Irrigated Water Management under Climate Change Scenario Using Water Evaluation and Planning Model in Stung Sreng basin, Cambodia

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Abstract: Stung Sreng basin is the most potential one to extract water for both domestic used and agricultural sector; however, this basin encounters the management problem that can cause water scarcity. WEAP model was applied in this basin to determine the situation of irrigation water requirement under climate change scenario. The current and future streamflow were generated from SWAT model. As a result, the reference scenario defines irrigated demand from 2018 to 2030, and it is founded that the water demand is 679 MCM and unmet demand is around 95 MCM. There are only 2 irrigation schemes among 51 schemes that require most water demand which is around 150 to 200 MCM. Furthermore, the scarcity of water will occur mostly in November and December around 35 to 60 MCM. Based on the annual increase scenario, the irrigated area in dry season increases every year by 5% until 2030. The result showed that water demand in this scenario is 684.483 MCM. It means the irrigation demand will have risen around 5.5 MCM by 2030. The scarcity of water in dry season does not occur. For climate change scenario which selected from climate model: GISS-E2-R-CC, the result illustrates that the trend of water and unmet demand are going to increase slightly for both RCP 2.6 and 8.5 compared to annual increase scenario. The peak of water demand in dry season is in March and November; on the contrary, for the lowest demand was in May and June. In addition, the most scarcity of water in this scenario is in November and December**.**

Keyword: WEAP model, Water demand, unmet demand and climate change scenario

I. INTRODUCTION

The abundant of water resources plays a vital role in developing national economic in many sectors. The management of the abundant of water resources must be deeply concerned and to be used in many sectors, including agricultural, manufacturing, energy, inland navigation, tourism, environmental protection, water supply, sanitation and domestic used; therefore, there are many developers who built some water resources modeling for studying about assessment and planning on water resources sector, such as Soil and Water Assessment Tool (SWAT) and Water Evaluation and Planning (WEAP) model, to prevent the issue of scarcity of water. The capacity of SWAT model can simulate streamflow in the past and future under various conditions. For example, the study, which is about hydrologic simulation of the little Washita river experimental watershed using SWAT, was used to evaluate the capabilities of SWAT to predict streamflow under varying climatic conditions. Eight years of precipitation and streamflow data were used to calibrate parameters in the model, and 15 years of data was used for model validation. Test results showed that once the model was calibrated for wet climatic conditions, it performed well in forecasting streamflow responses over wet, average, and dry climatic conditions selected for model validation (Van Liew and Garbrecht, 2003). After getting streamflow data from SWAT model, WEAP model can be applied for estimating water demand management under various conditions too. A research paper mentions about Simulation of water resources management scenarios in western Algeria watersheds using WEAP model. The model is applied to evaluate and analyze the existing balance and expected future water resources management scenarios by taking into account the different operating policies and factors that may affect the demand until 2030. The results showed that neither domestic demand nor agricultural demand met the basis year 2006. The results also pointed out that domestic demand can be satisfied for the considerable scenarios (Hamlat et al., 2013). In Cambodia, water resources play role as the main factor for economic growth that is related to many sectors such as agricultural, water supply and sanitation, industrial, fisheries and tourism; meanwhile, Cambodia can also face a water shortage due to the lack of management technical and the impact of climate change. Thus, WEAP model application is applicable in the case study of Cambodia to identify the situation of water requirement and planning the future management work, for instance, the Assessment of Irrigated Water Allocation in the Stung Chrey Bak Catchment of Tonle sap Lake Basin using the WEAP model by (MONG et al.). This research aims to apply WEAP model to define the situation of supply water for irrigation schemes under the diverse scenarios. By the reason above, this study intentionally focuses on irrigated water management under climate scenario using water evaluation and planning model (WEAP) at Stung Sreng River basin, Tonle Sap Basin. The current baseline and future streamflow simulating from SWAT model will be used for this study in order to achieve the two main objectives which are to (1) estimate the irrigation water demand and unmet demand in each irrigation schemes under present and future under effect of climate change and (2) evaluate the different situation of irrigation water requirement under climate scenario RCP2.6 and RCP8.5.

