Investigating the Impacts of Climate Change and Adaptation Options in Handegama Tank for Irrigation Water Management

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ABSTRACT

Under the changing climate, major effects are likely to arise from changes to the freshwater resources systems. The water resources under Hadegama scheme are already stressed and under climate change the availability of irrigation water is expected to become a major issue. This study would help investigate impacts of climate change and adaptation options in Handegama tank for water security. Future scenarios for climate change were selected based on predicted climate information from literature and a reservoir operation was performed under changing irrigation demand. Behavior of the system pertaining to the changes in climatic parameters such as rainfall and evaporation is useful for planning purpose and identifying possible adaptation measures. The worst climate change scenario for Handegama tank was identified as the fifth scenario with decrease in the annual rainfall by 14% and an increase in temperature by 2°C while increasing evaporation by 8 % by 2050. The cropping intensity under this scenario reduced from 1.53 to 1.25, a decrease of 28%. The identified adaptation options were crop diversification and improvement of canal efficiency; both of them increased the cropping intensity by almost 18 %. Reduction in available water under the worst climate change scenario would cause a 28 % reduction in the cropping intensity. These results indicate the need for adaptation under climate change. The adaptation options identified in this study helps to increase the cropping intensity thereby proving to be beneficial to the water users within the system.

KEYWORDS: Climate Change, Water resources, Irrigation

1. Introduction

Sri Lanka's water requirements are met mainly by surface water resources. Water scarcity is expected to be a major challenge for most of the region as a result of increased water demand and lack of good management. Water is the first sector to be affected by changes in climate and these changes in climate leads to intensification of the hydrological cycle and subsequently it has serious effects on the frequency and intensity of extreme events (Cap-net, 2011). The impact of climate change on water resources is caused by climatic factors, which mainly include rainfall, and temperature changes (Nan, Bao-hui & Chunkun, 2011).

Water plays a critical role in food security. Uncertainty in climate will affect the seasonal yields since food production depends on water not only in the form of precipitation but also in the form of available water resources for irrigation.

Under the changing climate, the operational rules, system design and size, current policies and water use strategies will get affected. Climate change poses costly impacts in terms of maintenance, repairs and functionality; hence incorporating possible climate change impacts in infrastructure planning and water resource planning is of major importance. This study aims to investigate the impacts of climate change on Handegama tank system in Auradhapura District, Sri Lanka (Figure 1) and recommend possible adaptation strategies to aid in planning and management of water resources.

2. Data

Handegama tank is in the Agro Ecological Zone DL1 (ID, 1984). The tank has a capacity of 85.4 Ha and a catchment area of approximately 19.4 km². 75% probable rainfall, reference crop evapotranspiration and crop factors were taken as per the Irrigation guideline (ID, 1984). Area capacity curve and cultivation extents were collected from the Irrigation Department. Climate information from reviewed literature are taken as future scenarios.

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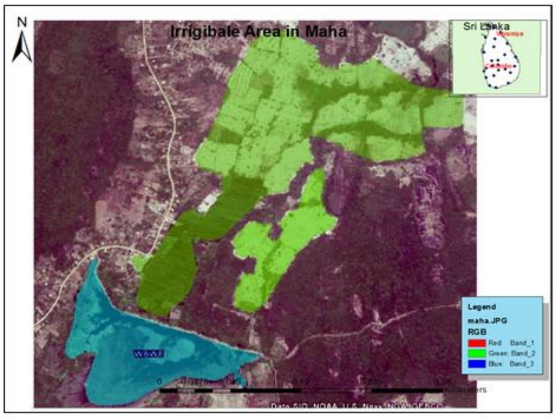

Figure 1: Study area

3. Analysis

3.1. System Water Balance

The monthly water balance equation used for this study is as given below;

Storage at beginning of month + Inflow – losses – Demand– Spillage = Storage at end of the month.

Inflow to the reservoir is the yield from the catchment and demand is the Irrigation requirement. Irrigation Demand for paddy cultivation of 135 days and 105 days for Maha and Yala was calculated according to the Irrigation guideline for a three stagger system. Application and conveyance losses were accounted for in the demand. Evaporation from water surface of reservoir and seepage were taken as losses. Spillage is the amount of inflow that flows out/ spills from the reservoir when it is full. Reservoir operation for the present scenario was performed assuming initial storage at minimum operating level.

3.2. Selection of Scenarios

In the current study, climate change scenarios were selected based on literature. The irrigation demand was calculated under these scenarios and reservoir operation performance is checked. The scenarios are described below.

