

Proposed Kalugal Oya Reservoir in Ampara District

M.M. Munas and K.P.P. Pathirana

Abstract: This study attempted to propose a methodology to optimize irrigation water with optimal cropping patterns and annual net profits to the proposed Kalugal Oya scheme, situated in Ampara District, Sri Lanka. The optimization approach was based on linear programming. Three models were formulated: 1) Maximize net profit, 2) Maximize irrigable area and 3) Maximize net profit in Maha and maximize irrigable area in Yala. The above models were analysed with three scenarios: Scenario I Multi crop cultivation, Scenario II OFC and Vegetable cultivation and Scenario III Paddy cultivation in Maha and OFC & Vegetables in Yala. Further, four major constraints were identified in the above models. The first constraint relates to the availability of land (L) for agriculture use. The second constraint defines the total amount of available water (W). Third major constraint is related to the internal crop consumption (C_{oi}) of a crop for food security requirement. Maximum level of crop production (S_i) of a crop for local marketing capacity was considered as the fourth constraint. Considering agricultural year 2012, the total annual net profit gained from Scenario II of Model 1 is estimated to be 60 Million Rupees, which is almost two and half times greater than the profit obtained when traditional cropping patterns are used in these areas (26 Million Rupees). The highest annual net profit in Scenarios I and II of Model 1 achieved mainly from the cultivation of Kurakkan, Cowpea and Brinjal. However, to satisfy the need of internal crops consumption (C_{oi}) of farmer families in these area, Paddy and Maize were recommended for cultivation though it is not profitable.

Keywords: Optimize Irrigation Water, Linear Programming Techniques, Annual Net Profit, Cropping Patterns

1. Introduction


One of the most important elements in the world is water and it constitutes the basis of human life (Qureshi et al., 2012). Nowadays, water crisis is the main problem in the world due to water scarcity.


Main area of water usage is in irrigated agriculture, industrial and other sectors. In many countries, effective water usage in irrigated agriculture often fails to compare with the other sectors. Therefore, comparatively, water usage in irrigated agriculture has many challenges not only in the developed countries but also in the developing countries.

The proposed Kalugal Oya scheme is located at latitude of $7^{\circ} 26'N$ and longitude of $81^{\circ} 33'E$. Also, it is situated in Uhana DS Division (DSD), Ampara District in Sri Lanka. The Kalugal Oya stream, the main stream of the proposed tank, falls within the catchment of the Navakiri Tank which is under the purview of Navakiri Division in the Batticaloa Range (EIA, 2014). The area directly upstream of the Navakiri Tank in the Ampara District has no irrigation

facilities for cultivation where it comes under the dry zone. More than 1000 farmer families living in these areas primarily depend on unpredicted rainfed chena cultivation and they face severe hardships during the dry season due to water scarcity (Feasibility study report, 2012).

The Department of Irrigation has proposed a commendable solution for this longstanding issue by constructing a reservoir across the Kalugal Oya to supply water to nearby areas. The catchment area of the proposed scheme is 23 square kilometres (8.85 square miles) and storage capacity of the reservoir is around 12

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MCM (10,000 Ac-Ft). Also, it is proposed to irrigate around 1215 ha (3000 acres) of land for agricultural activities. Proposed headwork and canal network in the schemes are as follows (Feasibility study report, 2012):

- 300 m long earth bund
- Two tower sluices
- Ogee type spillway
- Rip rap protection
- Toe filter
- Internal and surface drainage
- Two main canals, branch canals, distribution canals and field canals, with necessary turnouts, regulators, drop structures, check structures and other.

The major land use component in the Uhana DSD area is agriculture and the major cultivation is paddy, while other field crops (OFC) and vegetables etc. are grown in lesser quantities. Paddy cultivation is practiced only in the Maha season and other crops are mainly grown in the Yala season. However, Department of Agriculture and Land Use Division of Irrigation Department has recommended the wetland rice cultivation to be in the major rainy season, and upland annual crops in the minor rainy season and mid-season of the study area (Land Use Publication, 2017).

