Drought Resilient Farming System through Crop Diversification: The Case of Huruluwewa

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ABSTRACT: Drought is one of the major disasters in Sri Lanka and frequent water scarcities during dry season and even distribution of irrigation water through the canal network are two major challenges confronted by irrigation engineers. This study examines how to increase the net income of farmers by efficient water usage in Huruluwewa in dry season through crop diversification. The general objective of the study was to identify an optimal crop mixes along the canal net-work that maximizes net income of the farmers while efficiently using irrigation water. The water availability along the canal was measured through the water flow measurements. Sample of 10 farmers were randomly selected from head, middle and tail ends along the distribution canal 2 of Huruluwewa. A structured questionnaire was used to gather data. Linear programming models were developed for each of the 30 farmers and for three areas of head end, middle and tail end of the canal. Paddy, soybean and maize were selected as potential crops. The season was divided into 16 weeks and constraints were constructed weekly for all head, middle and tail. The crop mix solution of the D2 canal is 17.82% paddy, 20.36% soybean and 43.36% maize in head, in middle 14.43% paddy, 21.06% soybean and 55.23% maize and in tail 11.95% paddy, 24.05% soybean and 56.04% maize. Crop diversification away from paddy can not only increase net income of farming but it also increases efficiency in water usage.

1 INTRODUCTON

Among all identified 21 natural and man-made disasters in the Sri Lanka according to 'The Disaster Management Act No. 13, 2005' of the Government of Sri Lanka drought is listed as the most frequent disaster (Chithranarayana & Punyawardane, 2008). The main consequence of drought is, it reduce the water availability in particular period over a particular area as reported by the Beran & Rodier (1985). As the agricultural drought prevails in the country it leads to severe water scarcity in the dry seasons as the shortage of precipitation leads to low water availability in the reservoirs and it results in the water shortage for the irrigation lands and inefficient irrigation water management not only for the agricultural lands and also for various domestic uses and other needs.

In Maha season rain fed cultivation is mainly practiced as the water requirement is fulfilled through the high amount of precipitation. In Yala season where the water is scarce agricultural practices are highly dependent on irrigation water. In order to give solution for water scarcity and to make the water economically important for farmers, reservoirs and canal networks had been constructed in Sri Lanka through the Mahaweli Development Project. And it is primarily to supply water for the low land paddy fields in Sri Lanka where lack of rainfall is a major problem (Kularatne, 2011). Irrigation plays a vital role in agriculture production in Sri Lanka (Sivayoganathan & Mowjood, 2003). Despite the farmers are facing water scarcity problems as in Yala season due to increasing trend of temperature and decreasing trend of seasonal rainfall in Sri Lanka. Because of that the water storage in the reservoirs are severely affected and it is leading to reduction in water supply (Eriyagama, et al., 2010) equally to all the farms in canal network. This is high during the times when drought is experienced.

Sri Lankan farming communities are facing severe drought since 1974 continuously. There are about 283 dry spells occurred in 30 years of period from 1974. Even though disaster is a natural phenomenon it has socio and economic impacts on the living organisms. From the tank to field there is a long distance along the canal and the irrigation operators do not have full control over the canal inflow and usage of water along the canal. Therefore the distribution of water among the fields evenly is a complicated issue (Clemmens, 2012) and there are various problems found in irrigation canal network such as limited water availability, higher water consumption by the fields near the canal, illegal poaching of water along the canal, natural vegetation along the side of the canals, water losses due to canal erosion and etc. (Bosch, et al.,

1992). Therefore when irrigation network conveys the water to the field from canals the volume of water along the canal decreasing and tail end receives less water compared to the head end of canal in water scarcity periods (Hussain, et al., 2007).

To achieve the optimal crop yield from agriculture, it is necessary to supply timely and adequate amount of water required by the crop (Arunkumar & Ambujam, 2010). Crop diversification leads to efficient use of irrigation water and increase of production. Therefore developing an optimal crop mix mixture will increase the value of water along the canal (Murray-Rust, et al., 2003). Therefore, this study mainly concerns on the improvement of the farming efficiency and irrigation efficiency with decreasing availability of water with respect to changing climate and the applicability of other field crops (OFC) to increase economic efficiency of water through crop diversification.

2 RESEARCH SCOPE AND OBJECTIVES

Sri Lankan irrigation system water management is in strategic level and all the institutions involved have knowledge on the macro level water allocation. However in micro level they do not have such models developed for water allocation within a given system which at the operational level. Based on the traditional knowledge and experience gained, regional officers are making assumption for the water allocation.