3.2.1 First Scenario

IPCC have stated that the future increases in precipitation extremes related to the monsoon are very likely in East, South, and Southeast Asia (IPCC, 2008). De Silva (2006) predicts a 26-34 % decrease in the Northeast Monsoon (NEM) rainfall and a 16-38 % increase in the Southwest Monsoon (SWM) rainfall compared to 1961-1990 for scenarios B2-A2. The author predicts increases of 1.6°C under A2 and 1.2°C under B2 by 2050 and these increases would be mainly in the north, north-eastern and north-western regions (all within the dry zone). The author further suggests that by 2050, the average paddy irrigation water requirement during the maha season will increase due to reductions in average rainfall, increase in potential evapotranspiration and early ending of rainfall (De Siva, 2007). Hence in the current scenario, 34 % decrease in the NEM rainfall and 38 % increase in the SWM rainfall by 2050 (other months remaining same), for 1.6°C increase in temperature with increase in annual evaporation of 8% for every 0.9°C increase in temperature is considered and the future demand is calculated and the reservoir operation is performed.

3.2.2 Second Scenario

Under A2 scenario (AR3), increase in temperature of 0.9°C and increase in rainfall of 402 mm and 54 mm respectively for SWM and NEM respectively by 2050.

3.2.3 Third Scenario

As per IPCC, significant acceleration of warming in South Asia with higher warming is projected during the NEM than during the SWM (IPCC, 2008). Basnayake (2008) predicts 2.9 °C in NEM season and 2.5 °C in SWM season with increases in both NEM and SWM, with SWM having higher increase than NEM. Hence in this scenario, increase in rainfall of 20% for NEM and 30% for SWM with temperature increases of 2.9°C increase in NEM and 2.5°C in SWM respectively are selected.

3.2.4 Fourth Scenario

IPCC states that, there is a possibility that the monsoon onset dates are likely to become earlier or would not change significantly. A recent study by the Purdue University, especially on the South Asian summer monsoon also projects a weakened and delayed (by 5-15 days by the end of the twenty-first century) SWM over the majority of South Asia. Regional climate models for South Asia also project widespread warming in the region, including in Sri Lanka (rise in annual mean temperature in the range 2.5–4°C for IPCC scenario A2 and 2–3°C for B2) by 2050 (Kumar et al. 2006: Islam and Rehman 2004). In this scenario, a shift in monsoon by one month and temperature increase of 2.5°C by 2050 is considered with equivalent increase in evaporation of 8% for every 0.9°C increase in temperature.

3.2.5 Fifth Scenario

IPCC states that the wet areas will get wetter and the dry areas will get drier. Few authors have predicted decrease in mean annual rainfall, particularly in the dry zones. Reduced rainfall in dry zone areas such as Anuradhapura, Batticaloa and Trincomalee have been predicted (Basanayake, 2004). In this scenario a decrease in the annual rainfall by 14% and increase in temperature of 2°C with increasing evaporation of 8 % by 2050 is considered.

4. Results

4.1. Present Scenario

In the current scenario, there is insufficient water for cultivation in the Yala season. Actual rainfall data from 2010 to 2015 was substituted in place of 75% probable rainfall and the reservoir operation was performed. The cultivation extent under actual rainfall was found to be 100 % for both seasons but, since the actual rainfall is only for a short period, it is not representative of long term rainfall, hence it is not considered. The reservoir operation for the current scenario with 75% probable rainfall is presented in Table 4.1 and 4.2.

Table: 4.1 Reservoir operation (Maha)

Maha season						
	oct	nov	dec	jan	feb	mar
St-1	5.60	63.43	124.62	134.80	133.20	92.21
It	86.34	103.61	86.34	51.81	17.27	34.54
Et	1.27	5.36	8.22	8.85	9.80	10.95
Set	0.03	0.32	0.62	0.67	0.67	0.46
Dt	27.22	36.75	36.58	43.88	47.79	21.76
Spt	-	-	30.74	-	-	-
St	63.43	124.62	134.80	133.20	92.21	93.58

Table: 4.2 Reservoir operation (Yala)

Yala season						
	apr	may	jun	jul	aug	sep
St-1	93.58	134.80	134.80	95.56	47.75	14.91
It	86.34	34.54	8.63	-	8.63	17.27
Et	9.20	11.51	12.17	10.19	7.57	3.45
Set	0.47	0.67	0.67	0.48	0.24	0.07
Dt	-	19.59	35.03	37.14	33.67	23.05
Spt	35.45	2.77	-	-	-	-
St	134.80	134.80	95.56	47.75	14.91	5.60

4.2. Comparison of Scenarios

The irrigation demand for the Yala decreases under the first scenario due to increase in the rainfall of SEM by 38% but there is an increase in the irrigation demand in the Maha season due to decrease in rainfall in the NEM by 34%. . The cropping intensity is thus 7% higher in the first scenario compared to the base scenario, because of the increase in rainfall in the Yala season.

