ESTIMATION OF CROP WATER REQUIREMENT IN KOREA WITH CLIMATE CHANGE

EVALUATION DES BESOINS EN EAU AGRICOLE EN COREE PAR RAPPORT AU CHANGEMENT CLIMATIQUE

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ABSTRACT

The study aims to predict crop water requirement using future climate data obtained from MIROC3.2 considering A1B scenario. The future climate data at each station are corrected by bias-correction method, and downscaling procedures have been performed for calculation of crop water requirement with the method of change factor for accuracy. Results indicate that crop water requirement in the future will be increased due to the high potential ET (Evaportranspiration) caused by temperature rise. Therefore, it is necessary to secure additional water resources to adapt the climate change. The crop water requirement estimated with climate change can be used for formulation of a master plan of water resources in Korea. For further study it is required to develop downscaling method reflecting national conditions for reliable assessment of agricultural water resources according to the climate change.

Keywords: *Crop water requirement, Climate change, Evaportranspiratio (ET), Water resources, MIROC3.2, Korea.*

RESUME

L'étude vise à prévoir les besoins en eau agricole utilisant les données climatiques futures obtenues de MIROC3.2 compte tenu du scénario A1B. Les données climatiques futures sont corrigées à chaque station par la méthode de correction de biais et les procédures à l'échelle réduite mises en place pour le calcul des besoins en eau agricole utilisant la méthode du facteur de changement pour obtenir la précision. Les résultats indiquent que dans l'avenir les besoins en eau agricole augmenteront en raison du potentiel fort de l'ET

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causé par la hausse de température. Donc, il est nécessaire de sécuriser les ressources en eau supplémentaires pour adapter au changement climatique.

Les besoins en eau agricole évalués avec le changement climatique peuvent être utilisés pour formuler un plan de gestion des ressources en eau en Corée. Pour mener d'autres études, il est nécessaire de développer la méthode à l'échelle réduite reflétant les conditions nationales pour l'évaluation fiable des ressources en eau agricoles par rapport au changement climatique.

Mots clés: *Besoins en eau agricole, changement climatique, Evaportranspiration (ET), ressources en eau, MIROC3.2, Corée.*

1. INTRODUCTION

Since the industrial revolution, technology innovation and industrialization brought improvement of quality of life with rapid destruction of ecosystem and environment pollution. GHGs increase caused by fossil fuel consumption results in climate change with acceleration of global warming, which affects human being and natural environment. Emerging as an important issue, climate change becomes a first priority to be addressed by developed countries in the 21st century (Yun, 2010).

Scientist have identified that key cause of the climate change is the increase of global warming gases in the air associated with human activities out of the various climate modeling. According to the IPCC Fourth Assessment Report (AR4), a temperature rise of 6.4^{0}C is projected at the end of 21st century. Out of the observed change and projection of climate in the report it is likely that water resources will be vulnerable in climate change and affected by drought and extreme heavy precipitation. The aim of the study is to estimate potential evapotranspiration (ET_0) and crop water requirement using meteorological data from a coupled model MIROC3.2 (Model for Interdisciplinary Research on Climate) with A1B scenario. It intends to provide basic information with the estimation of crop water requirement change for agricultural water supply by irrigation reservoir reflecting future weather projection.

2. MATERIALS AND METHODS

2.1 Selected observation stations and study area

Criteria of station selection include availability of ET monitoring data and long-term observation data among the countryside for the study. Out of 18,000 agricultural reservoirs considering components for study area selection are as follows.

- Area that has little change of crop patterns
- Reservoir adjacent to observation station
- Thissen network
- Topographical conditions like mountainous area and
- Precision of reservoir volume

Table 1 demonstrates the selected stations and reservoirs. As shown in the table 1, there are two study stations in Gyeonggi province and Gyeongnam province.

