IMPACT OF CLIMATE CHANGE ON WATER RESOURCES AND ADAPTATION MEASURES IN THE CHAO PHRAYA RIVER BASIN

IMPACT DU CHANGEMENT CLIMATIQUE SUR LES ESSOURCES EN EAU ET MESURES D'ADAPTATION DANS LE BASSIN DU FLEUVE CHAO PHRAYA

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ABSTRACT

A hydrological model for the Chao Phraya river basin in Thailand was built up in order to evaluate the impact of climate change on irrigation systems in the basin. The model was used both for flood and drought conditions, and the impacts of climate change on irrigation systems were reported to the Royal Irrigation Department in Thailand.

In the year of 2100, at the 50-year probability drought, total available water resource will decrease; the average rainfall will be less by 350 mm/year compared with the present condition. Regarding the priority of new dam construction in the northern part of the Chao Phraya river basin, 5 catchment areas were selected for the comparison of water resource development: 1) Upper Ping dam, 2) Upper Taeng dam, 3) Link canal between Mae Ngad – Mae Kuang dam, 4) Mae Ngad dam and 5) Phrae. In conclusion, the link canal between Mae Ngad- Mae Kuang dam and Phrae area are recommended to be given the top priority for construction of irrigation facilities from the view point of the possible future climate change.

Key words: *Climate change, water resources, dam construction priority, Chao Phraya river basin, Thailand.*

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RESUME ET CONCLUSIONS

Un modèle hydrologique a été développé pour le bassin du fleuve Chao Phraya en Thaïlande pour évaluer l'impact du changement climatique sur les systèmes d'irrigation dans ledit bassin. Le modèle considère des cas d'inondation et de sécheresse, et les impacts du changement climatique sur les systèmes d'irrigation ont été signalés au département royal d'irrigation du pays.

Dans l'année 2100, pour une sécheresse probable d'une période de 50 ans, la quantité totale disponible des ressources en eau diminuera. La moyenne précipitation réduira de 350 mm/an par rapport à la situation actuelle. En ce qui concerne la priorité de construction d'un nouveau barrage dans la partie nord du bassin, 5 bassins versants ont été retenus pour la comparaison du développement des ressources en eau. Il s'agit: 1) du barrage supérieur de Ping; 2) du barrage supérieur de Taeng 3) du canal de liaison entre les barrages de Mae Ngad et de Kuang Mae; 4) du barrage de Mae Ngad; et 5) de la région de Phrae. En conclusion, il est recommandé d'accorder plus de priorité au canal de liaison entre les barrages de Mae Ngad et de Mae Kuang et la région de Phrae pour la construction des installations d'irrigation compte tenu du changement climatique à l'avenir.

Mots clés: *Changement climatique, ressources en eau, priorité de la construction du barrage, bassin fluvial de Chao Phraya, Thaïlande*

1. INTRODUCTION

The Ministry of Agriculture, Forestry and Fisheries of Japan has initiated the study on the impact of the climate change on irrigation systems in the Southeast Asian monsoon region, where the major agriculture product is rice from the paddy field, similar to Japan, Thailand is one of the countries, which has been addressing the issue of vigorously. Thailand frequently suffers from droughts and floods, which causes the high public awareness on the climate change risks. We studied the effects of drought and flood adaptation measures against the climate change in the Chao Phraya river basin.

2. OBJECTIVES

In order to evaluate the impact of the changes in the availability of water resources in the Chao Phraya river basin, we have examined the development priorities of the planned dams in the upstream. In addition, we considered the other scenarios for adapting to climate change and estimated the impact of each scenario.

3. METHODS

3.1. Study area

Storage capacity of the dams and size of the basin area are summarized in Table 1. Figure 1 shows location of the existing dams and planning of dams in the upstream of the Chao Phraya river basin.

Table 1. Dam storage and catchment area in each dam (Capacité et bassin versant de chaque barrage)

Project name	Dam storage (x 10^6 m^3)	Basin area (km^2)
Dam construction at Upper Ping	100	235
Dam construction at Upper Taeng	112	177
Link canal between Taeng-Mae Ngad dam-Mae Kuang dam	-	-
Mae Ngad dam (Existing)	256	1281
Mae Kuang dam (Existing)	325	569

Source: Royal Irrigation Development, Thailand and JIID Study Team.