The lands in the study area have good potential for agriculture, including paddy, vegetables and other field crops etc (EIA, 2014). As water is scarce in this area, optimum use of water in the proposed Kalugal Oya scheme for irrigation and other needs is very much essential.

2. Previous Studies

Irrigation water allocation of a reservoir for water optimization requires a comprehensive understanding of irrigation water demand, cropping pattern, designated area and reservoir operation (Hamideh et al., 2012).

Qureshi et al. (2012) say that, management of a proposed reservoir requires consideration of the various resources available including water, land and people. Therefore, there is a need to adjust the existing cropping patterns to optimize the net return from the irrigated agriculture based on the limitations on available water, land and other production constraints (Qureshi et al., 2012).

Al-Weshah (2001) carried out a case study at Jordan Valley. The objective function set in this study aims at maximizing the net revenue from the irrigated agriculture subjected to limitations on land, water and other production and marketing factors. Therefore, Al-Weshah (2000) developed a linear programming model to maximize the net revenue combining these three constraints. In this study, it shows that the problems of water scarcity could be overcome in irrigated agriculture by changing to a suitable cropping pattern. Further, he suggests that special attention should be paid to selecting crops which need less water, while maintaining the same level of profitability. This approach can be useful for water and agricultural planners. However, this optimization model needs to be simplified.

Similarly, Qureshi et al. (2012) carried out a pilot study in the secondary canal in the Sindh province of Pakistan. In this study, Qureshi et al. (2012) developed a computer model, and to run the model they applied Linear Interactive Discrete Optimizer (LINDO) techniques for optimization. This study shows that the optimal solution and maximum net benefits can be achieved in irrigated agriculture considering more on vegetable farming than sugar cane and cotton cultivation.

Hamideh et al. (2012) say that, to maximize the objective function three main constraints were considered in their study: (1) mass balance of the reservoir, (2) total available area for cultivation, and (3) physical limitations of the reservoir capacity.

3. Methodology

3.1 Data Collection

Data collection was carried out in the field level and also by contacting various governmental and nongovernmental organizations. Continuous field investigations were conducted to observe the present status of the study area, including agriculture practices, soil structure and climatic conditions.

Also, crop cutting survey was carried out to collect data on the crop yield, total cost of crop production, farm gate price of crops and domestic crop consumption etc.

During the reconnaissance survey, Agrarian Development Officer and staff, Divisional Secretary, Grama Niladari's, Agricultural Officers, Agriculture Research and Production

Assistants (ARPA), Irrigation Engineers, professional staff and farmers were consulted and interviewed to gather relevant information and for data collection.

Much effort has been taken for surveys and also to review different documents collected from various places to check the reliability and consistency of data, including climatic data (rainfall, monthly evaporation and monthly average wind speed), crop factors and crop growth stages as well.

3.2 Data Analysis

Figure 1 illustrates the methodology used in this study.