Table 1 Selected stations and reservoirs

Region	Observation station	Data Period years	Reservoir	Basin area (ha)	Irrigation area (ha)	osmotic quantity (mm)	Conveyance losses (%)	Effective storage capacity ($1,000m^3$)	Completed year
Gyeong-gi	Su-won	42 (‘67~‘08)	Ma-dun	1,240	529.5	4.0	10.0	3,486	1975
Gyeong-nam	Jin-ju	39 (‘70~’08)	Nam-seong	392	72.4	4.1	15.0	1,622	1984

2.2 GCM (General Climate Model) and scenarios

In this study four GCM models including MIROC3.2, ECHAM5, HadCM3, and ECHO-G are evaluated for the analysis out of the 23 GCM models. Greenhouse Gas Emission Mitigation Scenarios for the study is A1B (medium), which is a balanced emphasis on all energy sources. Comparing weather data in the model and 38 year observation data at Su-won station from 1971 – 2008, simulated precipitation by MIROC3.2 is 1,342 mm, which is higher than the observed data 1,304mm at the station. The precipitations simulated by other models are in the range of 720mm – 830mm. Therefore, the GCM model applied for the study is MIROC3.2 developed by the Center for Climate System Research.

2.3 Bias-correction method

GCM model requires flux correction to achieve a stable climate because it depends on the distances between countries and spatial resolution. The bias-correction method suggested by Alcamo et al. (1997) was employed for this study to minimize the uncertainty of simulation results like precipitation and weather. The method is generally accepted within the global change research community (IPCC) and based on the equation (1) and (2).

$$P'_{GCM,fut} = P_{GCM} \times (\overline{P}_{meas,his} / \overline{P}_{GCM,his}) \quad (1)$$

Where, $P'_{GCM,fut}$ is defined as future precipitation corrected; P_{GCM} future precipitation simulated by GCM; $\overline{P}_{meas,his}$ mean precipitation for past 30 years; and $\overline{P}_{GCM,his}$ mean precipitation simulated for past 30 years.

$$T'_{GCM,fut} = T_{GCM} + (\overline{T}_{meas,his} - \overline{T}_{GCM,his}) \quad (2)$$

Where, $T'_{GCM,fut}$ is defined as future temperature corrected; T_{GCM} future temperature simulated by GCM; $\overline{T}_{meas,his}$ mean temperature for past 30 years; and $\overline{T}_{GCM,his}$ mean temperature simulated for past 30 years.

Overall, precipitation and temperature simulated from MIROC3.2 were higher than the observed one. Correction of precipitation was performed by multiplication of correction factor 1.06 and 1.14 at Su-won and Jin-ju station respectively. Temperature was corrected by subtraction of correction factors 1.63 and 2.40 from the simulation data. Table 2 shows the corrected precipitation and temperature by using bias-correction method.

Table 2 Correction factor on temperature and precipitation

MIROC3.2			
Su-won station		**Jin-ju station**	
Precipitation	Temperature (°C)	Precipitation	Temperature (°C)
1.06	-1.63	1.14	-2.40

2.4 Downscaling and water balance analysis

Simulation results from the numerical GCM model by scenario are used for predicting impact of climate change on water requirement. However, GCM models are diverse, and projections by them are different according to the model. From the evaluation of GCM models (IPCC, 2001), current climate models are suitable to predict climate at global and continental level but have a low resolution at regional level. Therefore, downscaling procedures are required to feed small-scale impact models and to guarantee a correct representation of the hydrologic processes at a much finer spatial resolution (Fowler and Kilsby, 2007).

There are two types of downscaling methods: dynamical approach and statistical approach. Among the statistical approach CF (change factor) method was employed in the MIROC3.2 applied by Diaz-Nieto and Wilby (2005). Corrected climate data was calculated by using reference data in 2005, which is close to the mean observation data for past 30 years (1979 – 2008). ET, humidity, wind speed and radiation have been generated by Climate Change Weather Generator (CCWG). Crop water requirement change has been analyzed by using Hydrological Operation Model Water Resources System (HOMWRS) develop by Korea Agricultural & Rural Infrastructure Corporation (KARICO, 2001) for water balance analysis.

