Climate Scenario Identification and Evaluation of Irrigation Responses: Case Study Application of Rambakan Oya Reservoir Using Irrigation Department Guidelines

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ABSTRACT

Present study was carried out to demonstrate the capability of Irrigation Department Guideline (IDG) model to assess climate change impacts under variety of scenarios by carrying out a case study of Rambakan oya irrigation scheme. The IDG model was optimized for the current irrigable area and verified by checking the irrigable area, spilling months, maximum and minimum storages with qualitative field assessments. Six climate change scenario were developed and three scenarios were identified as critical scenario after evaluating the possible impacts on cultivation extents. Critical scenario were incorporated in to the optimized model in order to evaluate the response and it was observed that a 30% decrease in north-east monsoon (December to February) and 30% increase in south-west monsoon (May to September) keeping the annual total constant would give rise to the highest impact. Annual irrigation demand of Ramabakan Oya reservoir increases by 3% and the cropping intensity reduces from 1.0 to 0.76 and 0.83 to 0.72 in maha and yala seasons respectively. Since cropping intensity of the Rambakan Oya could reduce up to 20% under future climate change scenario, it would be better to incorporate adaptation measures to execute water management plans in the future. Project efficiency enhancement of 7% will allow the present cropping intensity to be maintained under the worst-case scenario for Rambakan oya irrigation scheme

KEYWORDS:-Climate change, Impacts, Irrigation schemes, Rambakan oya

1. Introduction

Climate change is considered as the greatest challenge for humanity to survive in a sustainable environment. The Intergovernmental Panel on Climate Change (IPCC) reports that the scientific evidence for warming of climate is unequivocal (IPCC 2014). As the earth's temperature continues to rise, significant impacts on water resources are expected. Water related effects of climate change and mostly due to variations in air and water temperature and rainfall, sea level rise and ocean acidification. These impacts are expected to significantly affect many water use sectors such as agriculture and food production, water supply and human health, energy production, fisheries, infrastructure, ecosystems.

Agriculture and Food production sector is probably facing the most critical situation mainly because of the increased climate change effects experienced at present combined with global population explosion. Agriculture sector is the cornerstone of Sri Lanka's economy with more than 70% of population in rural areas depending on agriculture as their livelihoods. Currently agriculture sector contributes to about 18% of the Gross Domestic Product (GDP) and 30% of the employment. Literature review on climate changes in Sri Lanka has shown that climate in Sri Lanka is changing in the direction of IPCC forecasts. Though there is a lack of perfect agreement between researchers, many attempts have been made to predict future scenario (Eriyagama and Smakthin 2010).

However, there is a void in the establishment of critical climate scenario for Sri Lanka to evaluate the impacts on the irrigated agriculture. As the evaluation of climate change on irrigation schemes in Sri Lanka does not appear sufficiently detailed the present work carried out a study to evaluate the potential impacts on agriculture in Sri Lanka by carrying out a study of Rambakan oya irrigation scheme. This study is expected to contribute towards systematic planning of water resources proceed to develop suitable water management policy for situations under climate change.

2. Literature Review

The 5th Assessment Report (AR4) of IPCC (IPCC 2014) provides global temperature predictions under four Representative Concentration Pathway (RCP) scenarios. Under all 4 scenarios global temperature is expected to increase by at least by 2°C by year 2100. Highest increase of 4°C is expected under the RCP 8.5 scenario. By 2100, the temperature increase in Sri Lanka, during South-West monsoon (SWM) season (May to September)

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is anticipated to be 2.5 °C, whilst the North-East monsoon (NWM) season (December to February) the expectation is 2.9 °C (Department of Meteorology, Sri Lanka). In this backdrop, it is fair to expect at least a 2 degree rise in the temperature increase by the mid-21st century. Due to the increase in temperature there is the possibility of rise in evaporation. Hence, determining evaporation rates is essential for efficient management of reservoirs and water resources. (Helfer, Lemckert & Zang, 2012) in a climate change impact study with a large reservoir in Australia stated that between 2030 - 2050 annual evaporation will be 8% higher than that estimated for the current temperature increase of 0.9 °C.

IPCC (2014) states that future increases in precipitation extremes related to monsoon are very likely in East, South, and Southeast Asia. Moreover, it states that all models and all scenario project an increase in both the mean and extreme precipitation in the Indian summer monsoon and Southern Asia. In the case of Sri Lanka peer reviewed studies on changes in precipitation are limited. (Eriyagama and Smakhtin, 2010) states that it is evident that Sri Lanka's climate has already changed and although attempts have been made to project Sri Lanka's climate in the twenty-first century, these studies lack consensuses and their results and projections are contradictory.

