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Assessment of Water Use for Improved Water Governance under Climate Change Scenarios in the Stung Chrey Bak Catchment of Tonlesap Lake Basin in Cambodia

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Abstract: *The influences of climate change have also covered Stung Chrey Bak Catchment,with increasing the significant issues over water demands for irrigation schemes. Thus, the aim of this research is to predict water demands of each irrigation schemes through climate change scenarios, using Water Evaluation and Planning model (WEAP). Stung Chrey Bak catchment consists of seven irrigation schemes. Two demand management scenarios were developed for this study –reference and 5 percent annual increase in irrigated area. To achieve this, SWAT model was used to generate flow discharge in each stream, command area and the irrigation demand for each irrigation scheme. As the result, water demand was reported enough for all scenarios in wet season. In contrast, the dry season rice meets water shortage especially in Tang Krasang for baseline scenario around 9262 m^3 in January, 47752 m^3 in February. In reference scenario, water scarcity occurred only in Tang Krasang, decreasing from 64547 m^3 in 2014 to 51007 m^3 in 2024. Moreover, if the farmers have continued to expand 5% of cultivated area, the irrigation water demand will highly increase from 27 million m^3 in 2014 to 41 million m^3 in 2025, causing unmet demand occurred in Tang Krasang, Chrey Bak, and Trapaeng Trabek. For climate change scenario B2 and A2, there is no water scarcity in both dry and wet season since water demands for agriculture are less than stream flow. In a situation of water limitation, water allowance between the three schemes facing unmet demands is very important for optimizing the use of water for agriculture. Cropping patterns should be applied for this situation, namely Chrey Bak scheme starting in early November and Trapaeng Trabek scheme in mid or late November in order to avoid an overlapping of irrigation peak demand.*

Keywords: water allocation; water scarcity; WEAP model, Tonlesap Basin

1. INTRODUCTION

Cambodia is highly susceptible to suffer from increased climate variability for instance: floods, droughts and windstorms. People whose their livelihoods depend strongly on natural resources such as farming and fishing are the most vulnerabler to suffer from climate-related harm due to low adaptive capacity.

Good governance and effective water resource management can contribute strongly to minimize the negative impact of water shortages, resulted from climate change. Moreover, the vulnerability and the adaptive capacity of local people, with the sound knowledge of water use are the critical factors to family with climate change. The effective irrigation development and management can ensure the sustainable use of water for agriculture against natural disasters.

Two research questions have been indicated in this study. How can different hydrological scenarios be presented and communicated as part of decision-support process within a forum of catchment level water users and manager? How does supply of water in each irrigation scheme vary by difference scenario?.

The purpose of this study is to understand the possibility of supporting improved water management in Stung Chrey Bak Catchment through Climate Change Scenarios, using WEAP Model, and to predict the amount of water demand for irrigation scheme in the Stung Chrey Bak catchment with difference scenario of Reference Scenario, Annual increase in irrigation demand.

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2. METHODOLOGY

2.1. *Study area*

The study was conducted in the Stung Chrey Bak catchment, located in Kampong Chhnag Province with the area of about 700 km^2 . It consist of 3 main rivers, namely Srae Bak, Chakteum, and Chrey Bak main stream with the parallel length of 23km, 28km, and 54km. The irrigation scheme in the catchment is distribute from upstream to downstream of catchment as shown in the figure 1 below.

Figure 1. Irrigaton schemes in Stung Chrey Bak

2.2. *Water Availability in Stung Chrey Bak Catchment*

Stream discharge was generated from SWAT model (Oeurng *et al*, 2015). Three different water availability scenarios were built to assess the possibility of supporting improved water use in Stung Chrey Bak Catchment. These are Baseline Scenario and Climate Change Scenarios in B2 and A2, respectively.