3. RESULTS AND DISCUSSION

3.1 Evapotranspiration

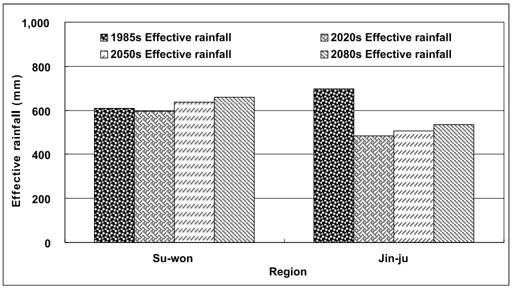
As shown in the Table 3, mean potential ET and actual ET were calculated by regions according to the CF method. Potential ET at Su-won was increased by 5.3 – 12.5% comparing with the one in the 1986s and ET_0 at Jin-ju by 5.1 – 12.9%. Actual ET at Su-won and Jin-ju was increased by 6.6 – 14.1 % and 5.6 – 14.8 % respectively.

Table 3 Result of evapotranspiration by regions over years

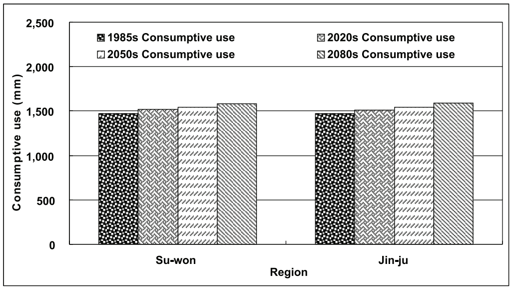
Region	Potential evapotranspiration (ET_0 mm)				Actual evapotranspiration (ET mm)			
	1985s	2020s	2050s	2080s	1985s	2020s	2050s	2080s
Su-won	629	663.9	688	718.9	683.7	732.1	758.7	795.9
Jin-ju	617.4	650.6	676.6	709	664.2	703.6	732.8	779.7

3.2 Crop water requirement

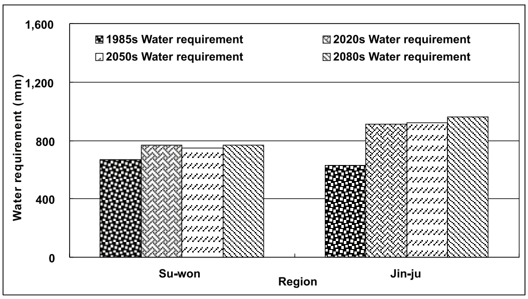
Increase of crop water requirement in the 2020s, 2050s, and 2080s can be observed due to the ET_0 rise. Fig 1 depicts simulated water requirement with effective rainfall and consumptive water use at the two stations Su-won and Jin-ju.



Effective rainfall



Consumptive use



Crop water requirement

Fig. 1 Simulated water requirement using CF

According to the estimation result of water requirement, the higher the temperature, the higher demand of water requirement. It can be seen that crop water requirement increases with the ET rise by the 2080s. Water requirement at Su-won station in the 1985s was 1,480mm, and it was increased by 82mm gradually, accounting for 1,572mm in the 2080s. Even though increase of effective rainfall was observed, it did not affect the change of water requirement dominantly at Su-won station. While, the decrease of effective rainfall at Jin-ju station contributes to the increase of water requirement greatly. It can be seen that precipitation intensification at non-irrigation period brings effective precipitation decrease, which contributes to higher demand of crop water at irrigation period. Therefore, it is necessary to secure additional water resources to adapt the climate change.

4. CONCLUSIONS

Crop water requirements from MIROC3.2 model are simulated according to the climate change scenario A1B. Bias-correction method has been applied to minimize uncertainty of the analysis and CF approach for downscaling to increase precision. The key findings from the study are as follows:

- Increase water requirement due to evapotranspiration rise can be observed out of the analysis comparing with the reference year the 1985s. It is caused by temperature rise which leads to high demand of crop water from increased ET.
- Precipitation intensification at non-irrigation period brings effective precipitation decrease, which contributes to higher demand of crop water at irrigation period. It is necessary to secure additional water resources to adapt the climate change.
- It is expected that estimation on potential evapotranspiration in this study can be used for formulation of master plan of water resources.
- For further study it is required to develop downscaling method reflecting national conditions for reliable assessment of agricultural water resources according to the climate change.

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