Determine the optimal cropping pattern that maximize returns, and effectively utilize the available water for agriculture in the ASC areas in the Valigamam region, and

c. Develop information which will be useful in adjusting cropping pattern to the changing water economy in the Jaffna district.

METHODS AND DATA

Study area

The Valigamam region in the Jaffna district was selected for this study (Figure 1). It is located within the western and northern zones of the Jaffna district, and separated from the other two land masses of the district by several saline water lagoons. This region covers about 32% (34,321 ha) of the total land area, and consists of about 53% (418,253 persons) of the total population of the Jaffna district. Over 50% of the population is involved in agriculture in the Valigamam region (Balasundarampillai and Rupamoorthy, 1983).

The ground-water source in this region is the largest and most utilized in the Jaffna district (Anonymous, 1983a). There are five ASC areas in this region, namely, Puttur, Uduvil, Nallur, Keerimalai and Tholpuram. Cropping patterns in these areas are affected mainly by water availability and the market prices.

Data collection

To achieve the study objectives, data were collected from secondary and primary sources for each ASC area in the Valigamam region. Data on cropping pattern, irrigation, input use, cost of production for cash crops, output prices, capital availability, labour supply, ground-water conditions *etc.*, were collected by personal interviews and group discussions with farmers and agricultural officers. A complete set of the latest (1971-1980) climatological data available from the Department of Meteorology were used in the hydrological analysis. Other data on water resources, crop data, land use, soil type *etc.*, were collected mainly from the Department of Agriculture, Water Resource Board from 1980 to 1989.

A - Keerimalai B - Tholpuram C - Uduvil D - Puttur E - Nallur

Figure 1. Agrarian Service Centre divisions in Valigamam region.

Analytical procedure

The basic data and various stages of the analysis are schematically illustrated in Figure 2. At the first stage, a simple soil moisture model was built to estimate the recharge from rainfall. Then, fortnight irrigation requirements at 40% irrigation efficiency were estimated for five main crops, such as, chillie, red onion, potato, tobacco and vegetables using the CROPWAT programme (Smith, 1992). Subsequently, water balance calculations were made at monthly intervals to estimate the present use of water in agriculture. Water requirement for non agricultural uses and for home gardening and tree crops were kept as mandatory requirements. These hydrologic estimations in the first stage were done from October to September in the following year, for ten years (1971-1980), in five ASC areas separately.

The information generated from the hydrologic models was entered into a linear programming model (LP) in a dynamic fashion, at the second stage. It was an annual decision making model, which maximizes net returns through the selection of crop mix, planting time, irrigation schedules and input usage, under conditions of limited water availability and other resources. These mean optimal values were evaluated by comparing them with those observed from the existing ones in each ASC area. Socio-economic data, such as, labour supply, input and output prices, capital availability *etc.*, from 1980 to 1989 were used for the economic analysis. On average, each of the 50 models consists of 140 activities and 124 constraints. The LP model expressed in matrix form is as follows:

Maximize

$$Z = c'x$$

subjected to:

$$q'x - M + R < W$$

$$G x < d$$

$$x > 0$$

where c' is vector of net income parameters; x, vector of activity levels; W, total amount of water available for the season; q', vector irrigation requirement by crops for each two weeks period; M, fortnight mandatory water requirements; R, fortnight recharge; d, vector of other constraints; and G input output coefficients.

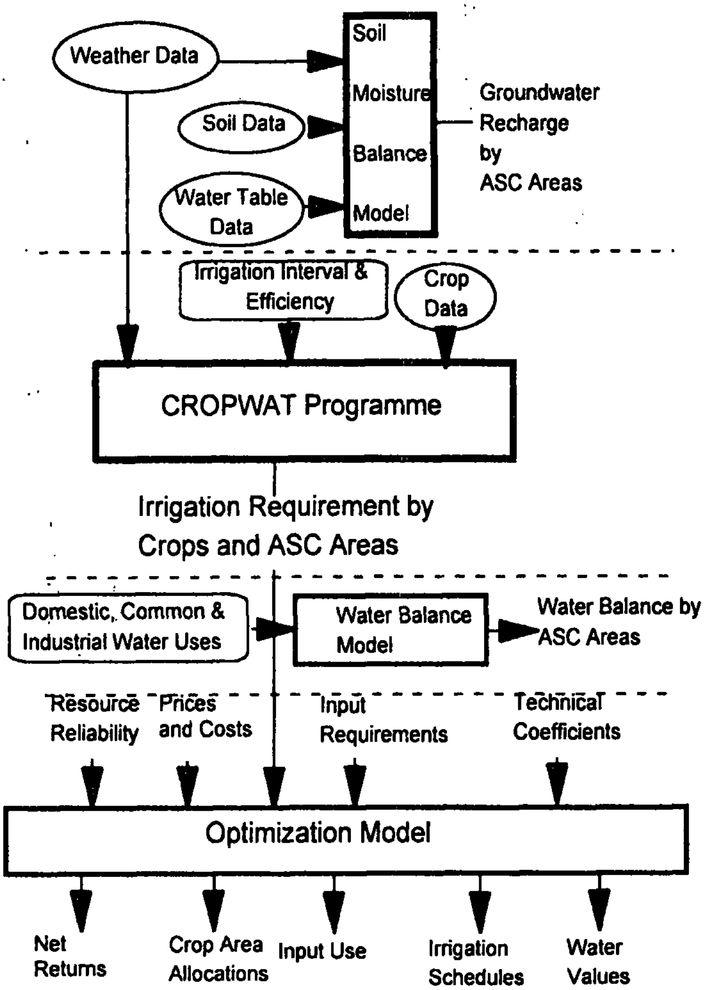

Figure 2. **Schematic diagram of data flow and analytical structure of the mathematical model.**

RESULTS AND DISCUSSION

The recharge estimations of the ten year period have shown that the average recharge in the Valigamam region is 136.70 million cu.m. (MCM). Previous estimates of recharge in the whole study area by various researchers were 139.9 MCM (Balendran, 1968), 65.9 MCM above only the mean sea level (Misler, 1978), 105 MCM (Gunasekeram, 1977) and 212 MCM (Anonymous, 1983a). The estimated average recharges for Puttur, Nallur, Uduvil, Keerimalai and Tholpuram ASC areas are 77.38, 12.47, 15.39, 17.90 and 13.59 MCM respectively. These estimates are important to decide the cropping pattern of each ASC area.