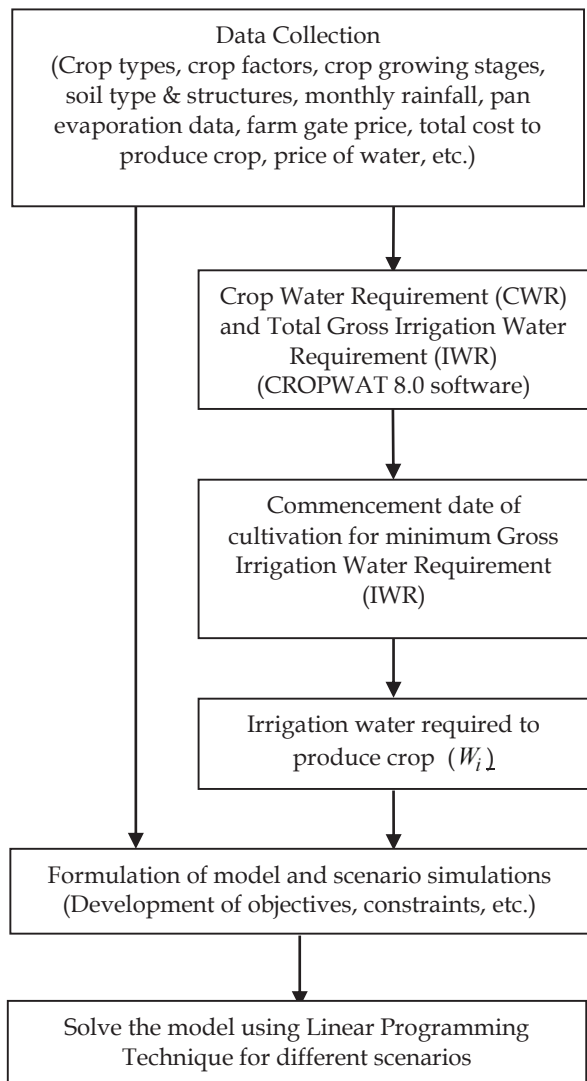


Figure 1- Methodology used in this study

a. Computation of crop water requirement and irrigation water requirement

CROPWAT software package (Version 8.0) developed by Food and Agriculture Organization (FAO) was used to compute crop water requirement (CWR) and total gross

irrigation water requirement (IWR) for different crops considered in this study. The software calculates the CWR and IWR for given climatic, soil and crop data. Procedures for calculation of the CWR and IWR are mainly based on the methodology presented in FAO, Irrigation and Drainage paper No. 24 (Doorenbos and Pruitt., 1977).

b. Analysis of the commencement date of cultivation

Based on the available climatic and crop data, the total gross irrigation for a crop can be calculated according to the respective commencement date of cultivation.

By varying the date of commencement of cultivation, different total gross irrigation water requirements were computed for each crop (Dharmasena, 1990). The critical month of commencement for cultivation is identified as the one that gives the minimum total gross irrigation water requirement for the cultivation season.

c. Determination of annual gross irrigation water requirement IR (W_i) for each crop

Based on the aforementioned minimum total gross irrigation with respect to the critical date, optimum gross irrigation water requirement (IR) for each crop in both Maha and Yala seasons were computed and shown in Table 1.

Table 1 - Annual gross irrigation water requirement IR (W_i)

Crops	Maha/ mm	Yala/ mm	Total/ mm	m ³ / Acre
Paddy	612	1696	2308	9,339
Brinjal	339	828	1168	4,725
Cowpea	110	533	643	2,601
Maize	0	395	395	1,597
Manioc	178	980	1159	4,688
Kurakkan	178	980	1159	4,688

3.3 Model formulation

Three models were formulated and analysed using a linear programming technique. These models are:

Model 1: Maximize net profit in both Maha and Yala seasons

Model 2: Maximize irrigable areas in both Maha and Yala seasons

Model 3: Maximize net profit in Maha and maximize irrigable area in Yala seasons



(a) Model 1: Maximize net profit in both Maha and Yala seasons

A linear programming model is formulated to maximize the net profit (Z) in agriculture in the proposed Kalugal Oya reservoir during both Maha and Yala seasons. The net profit from agricultural farming at Kalugal Oya can be expressed as in Equation (1).

$$Z = \text{Max} \left[\sum_{i=1}^n P_i * X_i - \sum_{i=1}^n C_i * L_i * X_i - \sum_{i=1}^n W_i * L_i * X_i * P_w \right] \dots(1)$$

where,

i = An integer pertaining to the crop
($i=1,2,\dots,6$) and $n = 6$

P_i = Price for crop i (Rupees/kg)

X_i = Output of crop i (kg)

C_i = Total cost to produce crop i (Rupees/ha)

L_i = Extent of land required to grow one kg of
Crop i (ha/kg)

W_i = Water required to produce crop i (m³/ha)

P_w = Price of water for agricultural use
(Rupees/m³)

C_{oi} = Internal consumptions of crop i (kg)

S_i = Maximum level of a crop production of
Crop i for local marketing capacity (kg)

Equation (1) gives the objective function of the model, which is to maximize the net profit (Z). Four major constraints were identified. The first constraint relates to the availability of land (L) for agriculture use. The second constraint defines the total amount of available water (W). Third major constraint is related to the internal crops consumption (C_{oi}) of a crop for food security requirement. Maximum level of crop production (S_i) of a crop for local marketing capacity was considered as the fourth constraint.

