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Impacts of climate change on irrigation water management by the Bhumibol dam in Thailand

Tuantan Kitpaisalsakul

Department of Water Resources Engineering, Faculty of Engineering, Chulalongkorn University
Bangkok 10330, Thailand

Abstract

The trends of the impacts of climate change on the irrigation water management by the Bhumibol reservoir, the largest dam in Thailand, which supplies water to the irrigation areas in the Chao Phraya basin is determined. Three periods: present (1979-2006), near future (2015-2039) and far future (2075-2099) are considered. The study result shows various trends in the climate and hydrological parameters which have associated impacts on water management. Thus, the air temperature will increase but the relative humidity will decrease. The evapotranspiration and irrigation water demand will increase. Both rainfall and inflow to the reservoir will increase. Because of that, the water management for the irrigation areas will be affected, such that the water deficit and number of deficit years will decrease in the near and far futures. This astounding positive impact is due to the fact that the increase of the water supply by the Bhumibol reservoir will exceed the increase of the water demand. For possible adaptation measures to future climate change, various non structural and structural measures are proposed for implementation.

Keywords: trends of climate change, irrigation water management, Bhumibol dam, Chao Phraya basin

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1. Introduction

Climate change affects the reservoir operation and also the water management for the irrigation areas in the Chao Phraya basin or the Central Plain basin in Thailand. Bhumibol reservoir is one of the major water resources of that country, supplying water to the irrigation areas in the basin. The reservoir water budget and water allocation are often limited and causes water shortage during dry seasons. In addition, the trends of climate change and their impacts on water management is another risk. This paper presents the study results of the trends and impact of climate change on water management under reservoir operation of the Bhumibol dam [1, 2].

2. Materials and Methods

2.1 Objective of study

The objective of the study is to analyze the trends and impact of climate change on water management of Bhumibol dam on the irrigation areas in the Chao Phraya basin in 3 time periods : present (1979-2006), near future (2015-2039) and far future (2075-2099). The study results on water management are the amount of water deficit and number of deficit years.

2.2 Study area

The Bhumibol dam is located in the Ping basin in the northern region of Thailand and delivers water to the irrigation areas in the Chao Phraya basin. The reservoir has the total storage of 13,462 Million cu.m., active storage of 9,662 Million cu.m. and the average annual inflow is 5,627 Million cu.m. The study area, with the Chao Phraya basin, is shown in Figure 1.

2.3 Bhumibol reservoir operation rule curves used presently

In general, the reservoir operation rule curves, namely general rule curves, are developed from the hydrological data of long periods of 30 years or longer. The rule curves are applied to the reservoir operation in every water year, whether it is a wet, normal or dry year. The upper and lower rule curves are applied for different water conditions. The reservoir water level is operated not to be above the upper rule curve in the wet years and not to be below the lower rule curve in the dry years. Recently, due to the large flood event throughout the Chao Phraya basin, affecting even Bangkok, in year 2011, the Royal Irrigation Department of Thailand has developed one more set of reservoir operation rule curves, namely flood rule curves, which are applied to reservoir operation in a large flood year as it had happened in year 2011. These new flood rule curves, in order to prepare for more storage for large flood inflow, are defining lower storage levels than the general rule curves. However, these new flood rule curves can reduce the adverse flood conditions in flood years, they may increase water deficits in other, normal or dry years [1]. In this study, the general rule curves are applied to determine the water deficits in every

