Possibility of Increasing the Land and Water Productivity of Command Area in Labunoruwa Irrigation Tank, Anuradapura, Sri Lanka

M.B. Sharifi and N.T.S. Wijesekera

ABSTRACT

In Sri Lanka, farmers prefer to grow paddy because it is their staple food. The most common reason given for the shortfall is the lack of sufficient irrigation water to rescue crop when the rainfall is lean. The lack of irrigation water is dependant of two aspects. One is the lack of storage and the other is the poor water management. Out of the two, the latter is considered very important because it is an activity that can be easily influenced from the first day of recognition. Therefore, the aim of this study is to carry out a systematic case study application demonstrating the potential to investigate the possibility of increasing land and water productivity through the management of crop types (Paddy, green gram, soya bean and cowpea) grown in each season. Irrigation department guidelines were used for computation of irrigation demand, evapotranspiration requirements and selection of the value of crop growth stages, crop factors and land preparation for Maha season and Yala season with 105 days and 135 days duration for paddy and OFC respectively. Land preparation water requirement, farm loss and the project efficiency were assumed as uniform inputs for all spatial units. Reservoir water balance model based on Irrigation Department guideline was applied to determine the smallest capacity of reservoir that would be required for cultivation of the largest required irrigable area for a pre-determined cropping pattern and intensity for both seasons. After computation of irrigation demand and reservoir water balance modeling, it was found that in all four options, full command area (100%) could be cultivated while in Yala season this result differs as follows. In option 1, paddy was considered for 16% of the command area, while in option 2 this cultivation could be as 10 % of the command area paddy and 28% of the command area green gram. In option 3 and option 4, the cultivable areas were found as 10% for paddy along with 19% for soya beans and 10% for paddy along with 21% for cowpea respectively. Consequently, the second option in which 10 % of the command area was considered for paddy and 28% of the command area for Green Gram was found as a best option to be practiced under Labunoruwa Irrigation Tank in order to increase the water productivity.

KEYWORDS: Irrigation, Water Productivity, Irrigation demand, Crop changing, Paddy & Green Gram, Labunoruwa Tank Sri Lanka

1. Introduction

Water availability plays an important role in agricultural. The world population is growing at a fast rate resulting in rising demand for household and irrigation water. Therefore, in the past decades irrigation water supply systems are under huge pressure in fulfilling the irrigation water requirement (Khan et al. 2009). Water resources can play a significant role in improving food security and household income. Irrigation is the most common means of ensuring sustainable agriculture and coping with periods of inadequate rainfall and drought (Dessalegn, 1999). Food security is becoming a major issue in today's society and irrigated agriculture is in the center of this discussion not only because it constitutes approximately 20% of the world's total cultivated farmland, but mainly because it responds for 40% of the food and fiber production (Hoffman and Evans, 2007). In the 20th century, worldwide irrigated area experienced a huge expansion of more than 500% with an increasing from 40 million to 270 million ha of irrigated land. Such numbers are part of the ability of humankind to produce food fast enough to meet population growth. But that remarkable ability, on the other hand, has its cost – a water crisis, characterized by water scarcity and competition, pollution and malnutrition (Molden, 2003). Experts' estimates

That demand for food crops will double during the next 50 years with limited land and water resources, farmers need to increase their output from existing cultivated areas to satisfy the food demand of increasing population. Irrigation systems will be essential to enhance crop productivity in order to meet future food needs and ensure food security. However, the irrigation sector must be revitalized to unlock its potential, by introducing innovative management practices and changing the way it is governed. (G. Pakhale et al, 2011).

Irrigation management is normally defined as "a process by which institutions or individuals set objectives for irrigation systems, establish appropriate conditions and identify, mobilize and use resources so as to attain these objectives

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while ensuring that all activities are performed without causing adverse effects" (IIMI, 1992). Participatory irrigation management has been considered as the driving force in the effective and efficient irrigation management by participating and involving the farmers in planning, operation and maintenance of the irrigation system (Gulati et al. 2005). Farmer- managed irrigation systems are found in varied environments and exploit a wide range of technologies to take advantage of different types of water sources for production of a diversity of crops. All these irrigation systems, however, require that certain indispensable tasks be accomplished if the system is to function productively (Edward and Robert, 1987). Small multi-purpose reservoirs are a widely used form of infrastructure for the provision of water. They supply water for domestic use, livestock watering, small scale irrigation, and other beneficial uses. Although clusters of reservoirs store significant quantities of water and effect on downstream flows, they have rarely been considered as systems, with synergies and tradeoffs resulting from their numbers and their density. (Simonne et al, 2012).