The model assesses and identifies possible solutions with respect to these limits in order to achieve the optimum objective function (Anon., 2001). Four major constraints of the model are generally expressed as follows:

Land constraint:

$$\sum_{i=1}^n L_i * X_i \leq L, \text{ where, } i=1 \text{ to } n$$

Water constraint:

$$\sum_{i=1}^n W_i * L_i * X_i \leq W, \text{ where, } i=1 \text{ to } n$$

Internal crop consumption requirement for food security

$$X_i \geq C_{oi}, \text{ where, } i=1 \text{ to } n$$

Local marketing capacity requirement

$$X_i \leq S_i, \text{ where, } i=1 \text{ to } n$$

The expansion of the above expression for n number of decision variables (6 number of crops) and respective constraints are defined as Land constraint:

$$L_1X_1 + L_2X_2 + L_3X_3 + L_4X_4 + L_5X_5 + L_6X_6 \leq L$$

Where, $L = 1215$ ha

Water constraint:

$$W_1L_1X_1 + W_2L_2X_2 + W_3L_3X_3 + W_4L_4X_4 + W_5L_5X_5 + W_6L_6X_6 \leq W$$

Where, $W = 6$ MCM (readily available water) for both seasons.

Internal crop consumption requirement for food security:

$$X_1 \geq C_{o1}$$

$$X_2 \geq C_{o2}$$

$$X_3 \geq C_{o3}$$

$$X_4 \geq C_{o4}$$

$$X_5 \geq C_{o5}$$

$$X_6 \geq C_{o6}$$

Local marketing capacity requirement:

$$X_1 \leq S_1$$

$$X_2 \leq S_2$$

$$X_3 \leq S_3$$

$$X_4 \leq S_4$$

$$X_5 \leq S_5$$

$$X_6 \leq S_6$$

(b) Model 2: Maximize irrigable area in both Maha and Yala seasons

Similarly, a second model was formulated to maximize the irrigable area (L) subject to available water (W), internal crop consumption (C_{oi}) of crop i and maximum level of crop production (S_i) of a crop.

$$L = \text{Max} \sum_{i=1}^n L_i * X_i \quad \dots(2)$$

Subject to following constraints:

Water constraint:

$$\sum_{i=1}^n W_i * L_i * X_i \leq W$$

Internal crop consumption requirement for food security:

$$X_i \geq C_{oi}, \text{ where } i = 1 \text{ to } n$$

Local marketing capacity requirement:

$$X_i \leq S_i \text{ where } i = 1 \text{ to } n$$

(c) Model 3: Maximize net profit in Maha and maximize irrigable area in Yala seasons

In this model, Equation (1) is used to maximize net profit in Maha season, while Equation (2) is used to maximize irrigable area in Yala season, which is subjected to available water in the reservoir (W), internal crop consumptions (C_{oi}) of a crop and maximum level of crop production (S_i) of a crop as constraints.

for Maha season

$$Z = \text{Max} \left[\sum_{i=1}^n P_i * X_i - \sum_{i=1}^n C_i * L_i * X_i - \sum_{i=1}^n W_i * L_i * X_i * P_w \right]$$

and

for Yala season

$$L = \text{Max} \sum_{i=1}^n L_i * X_i$$

Constraints of the model are as follows:

Land constraint:

$$\sum_{i=1}^n L_i * X_i \leq L, \text{ for Maha season}$$

Water constraint:

$$\sum_{i=1}^n W_i * L_i * X_i \leq W \text{ for both Maha and Yala}$$

seasons

Internal crop consumption requirement for food security:

$$X_i \geq C_{oi}, \text{ for both Maha and Yala seasons}$$

Local marketing capacity requirement:

$$X_i \leq S_i \text{ for both Maha and Yala seasons}$$

3.4 Model simulations for different scenarios

The above three models were analyzed with the following three scenarios to study different cropping patterns:

Scenario I: Multi crop cultivation (Paddy, OFC and Vegetables) during both Maha and Yala Seasons.

