

Impact of Climate Change on Wetland Functions

Duck Gil Kim¹, Hui Seong Noh, Na Rae Kang, and Hung Soo Kim

Department of Civil Engineering, Inha University, Korea

Abstract. Recently, there is a growing interest in the wetland management for biodiversity and preservation of ecosystem. One of the problems of the wetland management is climate change due to the global warming, and many studies have shown that the climate change influence on wetlands. Therefore, in this study, we estimated impact of climate change on wetland functions such as hydrologic, biogeochemical, plant habitat, and animal habitat functions. The study site is the Upo wetland in Korea which is the largest natural wetland in Korea, and the wetland is designated as a 'Protected Wetland' by the international Ramsar Convention. We assessed impact of climate change on the wetland functions using climate scenario, climate model, and analysis techniques of climate change. We performed functional assessment of wetland using Hydrogeomorphic (HGM) method. As a result, we found that the about 10% of wetland functions of will change in the future due to the climate change. This case study could be useful as a reference for the future wetland management planning.

Keywords: Climate change, Wetland Function, HGM

1. Introduction

In the past, a lot of wetlands were destroyed due to urbanization and industrialization. But recently, as the fact that wetlands are performing diverse functions has been known to the public, the importance of protection and preservation of wetland has been emphasized.

Accordingly, many countries are exerting efforts to protect and preserve wetlands. In case of Korea, the importance of preservation and protection of wetlands has been recognized since 1990s and have been exerting diverse efforts to protect and preserve wetlands as well ever since.

Wetlands are ecologically very important as habitats for diverse lives. However, even though there are efforts to assess the influence of climate change in order to establish a wetland management plan, accurate assessment is experiencing difficulties. Climate change will also change the environment of wetland, causing changes in the environment of habitats of living things and the numbers of individuals or species, and the studies for influence of climate change on wetland are underway to assess them. Mortsch (1998) had made an analysis on the influence of climate change on the ecology of wetland and hydrological characteristics with the shoreline of the Great Lakes as the subject, and Dawson, etc. (2003) had carried out the water-balance analysis in application of climate change scenario. As a result of their research, it was analyzed that there was a change in water-balance of wetland due to climate changes, and also, there was a change in diversity of species of the living things due to changes in environment of habitats because of the changes in water-

¹ Center for hydrology and Ecology
Civil Engineering Department
Inha University, Korea
Tel: 82-32-872-8729
e-mail: k1004dk@hanmail.net

balance. Withey and Van Kooten (2011) had analyzed the influence of climate change on wetland and water birds. As a result, it was analyzed that there was a change in the area of wetlands due to temperature rise and increase in the amount of precipitation, and the changes in the area of wetland had showed changes in the number of individuals of water birds. Erwin (2009) explained that the environment of wetland habitats is influenced by discharge and water quality, and such discharge and water quality are influenced by climate change, causing changes in the environment of wetland habitats.

Like the above, many researchers have been carrying out studies about the influence of climate change on wetland. Accordingly, in this study, it was intended to assess the influence of climate change on the functions of wetland with the wetlands of Korea as the subjects, and to apply HGM (Hydrogeomorphic) Method to assess the functions of wetland.

2. Climate Change Scenario and Climate Model

In this study, SRES A1B Scenario was applied to assess the influence of climate change on the functions of wetland. This scenario, which is generally referred to as SRES, was released as the Special Report on Emission Scenario, together with the 3rd Report of IPCC, which is widely divided into the storylines of A2, B1 and B2. Among them, A1 Scenario is divided into the Scenarios of A1F1 (mainly, fossil fuel is used), A1T (mainly, non-fossil fuel is used) and A1B (fuel considering future energy resources is used) according to what type of fuel shall be mainly used by the humans in the future. In this study, A1B Scenario was chosen because the entire world is now exerting considerable efforts to maximize the efficiency of the present energy resources and to find out the alternate energy.

It was intended to choose the climate model which is suitable for Korea among the 24 GCM climate models developed from 12 countries through DDC of IPCC. Kyeong, Min-Soo (2010) had examined BCM2, CNCM3, FGOLS and MIHR Models, which are simulating the Korean Peninsulas as a land among the GCM Models, and as a result, it was analyzed that CNCM3 is the most suitable climate model for Korea. Accordingly, CNCM3 Model was applied in this study.