Sri Lanka has an average production of Paddy reaching 3,876,000 MT per annum (Department of Census and Statistics Sri Lanka [DCS], 2008). The rural economy in Sri Lanka has revolved around paddy cultivation. Rice forming is not merely a livelihood; it is considered a way of life. With the advent of colonial rule, the domestic agriculture sector, especially farming in the dry zone areas was neglected. Historically the minor tanks have played a vital role in cultivation of crops in the dry zone of Sri Lanka, due to lack of maintenance of the head-works and distribution systems. Sri Lanka's dry zone consists of a vast number of minor reservoirs called village irrigation tanks Wijesekera (2011). He has quoted Fernando (1982) reports that there had been 35000 minor reservoirs in the island and more were being discovered. Theses reservoir are the pivotal point of dry zone farming communities. Sivayoganathan et al (2003) quoting, Merry et al (1988), reports that Irrigation systems under gravity irrigation in Sri Lanka can be categorized according to the size, water source and management. Major irrigation system is defined as one that has a command area of more than 1000 ha and medium schemes between 80 and 1000 ha. Small tanks or minor irrigation systems are those having an irrigated command area of 80 ha or less. Presently average duty of water use in Sri Lanka is approximately 1300 mm in the Maha season and 1770 mm in Yala the season (Imbulana & Merrey, 1995). There are over 600,000 hectares (ha) of irrigated farmland in Sri Lanka. Cultivation takes place during the two seasons with an average cropping intensity of 1.65. The main irrigated crop in the country is paddy (94% of irrigated area), with an average yield of 4.3 tones (t)/ha, and a surplus is being produced at the moment. While the current productivity ranges between 0.2-0.5 kilograms (kg)/cubic meter (m3), the irrigation efficiency at systems level is about 35-45% (IWMI, 2010). In Sri Lanka water schedule preparation and planning is done using the guidelines of the Department of Irrigation (Ponrajah,A.J.P, 1988).

In this case study, full command area cannot be cultivated in Yala seasons therefore it will affect living standard due to low income hence, to study the possibility of increasing land and water productivity of the scheme, irrigation management plays an important role because a better use of water not only supports more area to be reliably cultivated but also keeps the farmers secure.

1.1. Study Area

Labunoruwa Tank is situated in Anuradapura district of Sri Lanka. Its geographical coordinate is Latitude 80 9' 55" and longitude 800 36' 38". The tank is fed from rain through 7.55 km^2 of catchments area and its water is used for paddy cultivation of around 259 Ha of command area in Yala and Maha seasons.

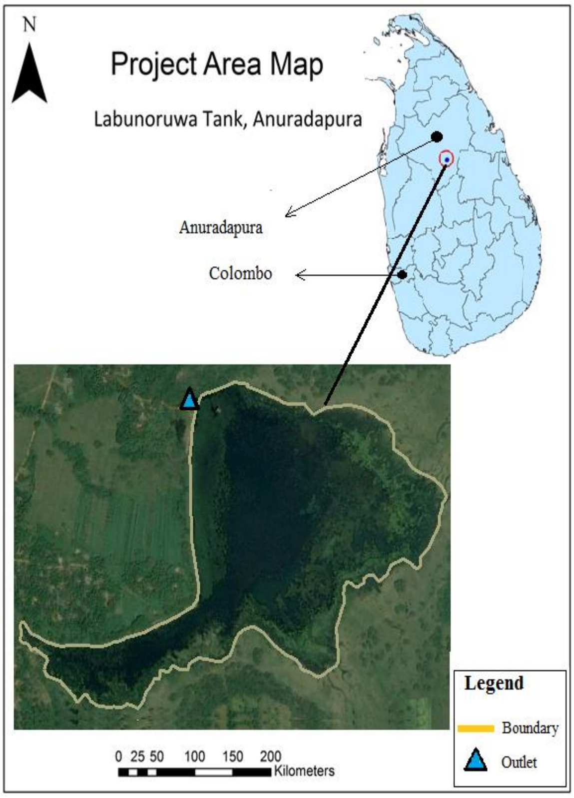

Figure 1. Area Map

2. Approach and Methodology

2.1. Data Collection

75% probable monthly rainfall, evaporation, reference crop evapotranspiration and yield map for Maha and Yala seasons were collected from Eng. A.J.P. Ponarajah's book (Head works for small catchments), while tank data, crop data and catchment data were collected from Irrigation department. The prepared spreadsheets (based on

Irrigation Department guideline) by Pro. N.T.S.Sohan.Wijesekera were used for reservoir operation and calculation of irrigation water requirement.