National level modeling, undertaken by the Sri Lankan Centre for Climate Change Studies, suggest that the changes in Sri Lanka broadly - but not completely - follow the regional expectations. Rainfall in Sri Lanka is expected to be slightly different from to the regional trend, with increases in rainfall levels anticipated in both SWM and NEM (Department of Meteorology, Sri Lanka). Eriyagama & Smakhtin, (2010) states that the two regional climate models (Kumar et al. 2006; and Islam and Rehman, 2004), and downscaled projections by Basnayake and Vithanage (2004) suggest increases in both SWM and NEM rainfall, with Basnayake and Vithanage (2004), suggesting higher increases in SWM than in NEM.

Eriyagama & Smakhtin, (2010) in their work mentioned that Statistically downscaled projections from the HadCM3 model by De Silva (2006) predicts a 26-34 % decrease in the NEM rainfall in the dry zone and a 16-38 % increase in the SWM rainfall in the wet zone by 2050. Downscaled projections from CSIRO models Basnayake and Vithanage, (2004) projected an increased rainfall in SWM and a decrease in NEM.

3. Methodology

A reservoir water balance model was developed to model the feasible irrigable area in Maha and Yala seasons for the current situations. Irrigation Demand for Paddy cultivation in Maha and Yala Seasons were calculated according to the Irrigation guideline (ID 1984). Model computations were based on the water balance of the reservoir system described in the guidelines of the Irrigation Department. Water Balance model was optimized for the current irrigable area by changing the storage at the beginning of October to match with the end storage at the end of September using a trial and error process. Model was verified by checking the irrigable area, spilling months in the model with actual cultivated land area. The calibrated model was used to carry out an annual water balance incorporating the identified critical scenario. to find out the impacts on cultivation extent.

4. Data

In the Rambakan Oya scheme a three-stagger system is practiced. In water balance computations, 75% probable rainfall was used as recommended by the ID (1984). 75% probable rainfall values in the guideline were compared with those calculated from monthly rainfall data of 25 years (1980/81 to 2004/05) considered in the feasibility study of the Rambakan Oya reservoir. Rainfall values used for the Feasibility Study were taken as inputs for the present work. Area capacity curve of Rambakan Oya Reservoir, thiessen averaged rainfall, cultivation patterns, crops and crop factors etc., used to develop the water balance model was obtained either from those collected by the Irrigation Department or from those in the ID (1984). Reference crop evapotranspiration (ET_0), Crop coefficients and monthly evaporation data were also obtained from the ID (1984). Location of the Rambakan oya reservoir is shown in figure 1.

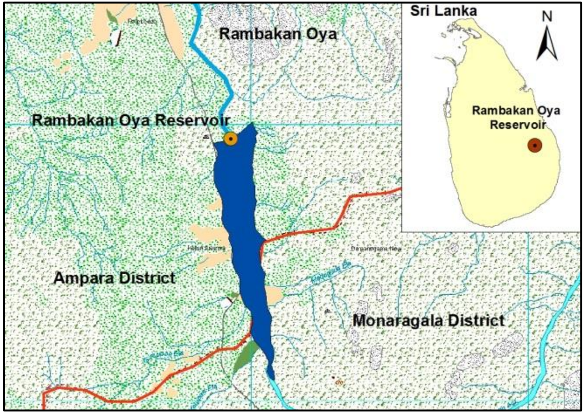

Figure 1 : Rambakan Oya Reservoir

5. Analysis

5.1. Climate Change Scenario

Based on the literature survey and an order of magnitude evaluation of situations identified the critical scenario described below.

Scenario - 01

A 15% evaporation increase for a 2 degree increase in temperature affecting the reservoir and cultivated crops.

Scenario – 02

10% increase of rainfall in NEM and 10% increase in SWM

Scenario - 03

30% increase of rainfall in NEM and a 30% decrease in SWM

Scenario - 04

30% increase of rainfall SWM and a 30% decrease in NEM

Scenario - 05

10% decrease of rainfall in NEM and 10% decrease in SWM

Scenario – 06

A one month backward shift of NEM and SWM season commencement.

5.2. System Water Balance

The water balance of the reservoir system is as in equation 1.