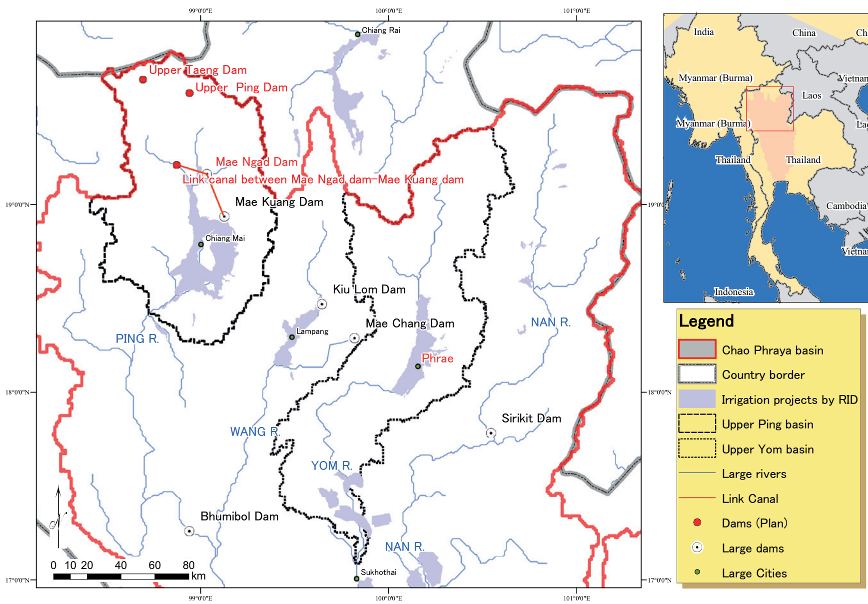


Fig. 1. Location of existing dams and planning of dam in the upstream of the Chao Phraya river basin (Emplacement des barrages existants et planning du barrage en amont du fleuve Chao Phraya)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

3.2. Water resource analysis

The rainfall data in the past and future were shared from the outcome of the supercomputer model in the Meteorological Research Institute (MRI) of Japan (Kitoh et al., 2009). Using the result of computer-generated rainfall by MRI, extreme hydrological events such as maximum daily rainfall and the annual rainfall at 50-year probability were calculated. In this study, two drought years were examined as 1979 and 2089 for the past and the future, respectively. The total available water resources were computed from the total rainfall amount after deduction of actual evapotranspiration.

The actual evapotranspiration (ET) is given by multiplication of a constant factor to the potential ET. ET can be calculated by the Thornthwaite method (Tangsomboon, 2006). Total available amount of water resource was calculated as below;

$$S_{tot} = R - ET_a \tag{1}$$

$$ET_a = C_{ETa} \times ET_p \tag{2}$$

where S_{tot}: Total available amount of water resource, R: Rainfall, ET_a: Actual ET, ET_p: Potential ET, C_{ETa}: Coefficient of ET.

Actual ET was calculated by multiplying Potential ET by a coefficient (0.7~0.8). Potential ET is calculated by the following Thonthwaite method.

$$E_{max} = 16\left(\frac{10T_m}{I_t}\right)^a\left(\frac{N}{12}\right), \tag{3}$$

where,

$$I_t = \sum_{m=1}^{12}\left(\frac{T_m}{5}\right)^{1.514}$$

$$a = \left(0.675I_t^3 - 77.1I_t^2 + 17{,}920I_t + 492{,}390\right)\times 10^{-6}$$

$$N = 24(\omega_0 / \pi)$$

$$\omega_0 = \cos^{-1}(-\tan\phi\tan\delta)$$

$$\delta = 0.4093\cos(0.01689(D - 173))$$

E_{max} : Monthly maximum ET (mm/month)

T_m : Monthly average temperature (Celsius degree)

N : Monthly average hours of sunshine (hour)

D : Number of days from 1st January (day)

∅ : Latitude (rad).

3.3. Scenario analysis

By water balance method, changes in water resource are estimated in case of the following four scenarios;

1) Priority of dam construction

2) Changes in cropping calendar
3) Changes in land use
4) Changes in domestic water consumption due to population growth.