Scenario II: Cultivation of OFC and Vegetables during both Maha and Yala Seasons.

Scenario III: Cultivation of Paddy during Maha Season, and OFC & Vegetables during Yala Season.

Microsoft Excel Solver (<http://www.economicsnetwork.ac.uk>) was used in this study to solve the above linear programming models developed for different scenarios. This analysis considered only six types of crops proposed in the study area, namely, paddy, manioc, kurakkan, cowpea, brinjal and maize.

4. Results and Discussion

4.1 Model 1: Maximize Net Profit in Both Maha and Yala Seasons

Results of this analysis are summarized in Tables 2, 3 and 4 for Scenarios I, II and III, respectively. In these Tables, crop types, cropping distribution (%) and net profit from each crop during Maha and Yala seasons are presented. Cropping distribution (%) indicated in the above mentioned tables are computed based on cropping area of a crop and the total irrigable area (1215 ha).

Cropped area estimated in Scenario I of Model 1 for paddy during Maha season is 294 ha. The above estimated area (294 ha) divided by total irrigable area (1215 ha) will provide the cropping distribution (24.24%). Similarly, cropping distribution of each crop is computed



based on the above method and results are in Tables 2 – 10.

Table 2 - Cropping distribution (%) and net profit in Scenario I of Model 1

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	24.24	1.33	3.74	-1.55	2
Manioc	5.46	0.30	4.22	-0.06	4
Kurakkan	18.18	1.00	15.15	-0.14	15
Cowpea	13.64	0.75	17.41	0.57	18
Brinjal	7.31	0.40	16.82	0.69	18
Maize	31.17	1.71	-8.23	-1.27	-10
Total	100	5	49	-2	47

Table 3 - Cropping distribution (%) and net profit in Scenario II of Model 1

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Manioc	7.20	0.30	5.57	-0.06	6
Kurakkan	24.00	1.00	20.00	-0.14	20
Cowpea	18.00	0.75	22.98	0.57	24
Brinjal	9.64	0.40	22.20	0.69	23
Maize	41.15	1.71	-10.86	-1.27	-12
Total	100	4	60	0	60

Table 4 - Cropping distribution (%) and net profit in Scenario III of Model 1

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	80.77		12.45		12
Manioc		0		0	0
Kurakkan		0		0	0
Cowpea		0		0	0
Brinjal		0		0	0
Maize		0		0	0
Total	81	0	12	0	12

4.2 Model 2: Maximize Irrigable Area in Both Maha and Yala Seasons

Table 5 - Cropping distribution (%) and net profit in Scenario I of Model 2

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	24.24	7.12	3.74	-8.27	-5
Manioc	5.46	1.60	4.22	-0.32	4
Kurakkan	18.18	5.34	15.15	-0.75	14
Cowpea	13.64	4.00	17.41	3.06	20
Brinjal	7.31	2.14	16.82	3.66	20
Maize	31.17	9.15	-8.23	-6.80	-15
Total	100	29	49	-9	40

Table 6 - Cropping distribution (%) and net profit in Scenario II of Model 2

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Manioc	7.20	4.32	5.57	-0.86	5
Kurakkan	24.00	14.39	20.00	-2.01	18
Cowpea	18.00	10.79	22.98	8.24	31
Brinjal	9.64	5.78	22.20	9.88	32
Maize	41.15	24.67	-10.86	-18.33	-29
Total	100	60	60	-3	57