* Corresponding author; e-mail: tuantan.k@chula.ac.th

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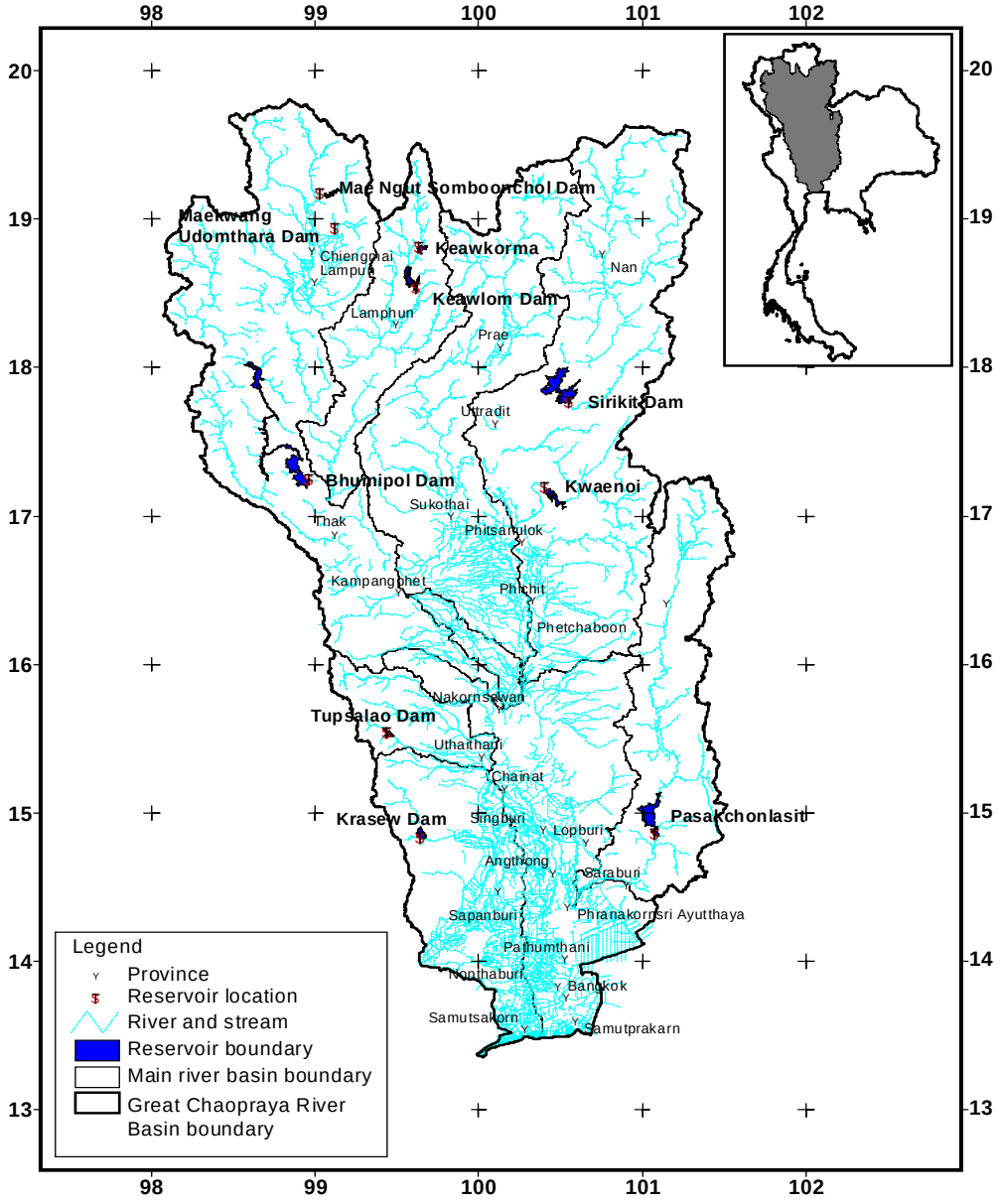

Figure 1 Map of Chao Phraya basin of Thailand with location of the Bhumibol dam

month of the years. The general (old) and flood (new) reservoir operation rule curves are shown in Figure 2.

2.4 Methods

The methods used to achieve the goals stated earlier are :
1) trend of climate and hydrology based on MRI GCM climate data model (Japan) with hybrid bias correction,
2) rainfall – runoff analysis (inflow to reservoir),
3) water demand estimation,
4) water release from reservoir operation and
5) water balance for water deficit study.

3. Results and discussion

3.1 Trend of climate and hydrology of the reservoir

1) Temperature and relative humidity

Annual mean air temperature and relative humidity at the Bhumibol Dam for present, near future and far future periods are analyzed and shown in Figure 3. The results show that annual mean air temperature values tend to increase in the near and far futures. The annual mean relative humidity values have also an increasing trend in the present period, though with wide