The existing system in Huruluwewa scheme has many complex problems. The Irrigation Department only collects and monitors the amount of water released at the head of each main canal. At the distribution canal levels were not calibrated hence the department's knowledge in knowing the actual water distributed along the canals is unknown and the field canal level is controlled by the farmers' organizations which they have no mechanisms to monitor the water flow.

There are no models for inflow measurements and no any fixed model for water distribution. If any canal faced the water scarcity or shortage they just rotate the water to that on ad-hoc basis, by reducing the amount of water in other canals and release to required canal with a certain degree of complexity. Hence, in order to use water efficiently there should be a technical change in cultivation practices. This research paper is going to investigate, how crop diversification affects the net income of farmers and productivity of water usage in Huruluwewa major irrigation scheme during the Yala season.

The main objective of the study is to examine the effects of crop diversification and its effect to livelihood change along the canal network.

The specific objectives are,

1. To determine the optimum crop mix according to the water availability.
2. To determine the economic value of the irrigation water spatially and temporally.
3. To estimate the farmer's income change according to the optimum crop mix.

3 METHODOLOGY

3.1 *Theoretical consideration and Empirical model*

The mathematical formulation of the linear programming analysis is a sum of a linear function of a number of variables to be maximized subject to a number of constraints in the form of linear equalities and inequalities. The objective function was to maximize net revenue where,

Maximize $Z = \sum C_j X_j$ …….…. (1)
Subject to a set of constraints,
$\sum a_j x_j \leq b_i$…… (2)
$X_j \geq 0$

Where:
Z – Value of the objective function (Net revenue or profit)
X_j – Level of the jth decision variable
C_j – Net revenue to fixed farm resources per unit of jth decision variable
a_j – Input of the resource per unit of the jth decision variable
b_i – Availability of the resource
$X \geq 0$ – Non negativity constraint

Model Development:

Equation 1 describes the net revenue expected from the decision variable which is acreage of the particular crop based on the resource constraints of equation 2 which is further broken down into land constraint, family labor hour constraint, water constraint and muddy land extent constraint (The land extent in the field where only paddy can be cultivated due to its high moisture content).

In general, different crops mature at different ages although they initially planted at the same time.

This is due to difference in crop duration and life cycle of the crop (Mohamad & Said, 2011). Thereby including the time variation in each constraint is essential in analysis. Each constraint is constructed for each week of the yala season where the yala season (April to August) is divided into 16 weeks.

In the case of net revenue the cost of crop cultivation deducted from the farm income.

C_j = Income per acre – Cost of inputs per acre

All the input costs including seeds, fertilizer, chemicals, hired labors and machineries deducted from the income of the crop per acre.

Maximize $Z = \sum C_j X_j$
Subject to:

Land:	$\sum a_{1jt} x_j \leq b_{1t}$
Family labor hours:	$\sum a_{2jt} x_j \leq b_{2t}$
Water:	$\sum a_{3jt} x_j \leq b_{3t}$
Muddy land extent:	$\sum a_{4jt} x_j \leq b_{4t}$
Non negativity constraint:	$X_j \geq 0$

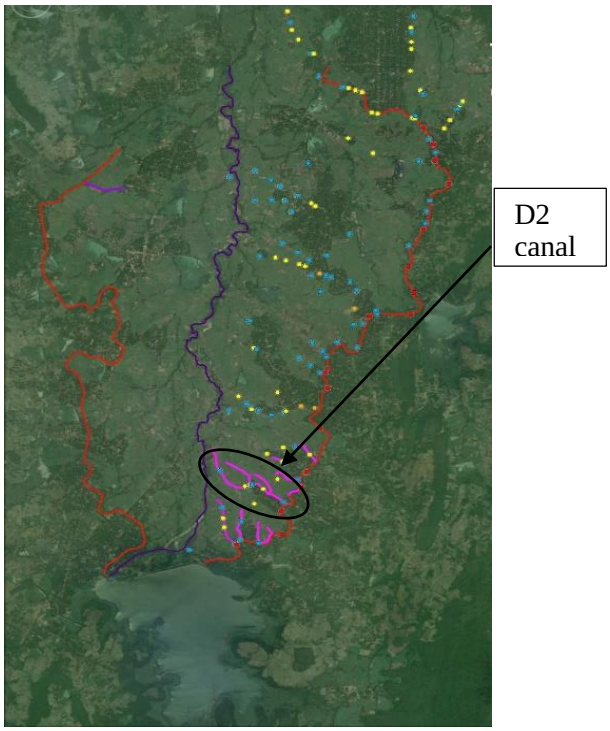
Where: $j = 1, 2, \ldots\ldots, m$
$t = 1, 2, \ldots\ldots, n$