4. RESULTS AND DISCUSSION

4.1 Water resources analysis

In the computed outcome of the extreme cases value of the daily rainfall in the wet season increased in the mountainous area of the four tributaries of the Chao Phraya River and decreased in the downstream of the Chao Phraya river near Bangkok city. The annual precipitation decreased significantly in the mountainous area during the drought year.

In case of flood, daily rainfall increased in mountainous area (Upstream area of the Chao Phraya river basin), on the other hand, daily rainfall decreased in the Basak river basin (Figure 2). In case of drought, annual rainfall in Lampaang Province and the catchment area of Sirikit dam decreased more than other areas (Figure 3).

Figure 4 shows the outcome of potential ET. The volume of the potential ET in the basin increased by an average of 529.2mm/year, and the increment in volume was higher in the plain area than in the mountain area. Having consideration of actual ET by Eq. (2), total available water resource decreased in the whole Chao Phraya river basin in spite of the increasing rainfall (Figure 5).

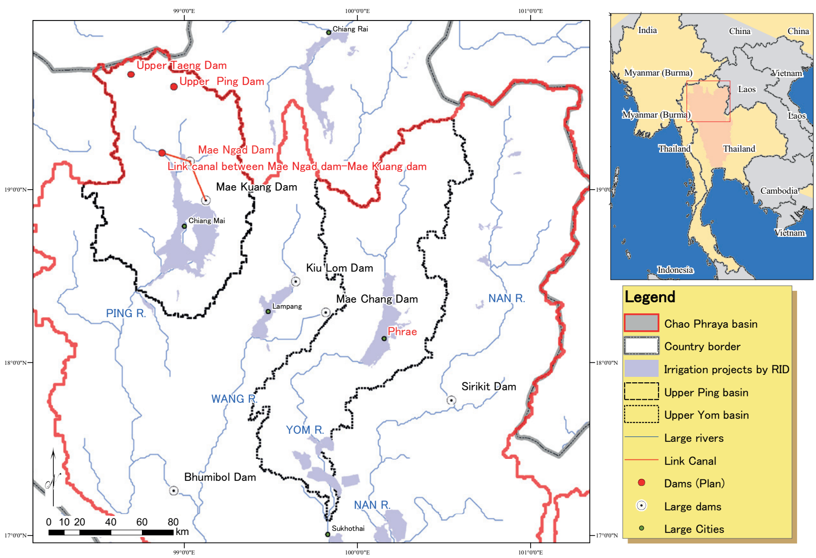


Fig. 2. Daily rainfall change in 50-Year Flood (Future – Present) in the Chao Phraya river basin (Variation des précipitations journalières pour une inondation de période de retour 50 ans (Futur - Présent) dans le bassin du fleuve Chao Phraya)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

The value of daily rainfall (Future - Present) increased in the mountainous area of the Ping river basin, the Wang River, the Yom River and the Nan river basin; while, the value of that decreased in the Basak river basin.

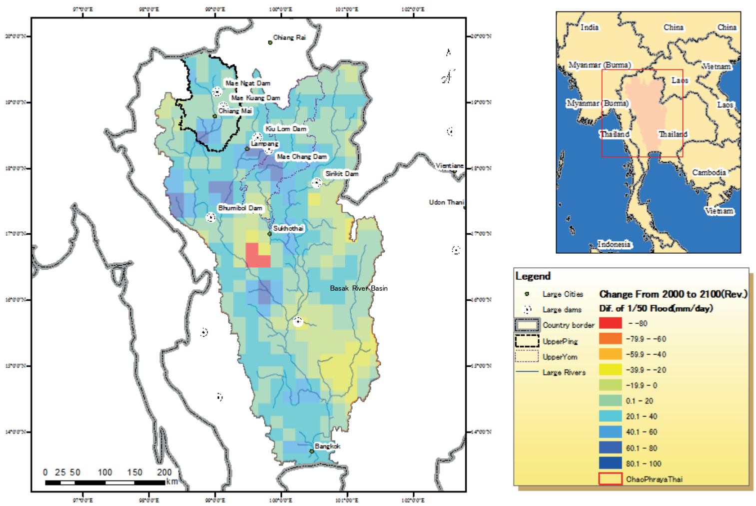


Fig. 3. Annual rainfall change in 50-Year Drought (Future – Present) in the Chao Phraya river basin (Variation annuelle de la pluviosité pour une sècheresse de période de retour 50 ans (Futur - Présent) dans le bassin du fleuve Chao Phraya)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

Annual rainfall decreased in mountainous areas, on the other hand, it decreased slightly or increased along the river side.