Estimation of agriculture water use for the Valigamam region at 40% irrigation efficiency is 106.86 MCM (78% of the total recharge), of which, field crops account for 72.49 MCM (53% of the total recharge). Previous estimates of water demand for agricultural purposes by other researchers in the study area were 122 MCM (Misler, 1978), 118 MCM (Anonymous, 1983b) and 379 MCM (Anonymous, 1983a). The latest calculations seems to have been over estimated.

Of the ASC areas the Nallur ASC area has the lowest (63%) irrigation water demand and in the other ASC areas the irrigation water demands are above 80% of the total recharge. There is a very high demand for water from January to April (75%). This higher demand in the middle of the season leads to less water availability for the rest of the season. The results of the water balance study indicate that, there was water scarcity from June to October in Nallur, Keerimalai and Tholpuram ASC areas.

The results of the optimizing exercises reveal that additional 1350 ha could be cultivated, particularly in the Puttur and Uduvil ASC areas (Table 1). This leads to 26% higher intensive land use than in actual practice (114%). The parametric programming options indicate that the solutions are insensitive to a wide range of recharges. Further, the relationship between the best acerage for different crops and the recharge levels is found to be non linear. This indicates the limitation of land and the distribution pattern of rainfall are the major constrains for the increase in cultivated extent.

The average optimal net return (Rs. 67,000/ha) is found to be about 14% higher than the present value (Rs. 57,000/ha) obtained in the Valigamam region. The significant correlation between the optimal value and the optimal extent cultivable indicates the importance of change in the present cropping pattern in the study area for higher returns.

The results of comparing the optimal crop mix with the actual cropping mix (Table 2) indicate that significant changes in the present cropping extent are needed to maximize income and harness the water.

Table 1. Potential increase in the present extent cultivated and land use intensity - Valigamam region by ASC areas.

	Puttur	Uduvil	K.Malai (ha)	T.Puram	Nallur	Valigamam
Cultivable extent.						
Actual	3318	865	1160	447	322	6146
Potential increase	951	209	143	9	20	1328
Land use intensity (%)						
Actual	128	122	112	208	112	115
Potential increase	37	30	7	4	6	26

Table 2. Potential changes in the actual crop mix extent-Valigamam region by ASC areas.

	Crop Extent in ha.										
ASC Areas	CH1	CH2	ON1	ON2	PO1	PO2	TO1	TO2	VE1	VE2	Total
Puttur	175	27	121	55	450	50	20	30	-3	46	951
Uduvil	38	32	39	-28	22	13	17	26	7	45	209
Keerimalai	57	-	158	-81	3	-	5	8	6	6	147
Tholpuram	25	-	21	-40	3	-	3	7	-12	-10	9
Nallur	-1	-	57	-14	2	6	-4	-9	-4	-14	20
VALIGAMAM	294	59	396	-118	480	69	41	62	1	78	1328

CH1 - *Maha* Chillie, CH2 - *Yala* Chillie, ON1 - *Maha* Onion, ON2 - *Yala*, Onion, PO1 - *Maha* Potato, PO2 - *Yala* Potato, TO1 - *Maha* Tobacco, TO2 - *Yala* Tobacco, VE1 - *Maha* Brinjal, VE2 - *Yala* Brinjal

The shadow prices are higher in ASC areas with deeper water table, such as, Puttur, Uduvil and Keerimalai. Derived demand and elasticities of irrigation water for each period could be useful for formulating policies in regulating water.

A simulation of increasing the institutional credit showed, that twice the amount of institutional credit leads to a higher return in all the ASC areas. Further, expensive hired labour can be reduced by using all the family labour available for the proposed plan.

CONCLUSIONS AND POLICY IMPLICATION

The applied model provides a package of information with reasonable precision on the limit of water availability and cropping pattern potentials under the existing conditions. This information can be used as a knowledge base in developing optimal cropping plans that maximize returns and harness the water in the study area. Updating and modifying the model is needed for improving the estimated coefficients.

There are significant opportunities for changing the cropping pattern at 40% irrigation efficiency. These changes, however, will involve substantial changes in the improvement of agricultural credit, input supply, market facilities *etc*. Poor management of water is found to be the main cause for inefficient land use. Thus, a comprehensive and integrated programme involving water conservation measures is important for the water economy of the study area.

The most important implications of the results of this study focus on the cropping pattern developed for conditions of limited water supply. The results would be useful to policy makers and administrators in promoting and implementing agricultural development plans in the study area.

Limitations of the study and future research needs

The study was carried out with the following limitations.

The reliability of data on water resources, extent of crops cultivated, cost of production, profit, population, *etc*., is limited. Therefore, the results of the analysis should only be taken as a guide. The number of ground-water situations in the study area needs to be examined in detail, as a separate study.

A non-linear dynamic optimization model might give a much better estimate on optimal use on water by capturing the non-linear nature of objective functions as well as other constraints. This should be considered in future studies.

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