$I_t - (E_t + Se_i + Sp_t + D_t) = S_t - S_{t-1}$ ----------------(1)

In this equation t is the time step which was considered as on month, I is the inflow, E is the evaporation from the reservoir water surface, Se is the seepage from the reservoir bed, Sp is the spillage from the reservoir, D is the irrigation demand, S is the storage of the reservoir. To model the irrigation demand for each month Irrigation demand for 135 day and 105 day paddy cultivation in maha and yala seasons respectively, was calculated according to the guideline of the Irrigation Department (1984). Following equations were used for the computation of Irrigation Demand

$(FWR)_t = (LP)_t + (Et_c) + (FL)_t$ --------------------(2)

$(FIR)_t = (FWR)_t - (ER)_t$ ----------------------------(3)

$(ID)_t = (FIR)_t / \eta$ ----------------------------------- (4)

In these equations, t is the considered time step for computations, Lp is the water requirement of land preparation, ET_C is the water requirement for crop evapotranspiration, and FL is the water requirement to compensate for farm losses. FWR is the field water requirement, ER is the effective rainfall, FIR is the field irrigation requirement, D is the irrigation demand and η is the project efficiency.

6. Results

6.1. Present Situation in Rambakan Oya Reservoir

Monthly storage at the beginning and end of each month, inflow to the reservoir, evaporation, seepage, irrigation demand and spillage in hectare meters (Ha.m) for the existing situation in Rambakan oya scheme is shown in table 6.1 and table 6.2

Table 6.1: Maha Season

Item	Oct	Nov	Dec	Jan	Feb	Mar
S_{t-1}	3471	3731	4581	5486	5500	4967
I_t	688	1278	1297	691	116	277
E_t	55	45	46	58	58	69
Se_t	17	19	23	27	28	25
D_t	356	364	323	470	563	283
Sp_t	-	-	-	123	-	-
S_t	3731	4581	5486	5500	4967	4868

Table 6.2: Yala Season

Item	Apr	May	June	July	Aug	Sep
S_{t-1}	4868	5119	4957	4291	3689	3184
I_t	343	308	68	148	182	537
E_t	68	77	90	86	78	66
Se_t	24	26	25	21	18	16
D_t	0	368	619	642	591	168
Sp_t	-	-	-	-	-	-
S_t	5119	4957	4291	3689	3184	3471

Annual and seasonal irrigation demand, present irrigable area and cropping intensity for the existing situation in Rambakan oya scheme is shown in table 6.3

Table 6.2: Seasonal Results

	Maha	Yala	Annual
Irrigation Demand (Ha.m.)	1626	1989	3615
Irrigable Area (Ha.)	1450	1200	2650
Cropping Intensity	1.00	0.83	1.83

6.2. Identification of Critical Scenarios (CS)

The changes in annual evaporation due to scenario 01 is less than 2% as a percentage of the inflow. Hence this scenario was not considered as a critical scenario. Under scenario 02, an even increase in the NEM and SWM both will lead to a better situation than the present. Hence this scenario was not considered as a critical situation. However, if an increase occurs then the irrigations planners may have to check the capacities to hold the water that would otherwise be spilled. If not, we will not be able to take advantage of the climate change.

According to scenario 03, increase in rainfall in NEM will not have much impact on the residual storage at the end of maha season since even for the existing situation reservoir is at full capacity at the end of January. Hence, decrease is SWM rainfall will have impact on the cultivation in yala season. Therefore, scenario 03 was selected as critical scenario 01 (CS – 01). Decrease in the NEM may affect the Maha season and also the Yala season due to the impact on the residual storage after the season. Since Yala rainfall is usually low, even if the SWM increases rainfall there is a high probability for the Yala season to be affected. Hence the scenario 04 was studied as the critical scenario 02 (CS – 02).

Under scenario 05 an even decrease in NEM and SWM rainfall will definitely have an impact on both seasons. Hence scenario 05 was categorized as critical scenario 03 (CS - 03). Cultivation activities such as land preparation, seeding, harvesting, etc., in a scheme is planned according to the rainfall pattern and expected monsoon onset dates.

Therefore, changes in rainfall pattern will have an impact on the cultivation activities. However, if the change in the pattern is straightforward then it can be recognized easily and then the farmers will adjust to the new rainfall pattern and plan their cultivation activities accordingly. Therefore, scenario 06 was not categorized as a critical scenario.