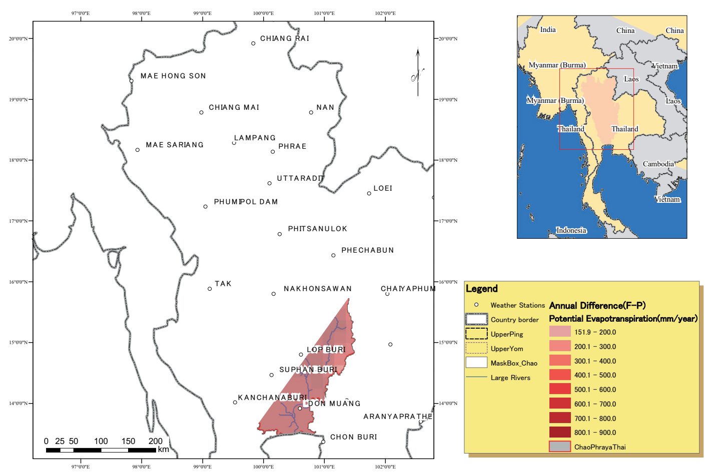


Fig. 4. Potential evapotranspiration change in 50-Year Drought (Future – Present) in the Chao Phraya river basin (Variation de l'évapotranspiration potentielle pour une sécheresse de période de retour 50 ans (Futur-Présent) dans le bassin du fleuve Chao Phraya)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

Potential ET increased in the plain area and higher than that of the mountainous area.

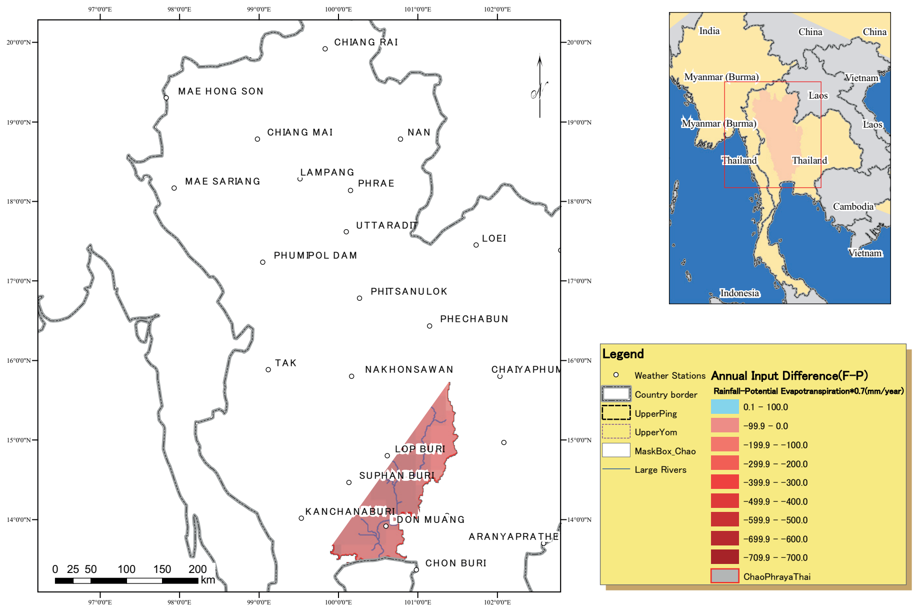


Fig. 5. Total available water resource change in 50-Year Drought (Future – Present) in the Chao Phraya river basin (Variation de la quantité totale des ressources en eau pour une sécheresse de période de retour 50 ans (Futur-Présent) dans le bassin du fleuve Chao Phraya)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

Total available water resource decreased in the whole Chao Phraya river basin.