II. METHODOLOGY

2.1. Study area

The Stung Sreng River Basin was considered as the study area which is located at the northwest of Cambodia as shown in Figure 1. Understandably, it is a tributary within the third largest river basin of Tonle Sap Great Lake, lower Mekong River Basin. The river basin area is totally 9 986 km^2 and is covered by three provinces, including Banteay Meanchey, Oddar Meanchey, and Siem Reap province. There are around 51 irrigation schemes which equal nearly 53 000 ha of land.

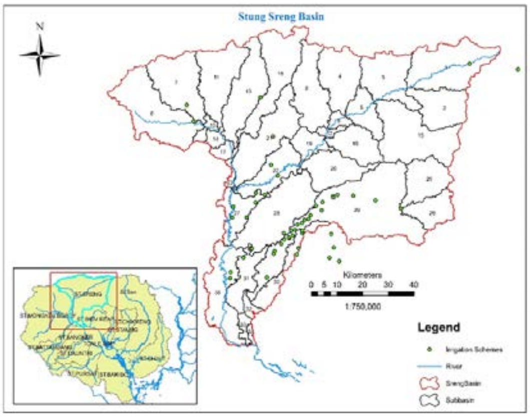


Fig.1. Map of Stung Sreng Catchment

2.2. Generality of WEAP model

The Water Evaluation and Planning (WEAP) model was developed by the Stockholm Environment Institute (SEI). It provides a comprehensive, flexible and user-friendly framework for policy analysis. It operates at a monthly step on the basic principle of water balance accounting. The user represents the system in terms of its various sources of supply (e.g. rivers, groundwater, and reservoirs), withdrawals, water demands, and ecosystem requirements. The result of the model was calculated as water demand in each irrigation scheme and amount of water shortage in the scheme.

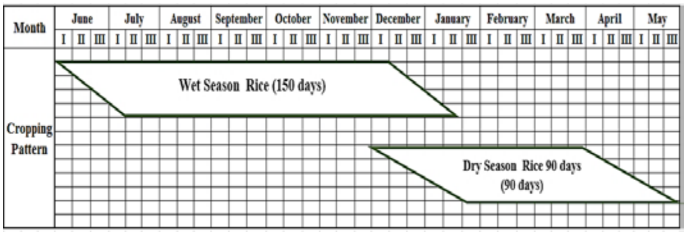
2.3. Stream flow in Stung Sreng Basin

The streamflow in Stung Sreng catchment was divided into 35 sub-basins that was generated from Soil and Water Assessment Tool (SWAT) model credited by (Heng et Oeurng, 2018). The observed daily streamflow from 1994 to 2013 recorded by the Department of Hydrology and River Works of Ministry of Water resources and Meteorology in Stung Sreng basin at Kralanh station was used to compare between the simulated and measured discharge based on Model analysis calibration and validation of SWAT-CUP. The average of monthly streamflow from SWAT was regarded as an input data of Water Evaluation and Planning model (WEAP) in Current Account (2018), and Reference Scenario and Annual Increase Scenario (2017 to 2069). The future stream is projected to change due to the alteration in climate data. By adjusting the change factor in basin parameters of climate data, including temperature, humidity, solar radiation and precipitation, that was downscaled by MRC into SWAT model to simulate the future change of streamflow under climate change scenario.

2.4. Cropping pattern

Water balance calculations in this study are considered two cropping patterns distributed in a year round: wet season rice and dry season rice. Cropping patterns for the season rice crops are based on the assumption that the transplanting method is used as the prevailing and dominant farming practice. This method produces a higher unit yield of rice than the direct sowing method (CDRI, 2015).