3.2 *Study area and Data collection*

The Huruluwewa major irrigation scheme is located in Anuradhapura district which is in north central dry zone of Sri Lanka under the jurisdiction of the Galenbidunuwewa Divisional Secretariat Division of the Anuradhapura District. It has two main (Right and left) channel and 16km distance each. Its commanding area is more than 80 hectares therefore, it identified as one of major tank and irrigation scheme in Sri Lanka.

The study is focused on the right bank main canal. The right bank main canal has 13 distribution canals including two branch canals. The branch canal no. 1 branches into distribution canals 5 and 6. And the branch canal no. 2 branches into distribution canals no. 7, 8 and 9. There are five types of farming community clusters in the right bank main canal area. They are, irrigated lands from main canal, irrigated lands from distribution canals, irrigated lands from branch canals, irrigated lands from field canals and irrigated lands using drainage canals.

The study is specifically focused on Distribution canal 2 (D2). This canal feeds 97 individual fields through 8 field canals. Each field is averaged 3 acres of plot and also there are 10 acres of reservation land which is cultivated by farmers. Altogether the total command area is 301 acres.



The D2 canal stratified as head, middle and tail end. Sampling technique is stratified random sampling. From each part of the head, middle and tail ends 10 farmers were selected randomly along the canal. The total sample size is 30 farming households. The aim of the study is to propose a crop mix to increase the productivity of the water in terms of water usage efficiency and ultimately increasing the net revenue of the farmers. The data for this study was obtained through primary data, which is gathered by pre structured questionnaire. The questionnaire was administrated faced to face method with close ended questions. Questionnaire survey was conducted during October in 3 GN divisions no. 193- Nuwaraeli Colony, 194-Kurunegala Colony and 195-Nuwaragam Colony.

And to identify the constraints semi-structured interviews were made with the Farmers Organization leaders and constraints selected are Land, Water, Family Labor hours and the muddy part of the land area where only paddy can be cultivated and OFC cultivation is difficult due to its high moisture content of the soil. And also paddy, soybean and maize were selected as the crops for the optimum crop mix as these crops are mostly cultivated by the farmers in Huruluwewa in the yala season and require more irrigation water.

The crop water requirement and the life stages of the crop data gathered through the secondary data

from Department of Agriculture and from literature. The data on water availability calculated through the water flow measurement and secondary data on water distribution from the Irrigation Department, Huruluwewa.

3.3 *Water availability calculation*

Department of Irrigation issues water in a rotational basis within the system after the land preparation stage. In general the rotation of water issue is for 10 days, though it varies depending on the weather conditions in a particular season. For single rotation the D2 canal receives water for 2.5 to 3 continuous days. In the D2 canal due to its improper construction of the turnout gates in the head of field canals all 3 days water issued for all the field canals.

Therefore the water availability in the canal was calculated based on the time period issued and the water flow. In order to build up water constraints weekly wise the total time the water issued in a week taken as T.

$$Q = (V*T)/A$$

Where;

Q – Volume of water (m^3)
V – Velocity of the water along the canal (m^3/s)
T – The total time period water issued (s)
A – The commanding area under D2 canal (m^2)

4 RESULTS AND DISCUSSION

4.1 *Socio-economic status of the farmers*

Paddy and Soybean were the mostly cultivated crops in the low land of this area. Farmers were also cultivating maize in their Chena lands where the water is separately taken from the upper catchment area of Huruluwewa. Paddy cultivation is 62% and Soybean cultivation is 32%. Other crops such as big onion and vegetables were cultivated in a small proportion when considering the whole D2 canal system. The farmer's cultivation practice in 2015 is summarized in Table 1.

Household labor contribution is fluctuating ranging from 1 to 3. But in all the farming household only the head of the family involving in the farming activity full time. The average hours the farmer works in a day is 8 hours and hires labors for the rest of farming activities. The data from the survey shows that farmers' confidence on their own knowledge in both paddy and OFC cultivation. More than 85% of the farmers have confidence in their own knowledge in each paddy and OFC cultivation in the sample farming household population. This shows adoption of the farmers to OFC cultivation from traditional paddy cultivation practice is possible.