4. 2. Scenario analysis

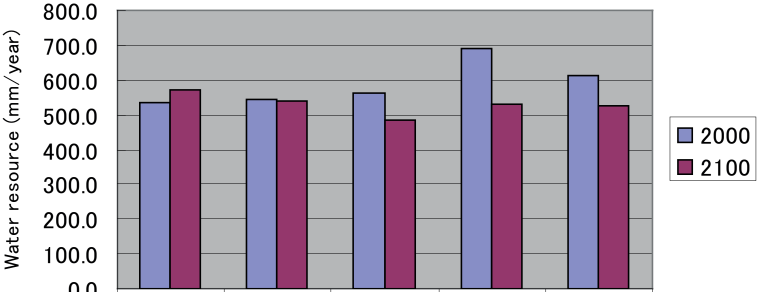
Four scenarios were considered for adaptation measures to climate change; 1) Dam construction, 2) Changes in cropping calendar, 3) Changes in land use and 4) Changes in domestic water consumption due to population growth.

4.2.1. Priority of dam construction

Thai government plans to construct several dams in the Northern part of the Chao Phraya river basin. Priority of construction is determined based on several factors, such as availability of water resources, ecological and/or political aspects. In this report we focused changes in the availability of water resources from the hydrological aspect.

Five catchment areas were selected for the comparison of water resource: 1) Upper Ping dam, 2) Upper Taeng dam, 3) Link canal to Mae Ngad – Mae Kuang dam (hereinafter mentioned as Link cannal), 4) Mae Ngad dam and 5) Phrae. Figure 6 shows changes in available water resource in 50-year probability drought in 2000 and 2100. Though in Upper Ping dam and Upper Taeng dam, total availability of water resource did not change greatly; however, water resources availability for the Link canal, Mae Ngad dam and Phare decreased by more than 50mm/year.

For the above reason, Link canal and Phrae are recommended for construction of irrigation facilities in view of the possible future climate change.



	UPPER PING	UPPER TEANG	LINK CANAL	MAE NGAD	PHRAE
2000	534.1	545.8	563.0	692.3	612.5
2100	573.2	540.4	485.8	529.2	527.0

Fig. 6. Water resource in case of 50-Years Drought in 2000 and 2100 (Ressource en eau dans le cas d'une sécheresse de période de retour 50 ans en 2000 et 2100)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

4.2.2. Changes in cropping calendar

The effect of shifting of cropping calendar was calculated. As a result, annual water demand in whole year was not clearly changed in case of shifting within 2 weeks advance and 2 weeks behind the present cropping calendar (Table 2).

Table 2. Irrigation water demand change in case of shifting crop calendar between 2 weeks advance and 2 weeks behind (Variation de la demande en eau d'irrigation en fonction du déplacement du calendrier cultural entre 2 semaines d'avance et 2 semaines de retard)

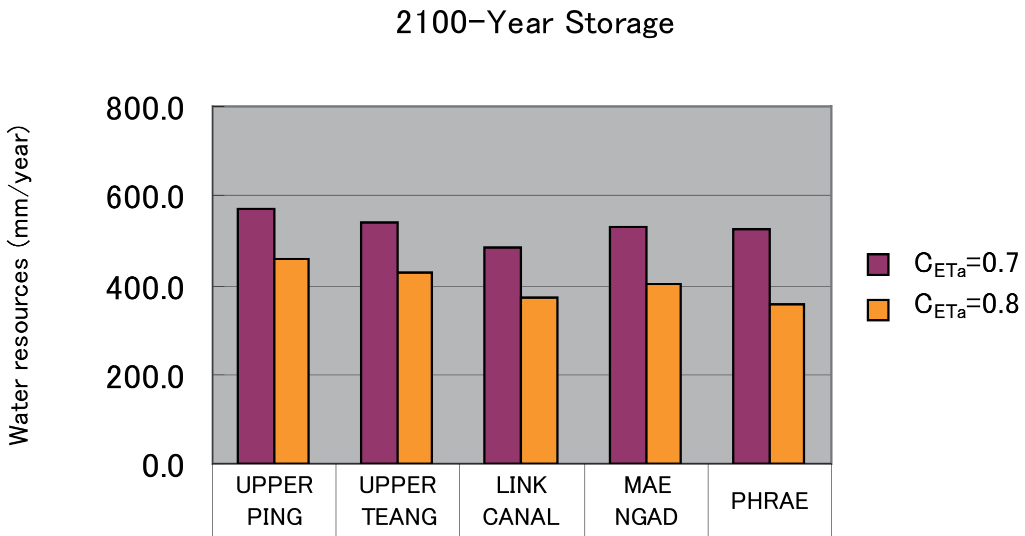
Case evaluated	Model: 2000 (m^3)	Ratio to Present (%)	Model: 2100 (m^3)	Ratio to Present (%)
2 weeks advance	1.383E + 08	99.5	1.326E + 08	97.7
1 week advance	1.388E + 08	99.8	1.342E + 08	98.9
Present	1.390E + 08	100.0	1.357E + 08	100.0
1 week behind	1.383E + 08	99.5	1.371E + 08	101.0
2 weeks behind	1.363E + 08	98.1	1.393E + 08	102.7

Source: Royal Irrigation Development, Thailand and JIID Study Team.