Table I Selected Cropping pattern



2.5. Irrigation water requirement

Irrigation water requirements (IWR) of each crop for each diversion unit were estimated based on a cropping calendar as shown in the following equation:

$$IWR = (ET_0 \times Kc + PR + Lp - ER) / IE \quad , \qquad (1)$$

Where:

- IWR: Irrigation water requirement for diversion unit
- ETo: Reference evapotranspiration
- Kc: Crop coefficient
- PR: Percolation rate (in case of paddy)
- Lp: Land preparation requirement
- ER: Effective rainfall
- IE: Irrigation efficiency

The irrigation water requirement for climate change scenario will be used the same formula by adjusting the values of future temperature and precipitation and those values were adjusted by Mekong River Commission (MRC, 2015). The future Reference Evapotranspiration and Effective Rainfall will be calculated as the formula below:

$$ET_0 = P \times (0.46\,T_{mean} + 8)\,, \qquad (2)$$

$$ER = 0.8 \times R\,(0.5 \le R \le 80\,mm)\,, \qquad (3)$$

2.6. Definiting of demand management scenarios

This demand management scenario creates three different scenarios: reference, annul increase of irrigation area and supply management scenario, and climate change scenario. The assumptions are presented as below:

Table II Scenarios assumption

Scenarios	Description
Reference	What if "question and key assumptions" The reference scenario will evaluate the reported irrigated

	area against the stream flow of the catchment, and then identify the water demand and unmet demand in each irrigation scheme.
Annual increase of irrigation area	This scenario assumes that the irrigated area in dry season will increase by 5% percent per year over the period from 2019-2030 (CDRI, 2011).
Climate change scenario, GISS-E2-R-CC: RCP2.6: low emissions RCP8.5: High emissions	The impact of climate change on local hydrological regime, mainly streamflow by producing an extended duration of drought in dry season and high intensity of rainfall in wet season.

2.7. Overal flowchart

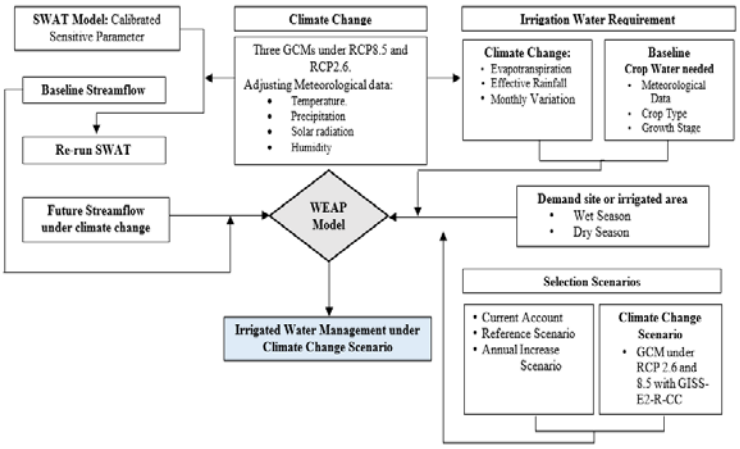


Fig.2. Overall flowchart

3. RESULT AND DISCUSSIONS

3.1. Current account

Irrigation water demand in the current account is calculated based on the irrigated area of 52 600 ha. The monthly variation in irrigation water demand was estimated based on the rice crop factor and the pattern of farmer's rice crop cultivation. The current account of irrigation demand in 2018 is about 679 million cubic meters per annum. As the result, because of the area of this irrigation scheme which is huge comparing to other schemes area, there are two reservoirs, Plang and Slaeng Spean that need a lot of irrigation demand, which are 191.36 and 151.28 MCM, respectively.

3.2. Reference scenarios

The reference scenario calculates the irrigation water demand from 2019 to 2030s at 679 million cubic meters per annum. As a result, the irrigation water demand in Stung Sreng Basin in dry season is low if comparing with wet season. The most water demand during dry season is in December at 93.930 MCM. On the other hand, the most irrigation water demand in wet season is in July and November at 110.168 and 172.471 million cubic meters per annum, respectively. Nevertheless, the total amount of unmet demand that occurs in this basin is 94.265 MCM, the irrigation scheme that mostly met the scarcity water is Kralanh irrigation scheme at 30.966 and 18.475 MCM in both November and December, respectively. Furthermore, there have no unmet demands in dry season because most of irrigation scheme in this basin does not activate.