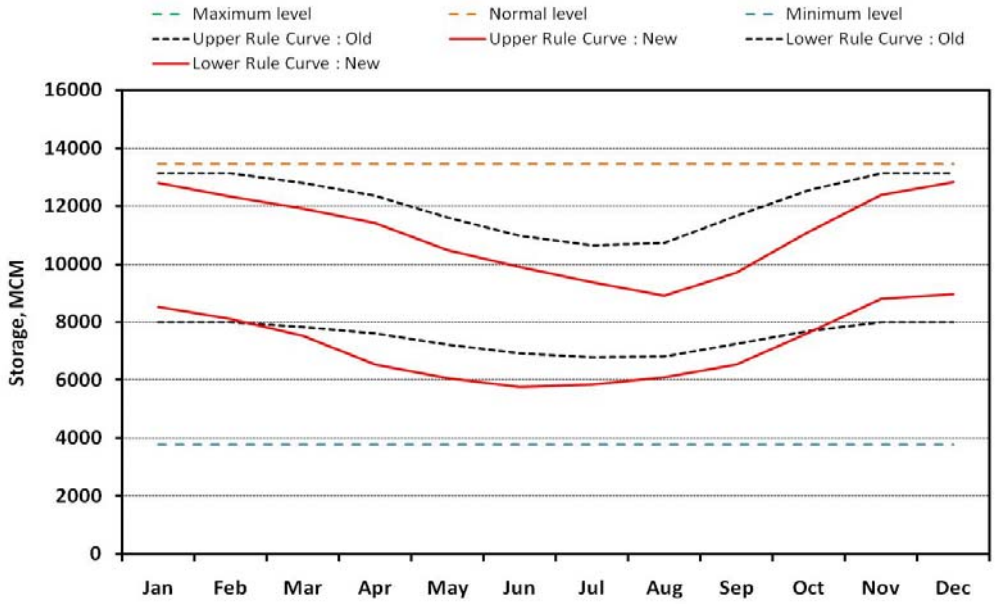

Figure 2 General and flood reservoir operation rule curves of Bhumibol dam

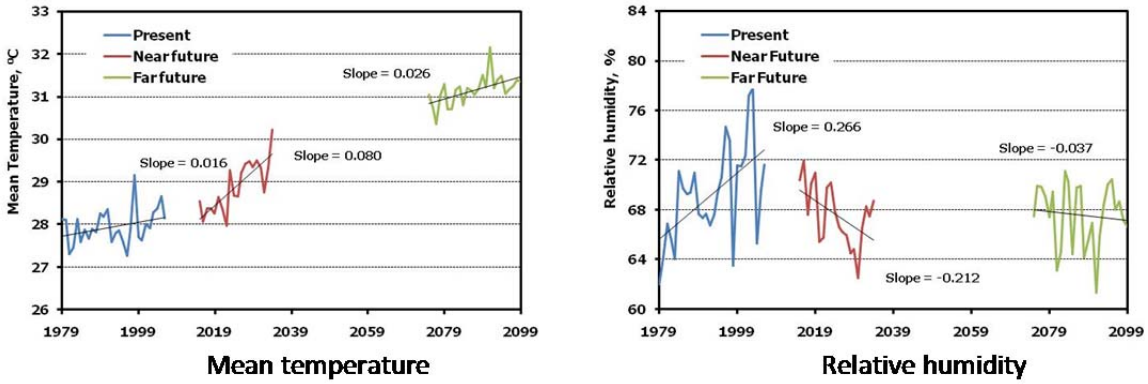

Figure 3 Time series of annual mean air temperature and relative humidity at the Bhumibol Dam