4.2.3. Changes in land use

Land use change such as deforestation, would be estimated by changing the value of C_{ETa} in Eq. (2). C_{ETa} is related with runoff rate. If runoff rate decreased, the coefficient, C_{ETa}, would increase.

Here, C_{ETa} is changed from 0.7 to 0.8 (Figure 7). In result, water resource decreases by 150mm/year, which is 1.5 times higher than the irrigation water demand; it would cause severe damage to crops.



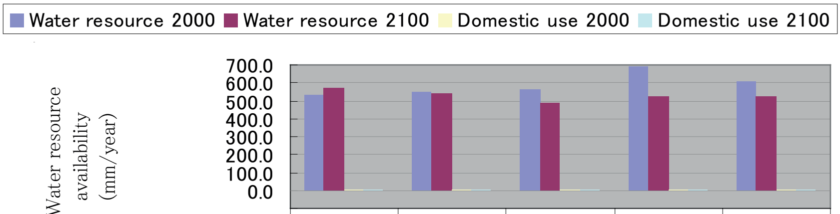
	UPPER PING	UPPER TEANG	LINK CANAL	MAE NGAD	PHRAE
C_{ETa}=0.7	573.2	540.4	485.8	529.2	527.0
C_{ETa}=0.8	460.8	429.4	370.5	402.5	358.3

Fig.7. Changes in available water resource by value of coefficient of actual evapotranspiration in Eq (2) (Variation des ressources disponibles en eau en fonction du coefficient de l'évapotranspiration réelle dans l'équation (2))

Source: Royal Irrigation Development, Thailand and JIID Study Team.

4.2.4. Changes in domestic water use by population growth

Domestic water use can be assumed based on expected population growth. Population in each catchments area was assumed from UN (2004) estimation and Royal Irrigation Department (2003: Table 3). Water demand was changed from 2.0mm (present), 2.5 mm (in 2050), and then 2.3mm (in 2100: Figure 8).



	UPPER PING	UPPER TEANG	LINK CANAL	MAE NGAD	PHRAE
Water resource 2000	534.1	545.8	563.0	692.3	612.5
Water resource 2100	573.2	540.4	485.8	529.2	527.0
Domestic use 2000	2.0	2.0	2.0	2.0	2.0
Domestic use 2100	2.3	2.3	2.3	2.3	2.3

Fig. 8. Domestic water use change by population growth (Variation de la consommation domestique en eau en fonction de la croissance démographique)

Source: Royal Irrigation Development, Thailand and JIID Study Team.

Table 3. Population growth in Thailand (Medium scenario; birth rate =1.85) (Croissance démographique en Thaïlande (Scénario moyen ; taux de natalité de 1.85))

Total Population, Medium Scenario: 1950 – 2300.

	1950	2000	2050	2100	2150	2200	2250	2300
Thailand (1000 person)	19,626	60,925	77,079	70,351	69,186	72,140	74,748	76,861
Thailand (100 in 2000)	32	100	127	115	114	118	123	126

Source: Department of Economic and Social Affairs; Population Division (2004): World Population to 2300 United Nations.

5. CONCLUSIONS

In order to evaluate the impact of climate change on irrigation systems in the Chao Phraya river basin in Thailand, a water balance model for the basin was developed. The model can calculate the changes in the total available water resources in the future using rainfall and evapotranspiration data. Compared with the total available water resource volume (100~140mm/year), the volume for domestic water use was insignificant (2.0~2.5mm/year). On the other hand, irrigation water was accounted for approximately 100mm. Therefore available water resource for irrigation water was limited in drought year. Total available water resource came to be in more severe situation in the future because of climate change. Utilization of existing structures was one of the adaptation measures for climate change. The other would be increase of existing dam capacity and construction of linkage canals between several existing dams.

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