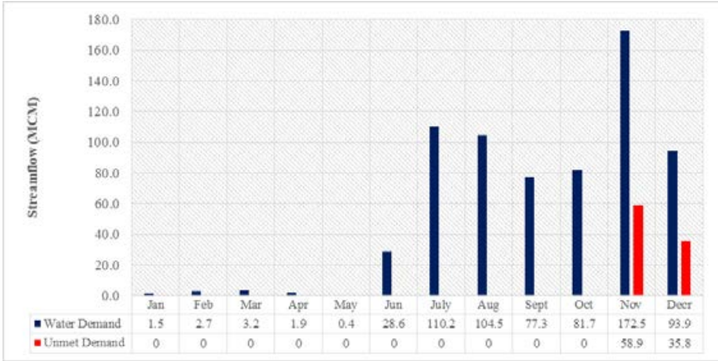


Fig.3. Monthly variation of water demand and unmet demand

3.3. Annual increase in irrigated area scenario

Annual increase in irrigation demand assumes that the command of dry season rice is increased annually by 5 percent. The command area in 2018 is 52 600 ha, whose irrigated area in dry season is 691 ha and it will go up 5% over the period of 2019 to 2030. The total command area in 2030 is approximately 53 100 ha.

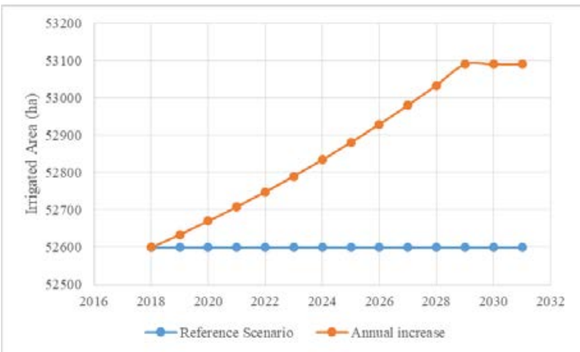


Fig. 4. Trend of increase in dry irrigated area

In the reference scenario, water demand is 678.35 MCM from 2018 to 2060s. The annual increase of irrigation area will be a steady increase in irrigation demand from 678.85 MCM in 2019 to 985.36 MCM in 2070s. This study was assumed that the irrigated area would remain stable from 2030 to 2070; hence, the annual irrigation would stay constant at 772.59 MCM until the end of study timeframe.

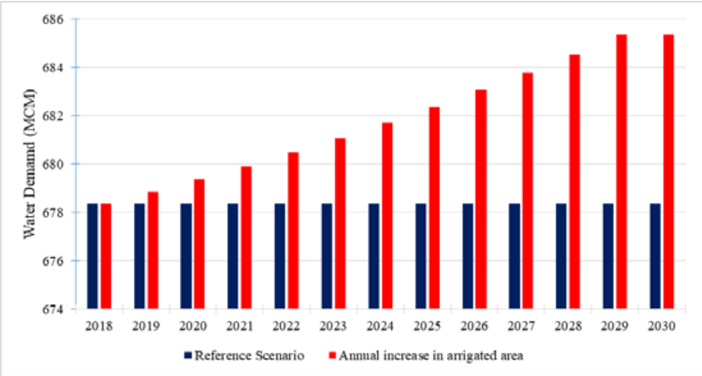


Fig.5. Comparison of water demand between reference and annual increase scenario

Moreover, the scarcity water in each irrigation scheme is happened only in November and December around 94.63 MCM per annum. The trend of unmet demand in annual increase scenario climbed moderately to nearly 100 MCM per annum.