2.2. Methodology

a) The required data was collected.
b) Situation analysis was done to know about the past and current performance of the area.
c) Water requirements for different crops and paddy were calculated.
d) Reservoir operation was done to determine the smallest capacity of reservoir that would be required for cultivation of the largest required irrigable area for a pre-determined cropping pattern and intensity for both seasons.
e) Crop patterns were changed to find the maximum area to be cultivated in Yala season.
f) All options were evaluated and finally the best option was found and proposed to be practiced in order to get more productivity with less water consumption.

3. Analysis and Calculations

3.1. Cultivation Performance

Full command area is being cultivated in Maha season while in Yala season the full command area cannot be cultivated due to water shortage. Since the farmers prefer the cultivation of paddy over other crops in both seasons therefore, they cannot get sufficient producs in Yala season due to less products. The crop intensity in Yala season is maintained in Figure 2.

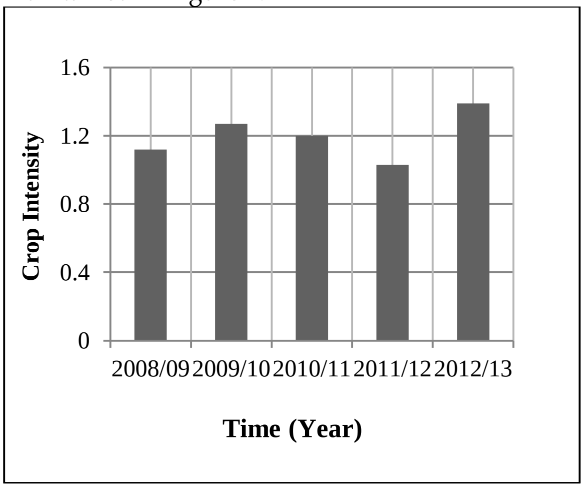

Figure 2. Crop intensity from 2008 to 2013

3.2. Calculation of Irrigation Demand

An irrigation water demand model in monthly time step according to the irrigation department guideline was applied for selected crops. Because, each crop has a specific crop water requirement depending on its crop development stage would require an amount of water as irrigation demand, given the land preparation requirements, farm losses and project efficiencies. Leading equations used for the computations are as follows.

$(FWR)t=(LP)t+(ETc)t+(FL)t$ …………..….. (1)
$(FIR)t=(FWR)t-(ER)t$ ………………... (2)
$(ID)t=(FIR)t/\eta$ ……………...…. (3)
$(ID)seasonal =\sum t^{n}(ID)t$ …………...… (4)

In these equations t is the time step for computation and n is the number of time steps per period. FWR is field water requirement, LP is water requirement for land preparation, ETc is the water requirement for crop evapotranspiration and FL is the water requirement to recompense for farm losses. FIR is the field irrigation requirement, ER is the effective rainfall, ID is the irrigation demand and η is the project efficiency.

Rainfall and evapotranspiration data were taken as input for model computations. Crop types were selected by farmers for both seasons Land preparation water requirement, farm loss and the project efficiency were assumed as uniform inputs for all spatial units since no spatially distributed data on crop types, planting dates etc., were available.

There are two types of paddy cultivation in Sri Lanka. These are with 105 days and 135 days duration and are recommended for Maha and Yala seasons respectively (Ponrajah, 1988). Accordingly the irrigation demand was computed for Maha season and Yala season with 105 days and 135 days duration respectively. In the OFC cultivation area, it was assumed that the same crop was cultivated and these crops were taken as green gram, soya bean and cowpea. For the computation of temporally distributed evapotranspiration requirements, the value of crop growth stages and crop factors given in the Irrigation Department guideline were used. According to the irrigation department, information for land preparation work given in the ID guidelines are generally used for irrigation system planning and design in Sri Lanka, and, therefore the ID guidelines for land preparations were used and land preparation for the Maha and Yala seasons was taken to commence in the months of October and May respectively.