Table 7 - Cropping distribution (%) and net profit in Scenario III of Model 2

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	80.77		12.45		12
Manioc		0		0	0
Kurakkan		0		0	0
Cowpea		0		0	0
Brinjal		0		0	0
Maize		0		0	0
Total	81	0	12	0	12

4.3 Model 3: Maximize Net Profit during Maha and Maximize Irrigable Area during Yala Seasons

Table 8 - Cropping distribution (%) and net profit in Scenario I of Model 3

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	24.24	7.12	3.74	-8.27	-5
Manioc	5.46	1.60	4.22	-0.32	4
Kurakkan	18.18	5.34	15.15	-0.75	14
Cowpea	13.64	4.00	17.41	3.06	20
Brinjal	7.31	2.14	16.82	3.66	20
Maize	31.17	9.15	-8.23	-6.80	-15
Total	100	29	49	-9	40

Table 9 - Cropping distribution (%) and net profit in Scenario II of Model 3

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Manioc	7.20	0.30	5.57	-0.06	6
Kurakkan	24.00	1.00	20.00	-0.14	20
Cowpea	18.00	0.75	22.98	0.57	24
Brinjal	9.64	0.40	22.20	0.69	23
Maize	41.15	92.76	-	-	-80
Total	100	95	60	-68	-8

Table 10 - Cropping distribution (%) and net profit in Scenario III of Model 3

Crop Type	Cropping distribution (%)		Net profit (Million Rupees)		
	Maha	Yala	Maha	Yala	Annual
Paddy	80.77		12.45		12
Manioc		0		0	0
Kurakkan		0		0	0
Cowpea		0		0	0
Brinjal		0		0	0
Maize		0		0	0
Total	81	0	12	0	12

4.4 Comparison of Different Scenarios Based on Annual Net Profits

Results of all optimization models for Scenarios I, II and III are summarized in Table 11.

Table 11 - Total annual net profit of all models for Scenarios I, II and III

Total annual net profit (Million Rupees)			
Scenarios	Model 1	Model 2	Model 3
Scenario I	47	40	40
Scenario II	60	57	-8
Scenario III	12	12	12

Results of this analysis indicate that (See Table 11), if the objective function is to maximize net profit (Model 1), the maximum total annual net profit is 60 Million Rupees from Scenario II of Model 1. But, total annual net profit of the same model from Scenario I is lower than Scenario II (47 Million Rupees).

On the other hand, if the objective function is to maximize irrigable area (Model 2), the maximum total annual net profit shown in Table 11 is 57 Million Rupees from Scenario II and 40 Million Rupees from Scenario I of Model 2.

Results of analysis for Model 3 indicate that total annual net profit is smaller than for Model 1 and equal to Model 2 except for Scenario II (See Table 11).

If the existing (Agriculture year 2012) traditional cropping pattern (%) is applied to the entire irrigable area (1215 ha) while considering other parameters and the constraints are same, the total annual net profit from this cropping pattern in both Maha and Yala seasons can be estimated around 26 Million Rupees.

4.5 Comparison of Different Scenarios Based on Irrigation Water Usage

Table 12 and Table 13 present the volume of water consumption in the proposed reservoir and added values of one cubic metre of water in all the models for Scenarios I, II and III. The added value of one cubic metre of water in this table is computed based on annual water consumption in the proposed reservoir and total annual net profit from each scenario. Table 13 illustrates the added value of one cubic metre of water used by agriculture for different cropping patterns.



Table 12 - Annual water consumption in the proposed reservoir (Million Cubic Metres)

Scenarios	Model 1 (MCM)	Model 2 (MCM)	Model 3 (MCM)
Scenario I	3.40	6.00	6.00
Scenario II	1.64	6.00	6.00
Scenario III	6.00	6.00	6.00

Table 13 - Added values of one cubic metre of water (Rupees per cubic metre)

Scenarios	Model 1 (Rupees /m ³)	Model 2 (Rupees /m ³)	Model 3 (Rupees /m ³)
Scenario I	13.9	6.6	6.6
Scenario II	36.4	9.5	-1.3
Scenario III	2.1	2.1	2.1

Results of this analysis indicate (See Table 13) that Scenario II of Model 1 will offer the maximum added value which is 36.4 Rupees per cubic metre of water. Comparison of total annual net profit versus added value of one cubic metre of water is indicated in Table 14.