Table 1: Summary table of 2015 yala cultivation

Variable	Head	Middle	Tail
Mean Low land extent per household (acre)	2.53	2.43	2.3
Mean low land cultivated in yala 2015 per household (acre)	2.53	2.43	2.3
Mean Muddy part of the of low land per acre (acre)	0.18	0.14	0.12
Percentage of paddy cultivation	68%	62%	57%
Mean paddy yield per acre (Bushel)	88	86	77
Percentage of OFC cultivation	32%	38%	43%
Mean Soybean yield per acre (Kg)	664	598	572

4.2 *Water availability and yield variation*

Figure 1 presents the drop of water availability along the canal shown in the Figure. When water passes along the canal water is consumed by the famers. Therefore, the available water in the canal is decreasing along the canal.

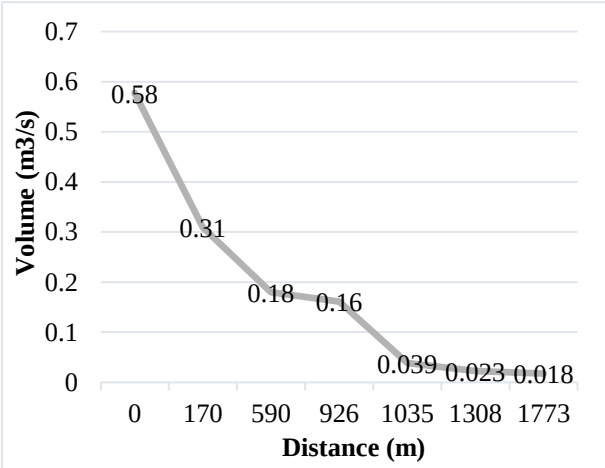


Fig. 1 Volume of water variation along the D2 canal

4.3 *Water availability and income distribution*

A variation in farm income can be seen in this canal along the head, middle and tail. They are Rs. 8,691.68, Rs. 27,610.31 and Rs. 25,523.1 in head, middle and tail end areas respectively. The mean net revenue per acre in head end area is lower than the middle and tail-end area. It is because the paddy cultivation in the high-end area is higher than the

other two. The net revenue from the paddy cultivation is lesser than the OFC cultivation. Therefore, the income of high-end farmers is lower than the middle and tail-end farmers.

There is a high variation of farm income among the farmers. In middle and tail end areas some farmer's farm income are high. This is because farmers in the middle and tail area cultivating less paddy and more OFCs. The net revenue from paddy is lesser than the OFCs. Even though the farmers facing a water scarcity problem in tail areas there net income is higher due to OFC cultivation.

4.4 *Crop mix solution*

The Linear programming model was separately run for the head, middle and tail of the canal. The maximum net revenue that can be obtained from the optimum crop mix and the land allocation for the each crop were given in the table 2.

Table 2: Linear programming solution with muddy area constraint

	Head	Middle	Tail
Maximum Net revenue (Rs.)	36,891.74	41,478.05	42,485.96
Paddy (Acre)	17.82%	14.43%	11.95%
Soy Bean (Acre)	20.36%	21.06%	24.05%
Maize (Acre)	43.36%	55.23%	56.04%

The different optimum solution was found when running the linear programming model separately to head, middle and tail part of the canal. In the optimal solution the acre of the land cultivation of each crop has been obtained. In the head area the paddy area extent is 0.1782acres, Soybean area extent is 0.2036acres and maize area extent is 0.4336acres. In the middle area the paddy area extent is 0.1443acres, Soybean area extent is 0.2106acres and maize area extent is 0.5523acres. In the tail area the paddy area extent is 0.1195acres, Soybean area extent is 0.2405acres and maize area extent is 0.5604acres.

There is a relationship between net revenue and crop cultivation in the optimal solution. Where the paddy cultivation area is lower the net revenue is high. The paddy extent is higher in the head area than middle and tail. In the middle area it is higher than the tail. The net revenue is less in the head than middle and less in middle than tail. This is due to the net revenue from the paddy cultivation is less than the Soybean and maize as the paddy price is lower with comparing to the other two crops. Although the other constraints are similar the muddy area constraint is different in all three parts. In the head area it is higher than other two as well as it is higher in the middle than tail. Therefore in the optimal crop mix the paddy extent is differing and there is an income difference. The results also showed that all the three crops are economical.