3.3. Reservoir Operation

An operation study is carried out for Labunoruwa Tank to forecast the performance of cultivation under the tank in Maha and Yala season and to monitor the water management. In other word, reservoir operation was done to determine the smallest capacity of reservoir that would be required for cultivation of the largest required irrigable area for a pre-determined cropping pattern and intensity for both seasons, considering to changes in inflow from rainfall, evaporation on reservoir water, irrigation demand due to crop water requirements of paddy for Maha season and paddy along with one OFC for Yala season. Model computations were based on reservoir water balance systems described in the guideline of Irrigation Department (ID 1984). Leading equation for water balance of reservoir system is shown in equation 5.

$$It - (Et + Sei + Spt + Dt) = St - St\text{-}1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

In this equation, t is the time step which was considered as one month, I is the inflow, E is evaporation from water surface, Se is the seepage from the reservoir bed, Sp is the spillage from the reservoir.

After reservoir operation it was found that, full command area (100%) can be cultivated in Maha season but, in Yala season full command area cannot be cultivated due to water shortage. Therefore to increase the water productivity in Yala season, crop types was changed and the investigation was done for the following four options to find the best option. In option one paddy was selected and it was found that 16% of the command area could be cultivated due to the water availability. For option 2, option 3 and option 4, for 10% of the command area paddy was allocated and for the rest of water different crops were selected as follows. Accordingly, for option 2, option 3, and option 4; green gram in 28% of the command area, soya bean in 19% of the command area and cowpea in 21% of the command area could be cultivated respectively.

4. Results and Discussion

4.1. Calculation of Irrigation Demand

In Maha season, full command area can be cultivated while in Yala season it cannot be cultivated and differs due to water shortage. Therefore, different types of crops were considered for Yala season to find the option with less water consumption and more productivity. The irrigation demand for all four options for paddy cultivation in Maha season was calculated as 1054.58 mm, and for Yala season it was found as 1860mm.

4.1.1. Option 1

In this option paddy was considered. Accordingly the irrigation demand was calculated as 1860.56 mm for Yala season. In Yala season for 16% of the area this value was found as 76.73 mm. Irrigation requirements for option 1 for both season and for the cultivable area are indicated in Figure 3 and Figure 4 respectively.

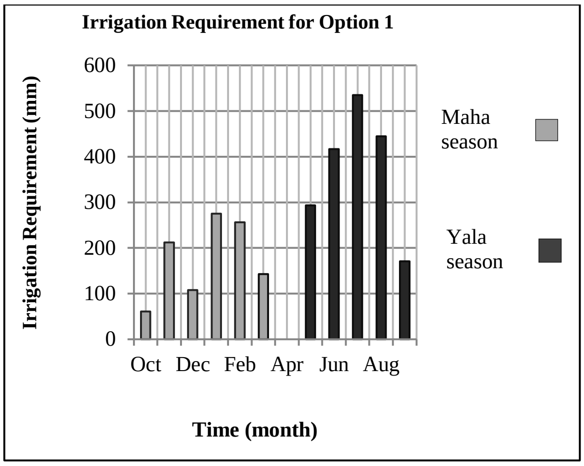

Figure 3: Irrigation Requirement for Option

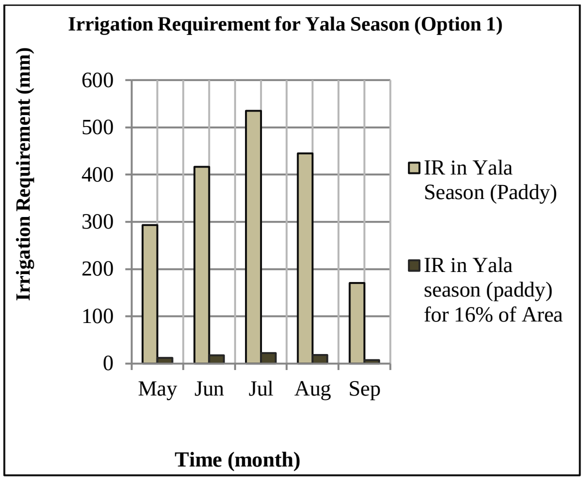

Figure 4: Irrigation Requirement in Yala Season (Option 1)

4.1.2. Option 2

In this option for Yala season, paddy along with green gram was considered (shown in Figure 5). Accordingly the irrigation demand was calculated as 1860.56 mm for Yala season. The irrigation demand for Yala season (Figure 6) for the 10% paddy and 28% green gram was found as 47.96mm and 57.75 mm respectively