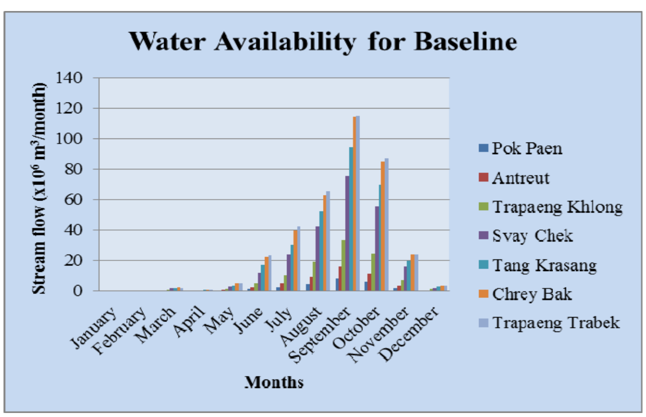

Figure 2. Water avialability for Baseline

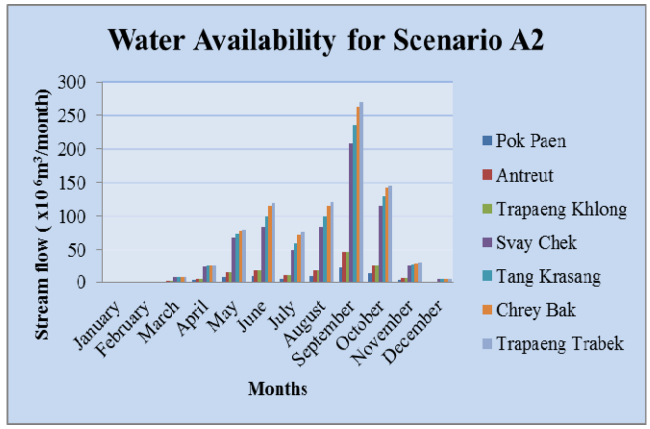

Figure 3. Water availability for Scenaro A2

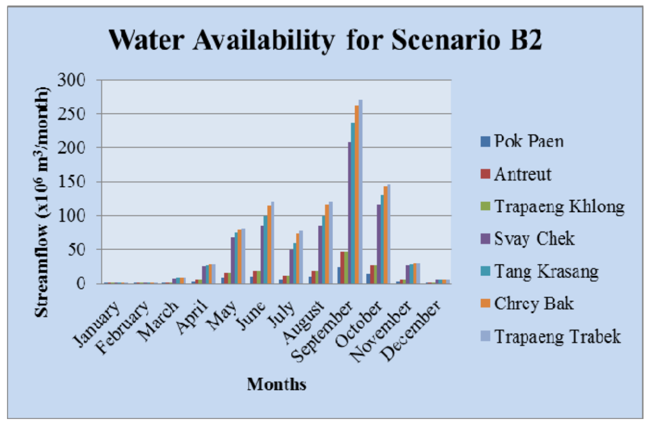

Figure 4. Water availability for Scenaro B2

2.3. *Rice Crop Water Requirement With Command Area*

Crop water requirement was calculated from CropWat model. The irrigation requirement is the different between the effective rainfall (Pe) and actual crop water requirement. Therefore, it can be calculated using the equation below:

$$IR = CR - Pe \qquad Eq.1$$

where IR, CR, Pe is presented in millimeter (mm). Considering all factore, Crop water requirement is calculated as the following table.

Table 1. Irrigation Scheme area with water requirement of each scheme per hectard.

Irrigation scheme	Irrigated area (ha)		Irrigation requirement (mm)	
	Wet	Dry	Wet (180days)	Dry (120days)
Scheme 1	621	-	5509	-
Scheme 2	335	-	5509	-
Scheme 3	920	-	5509	7300
Scheme 4	1800	-	5509	-
Scheme 5	5500	120	5509	7300
Scheme 6	350	105	5509	7300
Scheme 7	100	510	5509	7300
Total	9626	735		

2.4. Generality of WEAP Model

Developed by Stockholm Environmental Institute (SEI), WEAP operates at a monthly step on the basic principle of water balance accounting. This system is represented in the various sources of supply (e.g. rivers, groundwater and reservoirs), withdrawals, water demands and ecosystem requirements (SEI, 2001).

The result of the model was calculate as water demand in each irrigation scheme and amount of water shortage in the scheme. The model interface is shown in the figure 5 below.