4.5 *Economic value of Irrigation water*

One of the objective of the research study is to obtain the economic value of water. It can be obtained through the shadow prices of water through linear programming output which also known as shadow price. The shadow prices of water is determined separately for all 16 weeks as the water constrained is constructed separately for each week of the yala season. There is a shadow price for water is Rs. 71.22 in 1st week and Rs. 1,997.25 in 7th week in the head area. And in the middle and tail it is Rs. 149.39 in 1st week and Rs. 966.74 in 11th week for the middle and tail of the canal. In these weeks water is limiting the crop production and due to this total area of one acre is not be able to cultivate. The unit cubic meter increase of water increase the crop cultivation extent in the objective function.

During the first week farmers prepare the land and Irrigation department does not release water through rotational basis. The reason for it is in that period there is some rainfall. Therefore with the expectation of the rainfall, the release of water is less. With the assumption of there is no rainfall during the period the economic value of water was estimated. The water requirement of the crop is higher in the first week. Therefore there is a water scarcity in the 1st week. In the 7th week the available water per acre is very low as the paddy crop comes to its reproductive stage and requirement is high in this week and in the head area paddy extent is high. Therefore in that week there is no dual price in the middle and tail. Because in the middle and tail paddy extent is low. The 11th week is a crucial week for the soybean and maize as they are in the reproductive stage. The soybean and maize cultivation is higher in the middle and tail area of the canal. Therefore the water availability is not fulfilling the requirement and there is an economical value for the water.

4.1 *Optimum solution and farmer's livelihood change*

The Linear programming model was also run for each 30 farmers in the sample population along the canal and obtained optimum crop mix for each farmers and mean value obtained. The optimal crop mix is different from the actual crop mix farmers

practiced in the 2015 yala. In the optimal solution the paddy cultivation percentage is low. In 2015 yala farmers did not cultivate maize in their fields. This is due to most of the farmers have Chena lands in the catchment area and cultivating maize in those lands. But, if farmers also cultivate maize in their low lands they can get higher net revenue with less water usage.

The farmers mean income change and mean per capita expenditure change is given in the Table 3. In all three head, middle and tail part of the canal farmer's mean income can be increased with the optimal crop mix plan. The extra income obtained from the farming assumed to be included in the per capita consumption expenditure. The extra the farmers earn they spend more. The percentage mean per capita consumption expenditure increase also can be seen in all three head, middle and tail area.

Table 3: Farmers mean net revenue and mean per capita expenditure change.

	Head	Middle	Tail
Percentage increase of mean net revenue per acre	290%	42.62%	93.87%
Percentage of per capita consumption expenditure increase	30.72%	7.08%	16.5%

5 CONCLUSION

Drought severely resulting in water scarcity in irrigation water and the irrigated farming activities in the yala season. It can affect the net income from farming and per capita consumption expenditure of the household.

The availability of water is decreasing along the canal and mean yield from the farming land is decreasing along the canal. The Linear program solution for the given constraints has provided three optimal solutions separately for the head, middle and tail area. The farmers can obtain Rs. 36,891.74 per acre, Rs. 41,478.05 per acre and Rs. 42,485.96 per acre when following the crop mix plan with efficient use of irrigation water.

The optimum crop mix in head area include 17.82% paddy, 20.36% soybean and 43.36% maize. In the middle area the optimum crop mix is 14.43% paddy, 21.06% soybean and 55.23% maize. In the tail area the optimum crop mix is 11.95% paddy, 24.05% soybean and 56.04% maize. And all the three crops are economical to include in the crop mix when muddy area constraint included. Farmer's income will be generated due to crop diversification and it will impact on their livelihood change.

Effective extension services can be a tool to provide knowledge about crop water requirement and crop selection to the farmers in dry zone on the usage of efficient irrigation water among all the farmers along the canal network. When recommending a crop mix plan, the productivity of the land, tank water availability, and market price of the particular season should be considered.

The amount of irrigation water issued should be planed according to the optimal crop mix and the crop water requirements and the excess water supply in some weeks should be controlled and stored for the supply in the water scarce weeks. In the dry zone irrigation water is the main water source and investigations in other sources of water such as on-farm irrigation system and rain water harvesting are recommended.

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