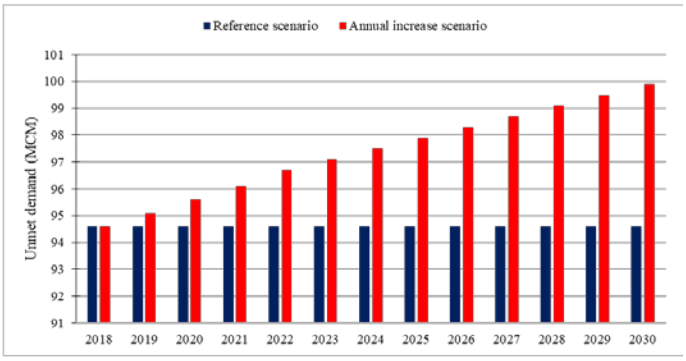


Fig.6. Comparison of unmet demand between reference and annual increase scenario

3.4. Climate change scenarios

The monthly irrigation demand under climate changes model (GISS-E2-CC) with two different RCPs from 2031 to 2069 will differ significantly from one another. The monthly irrigation water demand under climate change model was compared with annual increase in irrigated area, because both scenarios were assumed to be constant in irrigated area in dry season from 2031 to 2060.

- GISS-E2-R-CC in 2030s

The water demand in this scenario indicates the different trends between annual increase scenario and both RCPs. On November, the monthly water demand in this month is relatively high compared to other months in both scenarios while in May is the lowest water demand.

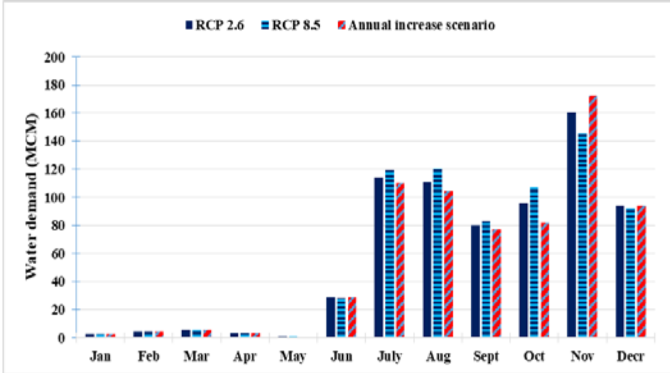


Fig.7. Monthly variation of water demand in each scenario at 2030s

Otherwise, for the scarcity of water, the monthly unmet demand in this month is high in November and December compared to other months in both scenarios. The graph demonstrates that the scarcity of water mostly occurs in rainy season.

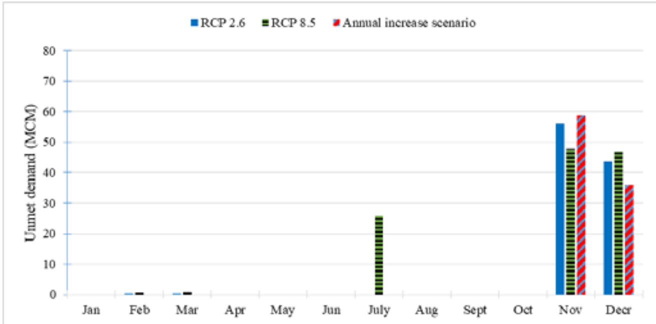


Fig.8. Monthly variation of unmet demand in each scenario at 2060s

- GISS-E2-R-CC in 2060s

In 2060s scenario, the values of each scenario are quite different from climate change scenario in 2030s, if considering on the monthly trend, yet the results show the same as the previous scenarios for both water demand and unmet demand. For the water demand, in November, the monthly water demand in this month is high compared to other months in both scenarios while in May is the lowest water demand. In contrast, the monthly unmet demand in this month is high in November and December compared to other months in both scenarios.