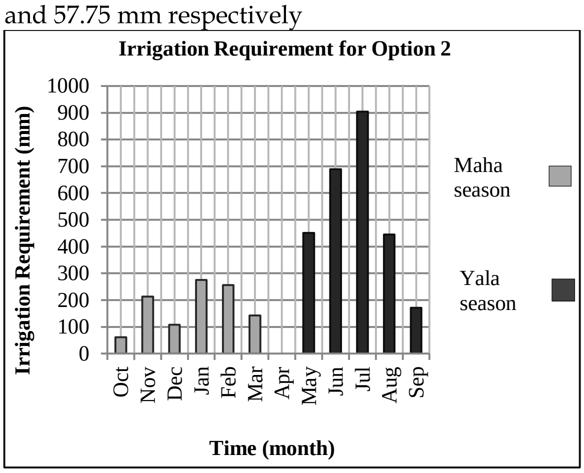

Figure 5: Irrigation Requirement for Option 2

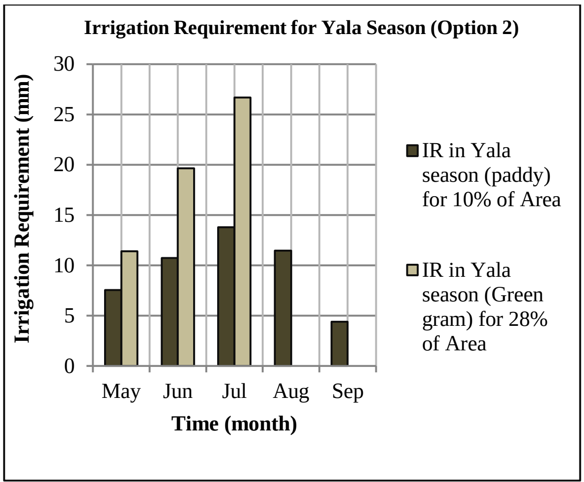

Figure 6: Irrigation Requirement in Yala Season (Option 2)

4.1.3. Option 3

For option 3 paddy with soya bean for Yala season were considered. The irrigation requirement for Maha season and Yala season were found as 1054.58 mm and 1231.03 mm respectively. These values in Yala season for the Cultivable area each 10% paddy and 19% soya beans were found as 47.96 mm and 60.29 mm respectively. Figure 7 and Figure 8 shows the irrigation requirement for option 3 and specifically for Yala season.

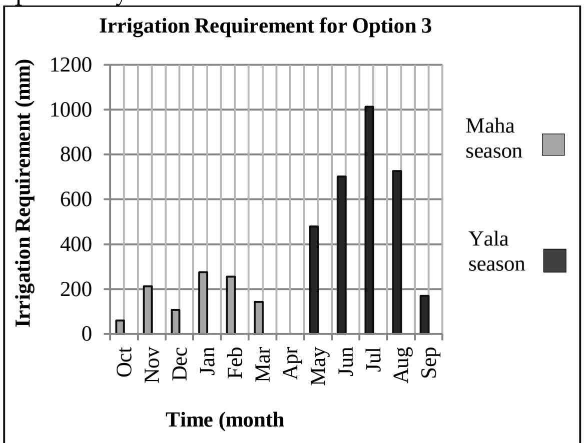

Figure 7: Irrigation Requirement for Option 3

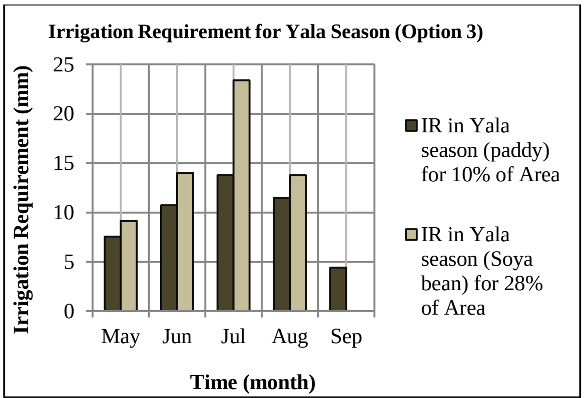

Figure 8: Irrigation Requirement in Yala Season (Option 3)

4.1.4. Option 4

Cowpea and paddy in Yala season and paddy for Maha season were considered. 1128.45 mm and 1054.98 were the calculated irrigation requirement for Yala and Maha seasona respectively. The irrigation requirement for Yala season for the cultivable area of 10% paddy and 21% cowpea were found as 47.9 mm and 61.1 mm respectively. Figure 9 and Figure 10 show the irrigation requirement for option 4 and Yala season respectively.