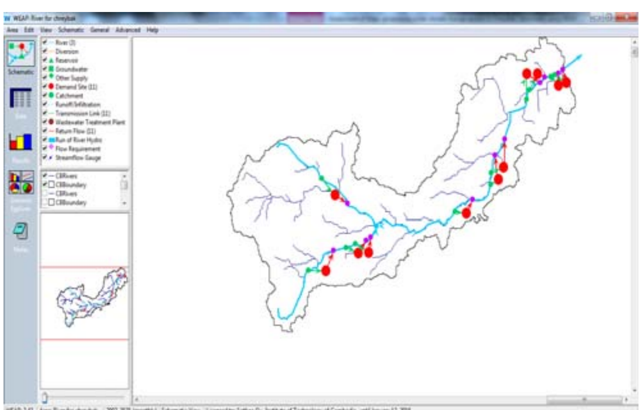

Figure 5. WEAP model interface

2.5. Calculate algorithm

- *Demand site*

A demand site's (DS) demand for water is calculated as the sum of the demands for all the demand site's bottom-level branches (Br). A bottom-level branch is one that has no branches below it.

$$AnnualDemand_{DS} = \sum Br(TotalActivityLevel_{Br} \, x WaterUseRate_{Br}) \quad Eq.\ 1$$

Where activity level totals is the command area of the irrigation scheme (hectare) and Water use rate (m^3/hectare)

- *Demand site inflow*

The amount supplied to a demand site is the sum of the inflows from its transmission links. (The inflow to the demand site from a supply source (Src) is defined as the outflow from the transmission link connecting them).

$$DemandSiteInflow_{DS} = \sum Src \, TransLinkOutflow_{Src,DS} \quad Eq.\ 2$$

The discharge is montly data in cubic meter per second (m^3/s).

2.6. Defining Scenarios

Two demand management scenarios were developed for this study –reference and 5 percent annual increase in irrigated area . The scenario were created to answer the question "What if".

Table 2. Defining scenarios

Demand management scenarios	"what if" question
Reference	Irrigation demand will be reduced by 1 percent if the physical infrastructure and management skill of operators are improved. Command area is kept at 10361ha.
Annual Increase in Irrigation demand	Irrigation demand will be reduced by 1 percent if the physical infrastructure and management skill of operators are improved. Annual increase in irrigation demand for 5 percent from 2014 to 2025 is assumed. Irrigated area is increase to 17720 ha.

3. RESULTS AND DISCUSSIONS

3.1. Baseline Scenarios

3.1.1. Current account irrigation simulation

Through WEAP model, water demand has been calculated as the below table in million cubic meters per period.

Table 3. Water demand in each irrigation scheme for wet season rice (x$10^6$$m^3$)

Irrigation	Ju	Jul	Aug	Sep	Oct	Nov
Antreut	0.14	0.15	0.15	0.14	0.15	0.14
Chrey Bak	0.15	0.16	0.16	0.15	0.16	0.15
Pok Paen	0.27	0.28	0.28	0.27	0.28	0.27
Svay Chek	0.77	0.80	0.80	0.77	0.80	0.77
Tang Krasang	2.36	2.44	2.44	2.36	2.44	2.36
Trapaeng Khlong	0.39	0.41	0.41	0.39	0.41	0.39
Trapaeng Trabek	0.04	0.04	0.04	0.04	0.04	0.04
SUM			25.17			

Based on Table 3, the irrigation demand for wet season rice was 25.17 million m^3 per annum. There was no unmet demand for wet season. The demand site for Tang Krasang Irrigation Scheme is high around 2.36 million^3 in June, September and November, compared to other irrigation schemes.

Table 4. Water demand for dry season rice (million m^3)

Irrigation scheme	Jan	Feb	Mar	Dec
Chrey Bak	0.062	0.056	0.062	0.062
Tang Krasang	0.070	0.064	0.070	0.070
Trapaeng Trabek	0.299	0.270	0.299	0.299
SUM	0.431	0.390	0.431	0.431

Table 5. Water scarcity in current account year (m^3)

	Chrey Bak	Tang Krasang	Trapaeng Trabek
Jan	0	9262	0
Feb	0	47752	0
Mar	0	0	0
Dec	0	0	0
Sum	0		0

According to Table 4, it showed that the Trapaeng Trabek Dry Irrigation Scheme consumed much water during dry season around 1.169 million m^3 as it has largely dry-cultivated area 510 hectares.