In the second scenario and third scenario, the rainfall in both seasons is increasing and hence there is a decrease in the irrigation demand in both seasons but there is increase in temperature with increasing evaporation. After incorporating evaporation losses of 8 %, the reservoir operation was done. The cropping intensity for the future scenarios was found to be 4% and 10% more than the base scenario because of the increase in rainfall in both seasons and the evaporative demand being much lesser than the increase in rainfall.

In the fourth scenario, the shift in the monsoon onset dates by a month and the corresponding temperature increase causes a reduction in the cultivation extent in the Yala season. The decrease in the cultivation extent was found to be only 2% of the present situation.

It was identified that the worst scenario for the current tank was scenario 5, where there is annual reduction in the rainfall with increase in temperature. The cultivation extent in the Maha is reduced to 22% compared to the base scenario and 11% in case of Yala season. The comparison of the cultivation extents and the cropping intensities are mentioned in Table 4.3.

Table: 4.3 Comparison of scenario

Scenario		BS	S1	S2	S3	S4	S5
Cultivation extent %	Maha	100	100	100	100	100	77.86
	Yala	53	60	56.8	62.5	52	47
Cropping Intensity		1.53	1.6	1.56	1.62	1.52	1.24

5. Adaptation Options

5.1. Crop Diversification

Out of the different crops selected, green gram was the most suitable crop which could increase the cropping intensity with minimum water requirement. The cultivation extent could be increased up to 17% in Yala season under the available water. The comparison of the irrigation demand for different crops is mentioned in Table 4.3 and the corresponding cropping intensities are mentioned in Table 4.3.

Table: 4.4 Irrigation demand for different crops

Green gram		
	Yala	Maha
ID/unit area	1101.05	1707.84
Soya bean		
	Yala	Maha
ID/unit area	1,591.06	1707.84
Ground nut		
	Yala	Maha
ID/unit area	1618.19	1707.84

Table 4.5 Cropping intensity for different crops

Crop type	Cultivation extent		Cropping Intensity
	Maha	Yala	
Paddy	100	53	1.53
Greengram	100	70	1.7
soya bean	100	68	1.68
Groundnut	100	69	1.69

5.2. Improving the System Efficiency

Canal efficiency can be improved by improving the water delivering efficiency. In the current study conveyance efficiency is increased upto 80%. The increase in the efficiency increases the cropping intensity by 18% compared to the current situation. Cropping intensity for the two adaptation options are mentioned in Table 4.6.

Table 4.6 Cropping intensity with adaptation options for present scenario.

		Adaptation options	
		Cultivation extent after improving canal efficiency	Cultivation extent after crop diversification
Cultivation extent %	Maha	100	100
	Yala	70.5	70
Cropping Intensity		1.705	1.7

Under the worst scenario, incorporating adaptation options considerably increases the cropping intensity. An increase of 25 % and 30% with improvement of system efficiency and crop diversification was identified in the study.

Both crop diversification and improvement of canal efficiency increases the cropping intensity, the Irrigation demand is reduced in terms of crop diversification, and the water can be used efficiently for other purposes. These options may help in securing irrigation water needs.

6. Conclusion and Recommendations

Reduction in cropping intensity of 28% was identified under the worst climate change scenario. Cropping intensity can be increased by 25% and 30% with improvement of system efficiency and crop diversification under the worst climate change scenario. These results indicate the need for adaptation under climate change and the importance of incorporating adaptation policies under climate change.

Under the future climate change, the already stressed water resources are projected to be further stressed. Moreover, the population is expected to increase and hence food security will become an issue. Hence it is important to come up with suitable adaptation and management options in order to sustainably manage water resources and to avoid disastrous situation in the future.

Improving water management practices and land use management practices can have important impacts on water. A change of land cover will either lead to a decrease or increase in annual stream flow. Catchment zoning and training in land use management can be taken as an option to increase water use efficiency. Conducting awareness programs among farmers about climate change and their consequences, and the importance of efficient water management can assure water security for irrigation needs.

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