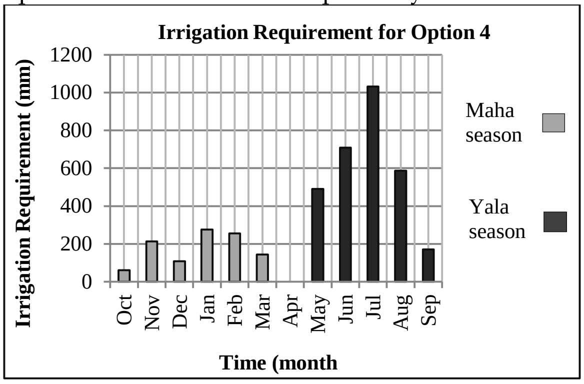

Figure 9: Irrigation Requirement for Option 3

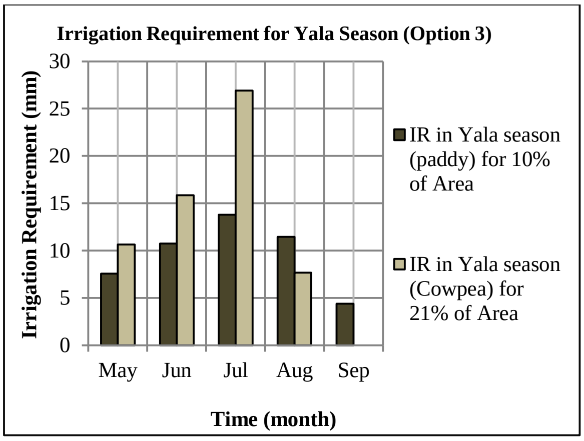

Figure 10: Irrigation Requirement in Yala Season (Option 4)

4.2. Reservoir Water Balance Modeling

Reservoir water balance model was applied for the irrigable area under the reservoir for Maha and Yala season considering changes to the inflow from rainfall, evaporation, irrigation demand due to changes in crop water requirement etc. All computations for reservoir water balance modeling were described in irrigation guideline ID (1984).

After comparison of all four options it was realized that the second option which was 10% of the command area paddy and 28 % of the command area green gram was found as the best option in terms of less water requirement and more productivity.

4.2.1. Option 1

For both seasons paddy was considered and consequently it was revealed that full command area could be cultivated in Maha season while 16% (41.24 ha) of the total area is cultivable in Yala season. Reservoir water balance modeling for option one is shown in Figure 11.

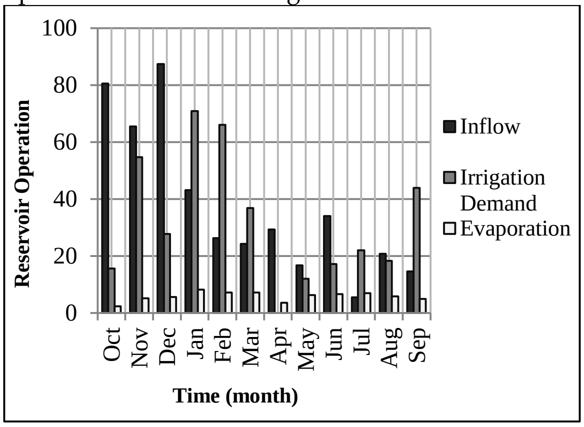

Figure 11: Irrigation Requirement in Yala Season (Option 1)

4.2.2. Option 2

Paddy and green gram for Yala season and Paddy for Maha season was considered. After application of reservoir water balance model, it was found that in Yala season 10% (41.24 ha) paddy and 28% (72.17 ha) green gram could be cultivated according to the available water, while the full command area can be cultivated in Maha season. Figure 12 shows reservoir water balance for option 2.