Table 14 - Comparison of total annual net profit versus added values

Scenarios	Total annual net profit (Million Rupees)			Added value (Rupees per m ³)		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Scenario I	47	40	40	13.9	6.6	6.6
Scenario II	60	57	-8	36.4	9.5	-1.3
Scenario III	12	12	12	2.1	2.1	2.1

From Table 14, it should be noted that the maximum total annual net profit (60 Million Rupees) and the maximum added value of one cubic metre of water (36.4 Rupees) will be achieved only in Scenario II of Model 1.

On the other hand, if objective function is to maximize irrigable area (Model 2), the maximum annual net profit and the added values of one cubic metre of water are fairly reduced compared to Model 1.

5. Conclusions and Recommendations

5.1 Conclusions

The linear programming model is suitable for the analysis of different scenarios in managing available water in the proposed Kalugal Oya reservoir, resulting in optimal cropping patterns, showing the water requirement and annual net profits.

Considering agricultural year 2012, the total annual net profit gained from Scenario II of Model 1 is estimated to be 60 Million Rupees, which is almost two and half times greater than the profit obtained when traditional cropping patterns are used in these areas (26 Million Rupees).

Further, the highest annual net profit in Scenarios I and II of Model 1 was achieved mainly from the cultivation of Kurakkan, Cowpea and Brinjal. Moreover, the annual net profit from the cultivation of paddy and Manioc are very small compared to Brinjal. Also, Maize cultivation in this model consumes more water and provides only a negative value as an annual net profit which indicates that the farmers will not get any returns other than a loss. However, to satisfy internal crop consumption (C_{io}) of farmer families in these areas, the above crops were recommended for cultivation though it is not profitable.

Similarly, the highest annual net profit of Model 2 is also achieved from the cultivation of Kurakkan, Cowpea and Brinjal. However, total annual net profit in this model slightly decreases due to the Maize cultivation. In Model 3, the total annual net profit gained from Scenarios I and II are smaller compared to Model 1 and equal to Model 2 except for Scenario II (See Table 11).

Maize cultivation in Scenarios I, II and III of each model provides only negative values as annual net profits, which imply that cultivation of Maize is not advisable. Similarly, cultivation of paddy during Yala season also provides the same outcome in each model. Therefore, paddy can be recommended only during Maha season to satisfy their internal crop consumption by the farmer families as well as for marketing purposes.

It is also concluded that the maximum added value per cubic meter of water usage is 36.4 Rupees which is gained only from Scenario II of Model 1. On the other hand, Scenario III of each

model was equal (2.1 Rupees) compared to others.

5.2 Recommendation for Further Studies

- In this study three models were formulated and analyzed. The output of the above models suggests the optimum irrigation water to be applied over a given period. However, from a practical point of view, it is better providing the appropriate irrigation schedule rather than only proposing the amount of water to be used. This suggests integrating the current models with a mathematical scheduling model.
- Further, the above models were analyzed with three scenarios to study different cropping patterns. However, this study did not account for climate change which is usually important for crop water requirement. Future studies can consider climate change impacts on the cropping system too.
- The capacity of the proposed reservoir is 12 MCM. After the reduction of conveyance losses and dead storage only 6 MCM has been taken into account as readily available water whole year. However, from a practical point of view, discharging amount of water from a reservoir is larger compared to the actual capacity due to seasonal changes of inflow.
- Only four major constraints were considered in this model. Therefore, several additional constraints can be added to enrich the model and to account for realistic restrictions in the system such as type of soil etc.

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