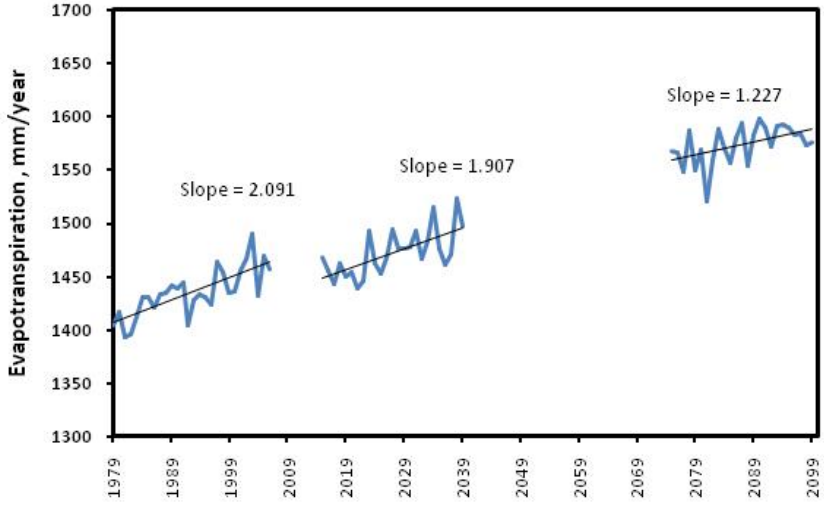

Figure 4 Time series of annual evapotranspiration of the Bhumibol Dam

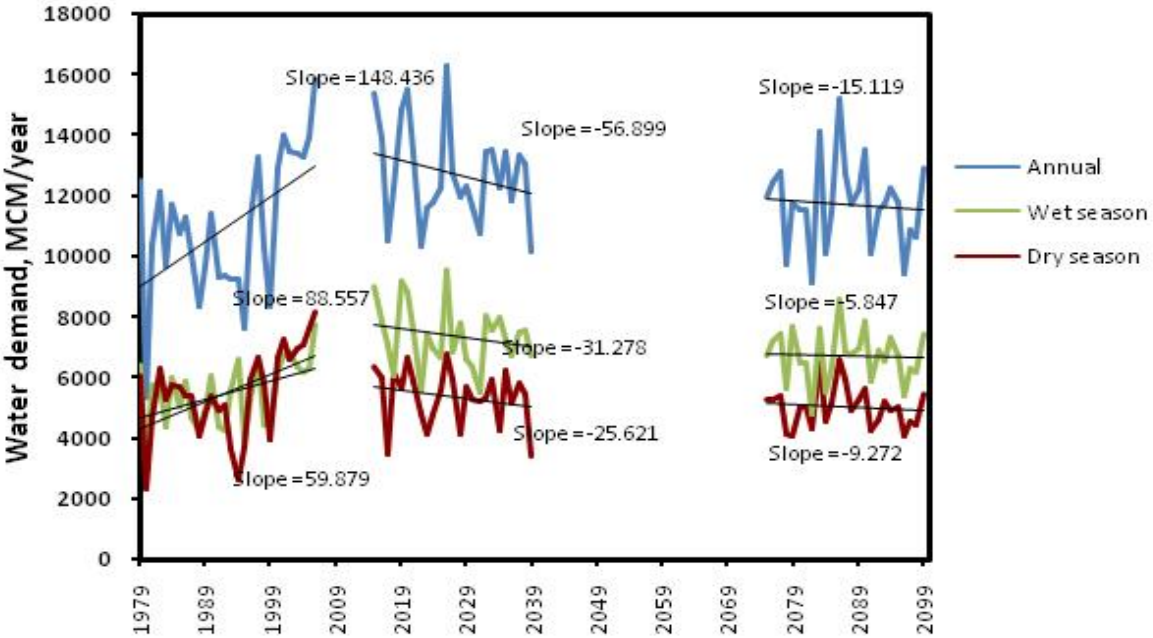

Figure 5 Time series of annual water demand of the Bhumibol dam

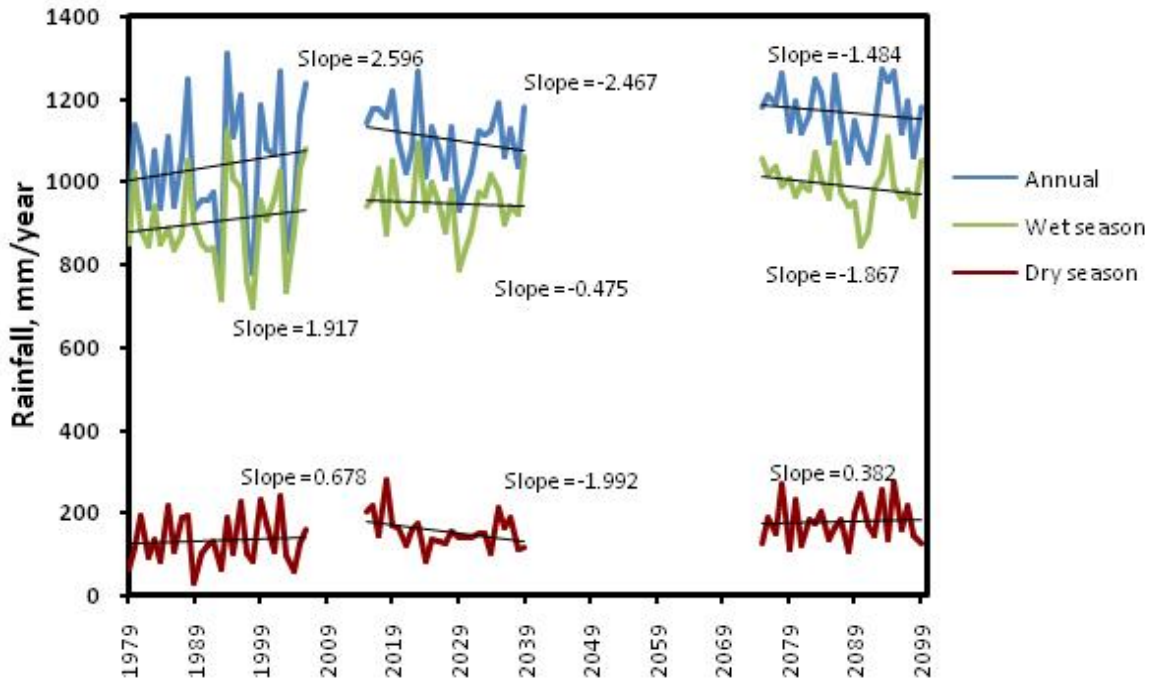

Figure 6 Time series of annual rainfall of Bhumibol dam

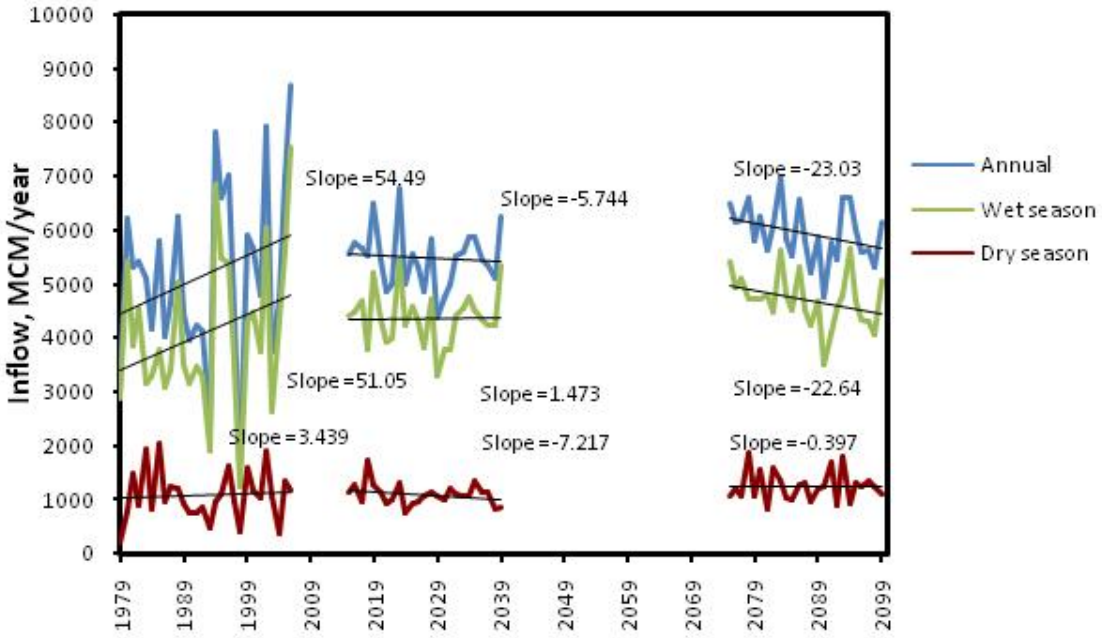

Figure 7 Time series of annual inflow of Bhumibol dam

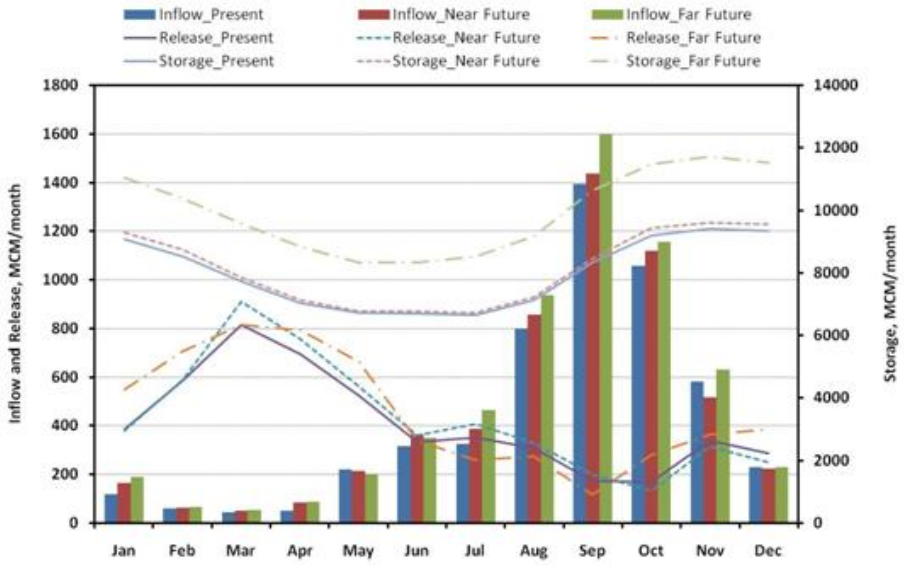

Figure 8 Monthly mean inflow, storage and release from the Bhumibol reservoir for present, near and far future periods

fluctuations, but tend to decrease with less fluctuations in the near and far futures.

2) Evapotranspiration and irrigation water demand

The estimated annual evapotranspiration and irrigation water demand of the Bhumibol dam in present, near future and far future periods are shown in Figures 4 and 5 respectively. The irrigation water demand for each cropping is determined from the total cropping areas and the cropping water requirement rate computed from the evapotranspiration rate minus the effective rainfall depth [1]. Both variables tend to increase which can be understood as a consequence of the air temperature increase as shown in Figure 3.

3) Rainfall

The annual rainfall at the Bhumibol dam tends to increase for the present period but decrease in the near and far futures as shown in Figure 6.

Table 1 Annual and seasonal irrigation water deficits of Bhumibol dam

Unit : Mm^3

Period	Dry	Wet	Annual	No. of deficit years