Moreover, based on the Table 5 shown in the context of dry season, there was unmet demand occurring only in Tang Krasang irrigation scheme around 9262 cubic meters in January, 47752 cubic meters in February.

3.1.2. Reference scenario

Reference scenario assumed that water demand would be decreased by 1 percent annually from 2014 to 2025. As a result, in water demand in Tang Krasang irrigation scheme decrease from 15.4 million m^3 to 14.5 million m^3 for wet seaso rice.

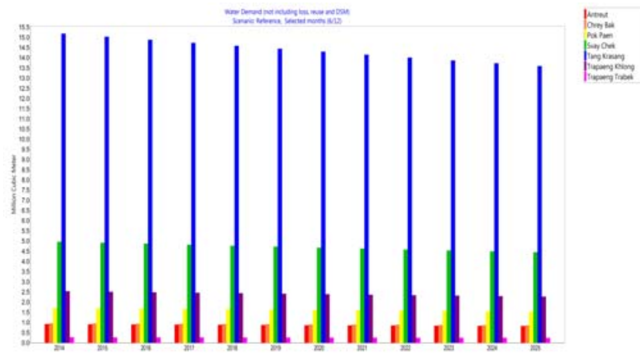

Figure 6. Water demand in referenc scenario for wet season (million m^3).

For dry season rice, water demand is reported to be decreased from 2.7 million m^3 to 2.4 million m^3.

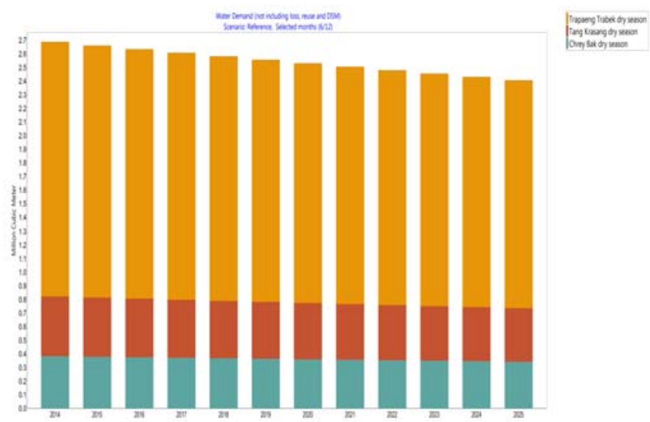

Figure 7. Water demand in referenc scenario for dry season (million m^3).

Moreover, the farmers who grow the dry season rice will face with water shortage for growing. The amount of water scarcity (m^3) indicated in Table 6 below decreased from 64547 m^3 in 2014 to 49726 m^3 in 2025:

Table 6. Water scacity in reference scenario (m^3)

Year	Chrey Bak	Tang Krasang	Trapaeng Trabek
2014	0	64547	0
2015	0	63130	0
2016	0	61728	0
2017	0	60340	0
2018	0	58966	0
2019	0	57607	0
2020	0	56274	0
2021	0	54932	0
2022	0	53606	0
2023	0	52300	0
2024	0	51007	0
2025	0	49726	0

3.1.3. Annual increase in irrigation demand scenario

The annual increase in irrigation demand scenario was used to respond the question what if the irrigated area annually increased by 5 percent per year, namely from 2014 to 2025. The expansion of cultivated in Strung Chrey Bak Catchment was occurred only in dry season cultivated areas which were demonstrated in Figure 8.