6.3. Responses of Irrigation Schemes Under Critical Climate Scenarios

Irrigation demand comparison of the three critical scenarios and the present situation is given table 6.4. It was observed that the irrigation demand increases Maha season by 10% and 4% respectively for CS 02 and CS 03. Irrigation demand reduces by 6% for the CS 01. In the Yala season irrigation demand increase by 2% and 1% for CS 01 and CS 03. For CS 02 irrigation demand reduces by 3%. Total irrigation demand increases by 3% and 2% for CS 02 and CS 03 respectively, whereas total irrigation demand reduces by 1% for CS 01.

Table 6.4: Irrigation Demand for Scenarios

Scenario	Irrigation Demand (mm)		
	Maha	Yala	Total
Present	1626	1989	3615
CS 01	1533	2032	3565
CS 02	1790	1935	3726
CS 03	1692	2005	3697

Comparison of possible cultivation extents are show in table 6.5. For all three scenarios, total cultivation extents during the year has reduced. Highest reduction in cultivation extent is due to CS 02. For CS 02 total cultivation reduction is 19% which results due to reduction in maha and yala seasons by 24% and 13% respectively. For CS 03 reduction in total cultivation extent is 12%. For maha and yala seasons it is 17% and 6% respectively. Even though the total cultivation extent reduces under CS 01, it was observed that due to the increase in rainfall in north east monsoon season cultivation extent can be increased than the present situation.

Table 6.5: Cultivation extents for scenarios

Scenario	Irrigable Area (Ha)		
	Maha	Yala	Total
Present	1450	1200	2650
CS 01	1525	1100	2625
CS 02	1100	1050	2150
CS 03	1200	1125	2330

Cropping intensities for each scenario is given in table 6.6, cropping intensity reduces under all three critical scenarios. Cropping intensity reduces from 1.83 to 1.48

Table 6.6: Cropping Intensity for scenarios

Case	Cropping Intensity		
	Maha	Yala	Total
Scenario	1.00	0.83	1.83
CS 01	1.00	0.76	1.76
CS 02	0.76	0.72	1.48
CS 03	0.83	0.78	1.60

7. Discussion

Future climate projections indicate that the climate is changing and impacts on agriculture sector can be expected. Worst climate change scenario for the Rambakan oya scheme is when the Northeast monsoon decrease while increasing the southwest monsoon. Worst climate scenario will reduce the cropping intensity of the scheme from 1.83 to 1.48, which is a decrease in 20%. Population growth in the future is also expected to increase and food scarcity is predicted in the future. So, it is important to at least maintain the existing irrigable in the future. Therefore, implementing adaptation options in the future is essential to the Rambakan Oya scheme.

It is apparent that the due to the worst-case climate change scenario irrigation demand for paddy cultivation increases by 3%. In order to counter these impacts adaptation measures as to be planned for the scheme. Most common measure which the water managers are proposing is crop diversification. By cultivation crops which requires less irrigation demand than paddy will enable farmers to cultivate the existing irrigable area. However, it is important to identify that the other field crop cultivation will not generate sufficient income compared to paddy. Therefore, increase in poverty among the farmers could become a major concern. In addition to that, if a proposed crop fails farmers want be able to generate any income at all. Hence, crop diversification may not be an acceptable adaptation measure moving forward.

One way to face the future scenario is to reduces the losses by increasing the project efficiency. It was identified that project efficiency enhancement of 7% would be sufficient to maintain the existing irrigable area under the worst-case climate change scenario. Hence, it is evident that most suitable adaptation measure is to increase the project efficiency. Adaptation measures such as development of resilient crops and early warning systems will be helpful to all irrigation schemes in the country.

In this study, it was identified that for some scenarios there could be greater rainfall in the maha season. Capturing this additional water by increasing the capacity is another point that the water managers should look at. Furthermore, present study assumed that the climate change effects of rainfall will be predictable and uniform both spatially and temporally. Then only the farmers can adapt to it provided that the change will become stationary. However, accuracy of these predictions is debatable. Therefore, it is important encourage more research work to predict the future climate scenarios more accurately.

8. Conclusions

Cropping intensity of the Rambakan Oya could reduce up to 20% under the expected worst-climate change scenario. Project efficiency enhancement of 7% will allow the present cropping intensity to be maintained under the worst-case scenario. Given the dependency of the agriculture in Sri Lanka it is important to study the possibility of development of resilient crops and early warning systems, and encourage more research work on climate change predictions since those would be helpful to all irrigation schemes in the country. Methodology used in this case study can be improved to develop a detailed approach to identify climate change impacts on irrigation schemes in Sri Lanka.

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10. References

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