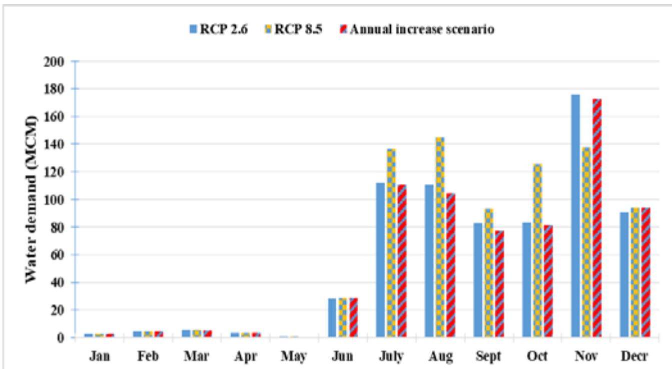


Fig. 9. Monthly variation of water demand in each scenario at 2060s

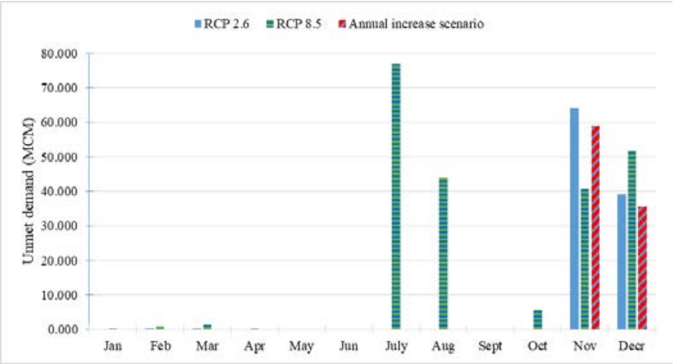


Fig.10. Monthly variation of water demand in each scenario at 2060s

4. Conclusion

To sum up, this study is attempted to apply WEAP model application to identify the situation of irrigation requirement in Stung Sreng Catchment in different scenarios, including scenario of increase in irrigated area and climate change under global circulation model. The results from the model have shown that in current account, the irrigation water demand to support irrigated area of almost 53 000 ha is about 678 MCM per year. For the reference scenario, it illustrates the water demand and unmet demand in this area from 2019 to 2030. The results have also demonstrated the water demand is 679 MCM and unmet demand is around 95 MCM. In addition, the annual increase scenario identifies the water demand and unmet demand situation when the irrigated area in dry season constantly increase 5% per year until 2030. The water demand in this scenario will be 684.483 MCM at 2030. It implies that irrigation demand increases roughly 5.5 MCM and the scarcity of water is around 100 MCM. For climate change scenario selected from climate model: GISS-E2-R-CC, the result reveals that the trend of water and unmet demand are going to increase gradually for both RCP 2.6 and 8.5 compared to annual increase scenario. The peak of water demand in dry season is in March and November. In contrast, for the lowest demand was in May and June. Additionally, the most scarcity of water in this scenario is in November and December.

References

CDRI, 2015. CLIMATE CHANGE AND WATER GOVERNANCE IN CAMBODIA, Challenge and Perspectives for Water Security and Climate Change in Selected Catchments, Cambodia.

CDRI. 2015. CLIMATE CHANGE AND WATER GOVERNANCE IN CAMBODIA, Challenge and Perspectives for Water Security and Climate Change in Selected Catchments, Cambodia.

Hamlat, A., Errih, M., Guidoum, A., 2013. Simulation of water resources management scenarios in western Algeria watersheds using WEAP model. Arabian Journal of Geosciences, 6(7), 2225-2236.

MOE. 2002. Cambodia's Initial National Communication under the United Nations Framework Convention on Climate Change. (Phnom Penh: MOE).

MONG, M., OEURNG, C., LY, S., Techno-Science Research Journal.

MRC. 2015. Pilot Stung Sreng River Basin Plan, Ministry of Water Resources and Meteorology, Cambodia.

Phalla, C., Paradis, S., 2011. Use of hydrological knowledge and community participation for improving decision-making on irrigation water allocation: CDRI.

Van Liew, M. W., Garbrecht, J., 2003. Hydrologic simulation of the little Washita river experimental watershed using SWAT 1. JAWRA Journal of the American Water Resources Association, 39(2), 413-426.