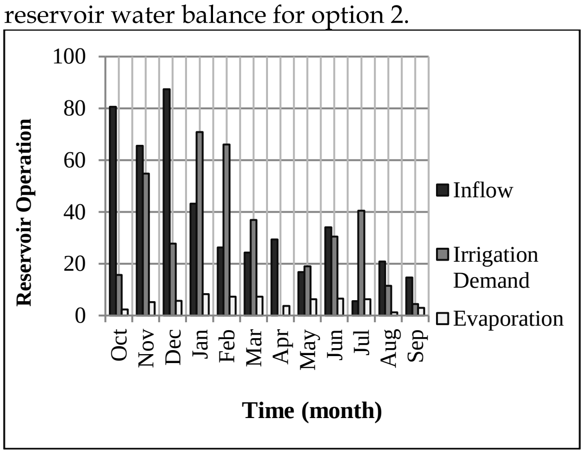

Figure 12: Irrigation Requirement in Yala Season (Option 2)

4.2.3. Option 3

Paddy for full command area in Maha season and paddy with soya bean for Yala season was considered for option 3. Reservoir operation was done and it was revealed that in Yala season 10% (25.77 ha) paddy and 19% (48.97 ha) soya bean could be cultivated. Figure 13 indicates reservoir water balance for option 3.

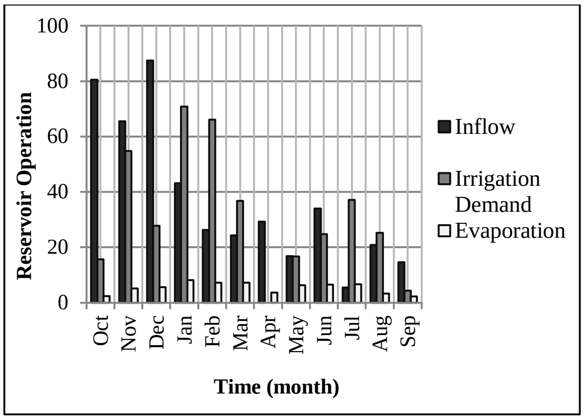

Figure 13: Irrigation Requirement in Yala Season (Option 3)

4.2.4. Option 4

Paddy and cowpea are the crops that were considered for option 4. After reservoir operation (Figure 14), it was realized that full command area can be cultivated in Maha season while, 10% (25.77 ha) paddy and 21% (54.13 ha) cowpea could be irrigated due to available water in Yala season.

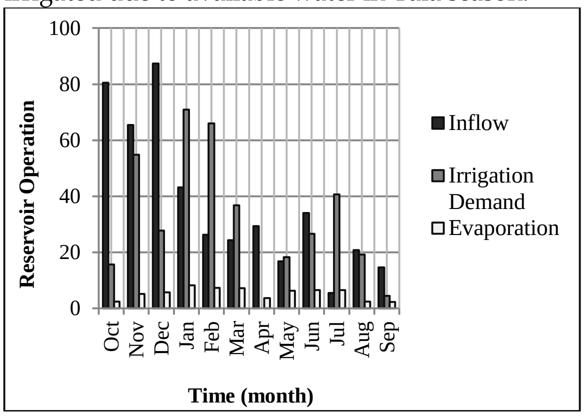

Figure 14: Irrigation Requirement in Yala Season (Option 2)

Among the all four options, the second option was identified as best and suitable option due to less water demand (3.77 MCM) and more productivity. In this option, there is possibility of cultivation in Maha season 100% Paddy (257.78 ha), while in Yala season there could be possibility to cultivate 10 % Paddy (41.24 ha) with 28% Green Gram (72.17 ha).

5. Conclusions

1) All necessary data were collected. Situation analysis was done to see the cropping intensity and cultivation performance and it was realized that full command area in Yala season cannot be cultivated due to water shortage.
2) After evaluation of cultivation performance, paddy, green gram, soya bean and cowpea were selected and the irrigation demand was calculated for each crop.
3) Reservoir water balance model was applied for all four options to find out the best option in order to improve water productivity. After computation, it was found that full command area can be cultivated while this result differs

for Yala season as follows. For option 1, only paddy was considered and it was found that 16% of the command area can be cultivated. Since paddy need more water therefore, the percentage of paddy cultivation was reduced from 16% to 10% and one more crop was selected along with paddy for option 2, option 3 and option 4, in order to improve the water productivity. After computations, Green gram for the 28% of the command area, soya bean for 19% of the command area and cowpea for 21% of the command area were found for option 2, option3, and option 4 respectively.

4) After comparison of all four options, the best option which is 100% Paddy in Maha and 10% paddy Yala with 28% Green gram was selected as best option to be practiced in order to improve the water productivity under Labunoruwa Irrigation Tank.

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