Present	625.16	1097.76	1722.92	14
Near Future	350.96	1011.86	1362.83	6
Far Future	491.25	868.40	1359.64	4

4) Annual inflow to the Bhumibol reservoir

The annual inflow to the Bhumibol reservoir during the present, near future and far future is shown in Figure 7. The trends of increasing inflow are similar to those of increasing rainfall.

5) Monthly inflow, storage and release from Bhumibol reservoir

Monthly mean values of inflow, storage and release from the Bhumibol reservoir in the present, near and far future periods are shown in Figure 8. All three variables tend to increase in the near and far future periods.

3.2 Impact of climate change on water deficit

The annual and seasonal water deficits in the irrigation areas under the Bhumibol reservoir operation are shown in Table 1. The amount of water deficit and number of deficit years will decrease in the near and far futures. This positive impact is due to the fact that the increase of the water supply by the Bhumibol reservoir will exceed the increase of the water demand. It is noted that the water deficits are higher for the wet season than for the dry season. This is because the cropping areas in the wet season are practiced more than those in the dry season due to the farmers having more confidence in more water availability in the wet season, thus encountering more water deficits particularly in the dry years.

3.3 Possible adaptation measures

As possible adaptation measures for mitigating the problems due to impacts of the future climate change, the following non structural and structural measures should be considered for implementation.

Recommended non structural measures are

1) monitor climate warning,
2) adjust crop pattern and agricultural areas,
3) adjust reservoir operation rule curves,
4) have more participation of stakeholders/ water users,
5) disseminate knowledge and
6) improve the telemetering system.

Recommended structural measures are

1) improve irrigation efficiency,
2) improve watershed management,
3) prepare temporary water storage (such as ponds),
4) promote reforestation and
5) increase reservoir storage (via enhancing dam embankment, dredging sediment and sediment control).

4. Conclusions

The trends of climate change during three periods (present, near future and far future) based on the predicted climate by bias-corrected MRI GCM data in the Chao Phraya basin of Thailand were determined. The air temperature will increase but the relative humidity will decrease. In parallel, evapotranspiration and irrigation water demand will increase. However, rainfall and inflow to the reservoir will also increase. This has impacts on the water management for the irrigation areas controlled by the Bhumibol reservoir. The results showed that the water deficit and number of deficit years will decrease in the near future and more so in the far future. For possible adaptation measures to future climate change, various non structural and structural measures are proposed for implementation.

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