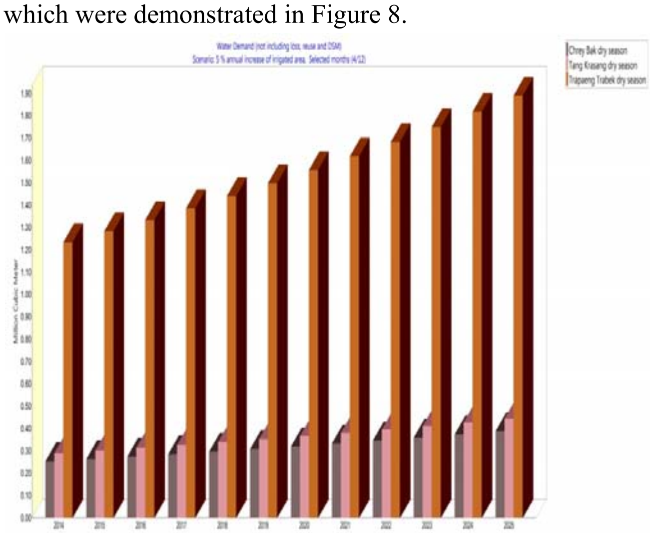

Figure 8. Water demand in 5 percents annual increase in irrigation demand (million m^3).

The Figure 8 illustrated above shows that the irrigation water demand will highly increase from 1.77 million m^3 in 2014 to 2.72 million m3 in 2025.

On this other hand, based on the Figure 9 illustrated below, water shortage occured in all irrigation schemes for dry season with the different year. For instance, Tang Krasang irrigation scheme meets unmet demand occuring from 2014 to 2015 while Trapaeng Trabek meets water scarcity from 2017 to 2025 and Chrey Bak from 2018 to 2025.

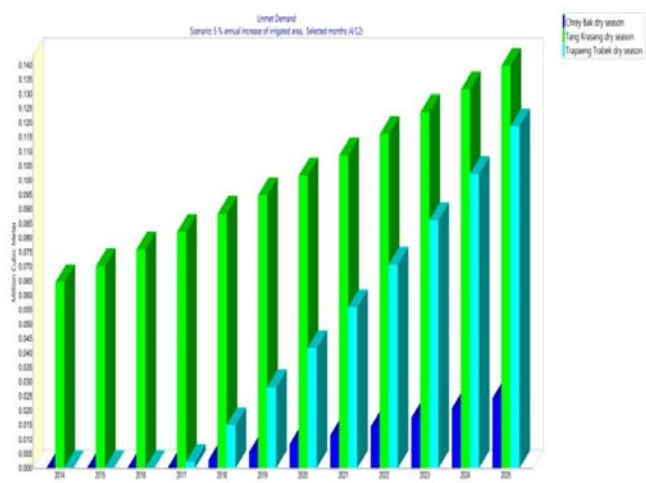

Figure 9. Water shortage in annual increase irrigation demand (million m^3).

3.2. Senario B2

Through the Water Availability for scenario B2, it showed there was no unmet demand as the water demands respectively 1.68 million m3 in dry season and 25.178 million m3 in dry season are less than stream flow.

Hence, there was no water shortage for scenario B2.

3.2. Scenario A2

According to Water Availability for climate change scenario A2, it shows there was no unmet demand as the water demand per annum, namely 1.68 million m3 in dry season and 25.178 million m3 in dry season, were less than stream flow evacuation respectively 14.52 million m3 in dry season and 710.81 million m3 in wet season per annum.

Therefore, Through the model, irrigation scheme in the catchment was reported enough water. There was no water shortage.

4. CONCLUSIONS

In the current account year 2014, water was reported to be enough for wet season rice. In contrast, water scarcity occured in dry season in Tang Krasang irrigation scheme in January and February. In reference scenario, water scarcity occurred only in Tang Krasang, decreasing from 64547 m^3 in 2014 to 51007 m^3 in 2024. Moreover, for 5% annual increase in cultivated area, the farmers would meet unmet demand occurring in Tang Krasang, Chrey Bak, and Trapaeng Trabek. For climate change scenario B2 and A2, there was no water scarcity in both dry and wet season since water demands for agriculture were less than stream flow availability.

In a situation of water limitation, water allowance between the three schemes facing unmet demands was very important for optimizing the use of water for irrigation. Cropping patterns should be applied for this situation, namely Chrey Bak scheme starting in early November and Trapaeng Trabek scheme in mid or late November in order to avoid an overlapping of irrigation peak demand.

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