3. HGM Method for Wetland Function Assessment

In this study, HGM (Hydrogeomorphic method) developed by US Army Corps of Engineers was applied to assess the functions of wetland. This method is classifying the wetlands into riverine, depressional, slope, mineral soil flats, organic soil flats, estuarine fringe and lacustrine fringe in consideration of hydrological aspects and geomorphological aspects. Study on wetland and reference wetland is required to assess the functions in application of HGM method. Among the HGM Methods, it was intended to apply the functional assessment method for the riverine, while functional assessment is separated into the aspects of Hydrologic, Biogeochemical, Plant Habitat and Animal Habitat to carry out with the method to compare the study area and reference area (Brinson, 1993). Each function is displayed in index and the range of such index is from 0.0 to 1.0.

Table 1. Four major categories for Assessment of the riverine wetland Functions

Hydrologic	Dynamic Surface Water Storage Long-Term Surface Water Storage Energy Dissipation Subsurface Storage of Water Moderation of Groundwater Flow of Discharge
Biogeochemical	Nutrient cycling Removal of Imported Elements and Compounds Retention of Particulates Organic Carbon Export
Plant Habitat	Maintain Characteristic Plant Communities Maintain Characteristic Detrital Biomass
Animal Habitat	Maintain Spatial Structure of Habitat Maintain Interspersion and Connectivity Maintain Distribution and Abundance of Invertebrates Maintain Distribution and Abundance of Vertebrates

4. Application and Results

In this study, future climate data was simulated in application of Climate Scenario and Climate Model, and such was applied to the functional assessment method of wetland to analyze the influence of climate change on the function of wetland.

4.1 The Study Area

The subject area of this study was Upo wetland, where the yearly average temperature and the amount of precipitation are 13.2°C and 1,112.5mm respectively. Upo wetland is the largest natural wetland in Korea, located at Changnyeong-Gun. Upo wetland comprises 4 small wetlands; Upo, Mokpo, Sajipo and JJokjibeol (Fig.1). Overall width of Upo wetland is approx. 2.5km, the length is 1.6km, and the area is 2,132,926km² (Ministry of Construction & Transportation, 2004). This area has been generally known as Upo Wetland because Upo is the largest among the 4 wetlands. In addition, Upo wetland was designated as a “Protected Wetland” according to the Ramsar Convention.

4.2 Simulation of Future Weather Data under Climate Change

In this study, the future climate data was simulated in application of CNM3 climate model to examine the influence of climate change on the functions of wetland. Two types of downscaling technique (spatial downscaling and temporal downscaling) were applied to simulate the climate data. Artificial Neural Network Model was applied as the spatial downscaling technique, while NN-GA (Kim, Soo-Jeon, 2011) was applied as the temporal downscaling technique). Simulation period of the future climate data was 100 years (2000~2099).

Monthly climate data during the future period for the place of Weather Station located in the subject area was spatially downscaled in application of the Artificial Neural Network Model. As a result, it was simulated that the monthly average amount of precipitation after 100 years is to increase by approx. 23mm, while the lowest and the highest temperatures are to rise by approx. 1°C and 0.5°C respectively.



Figure 1. The Upo Wetland

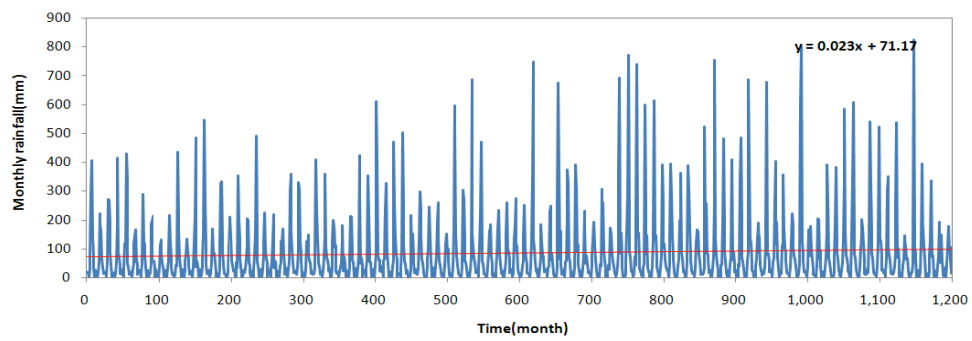


Figure 2. Monthly amount of precipitation for the future period

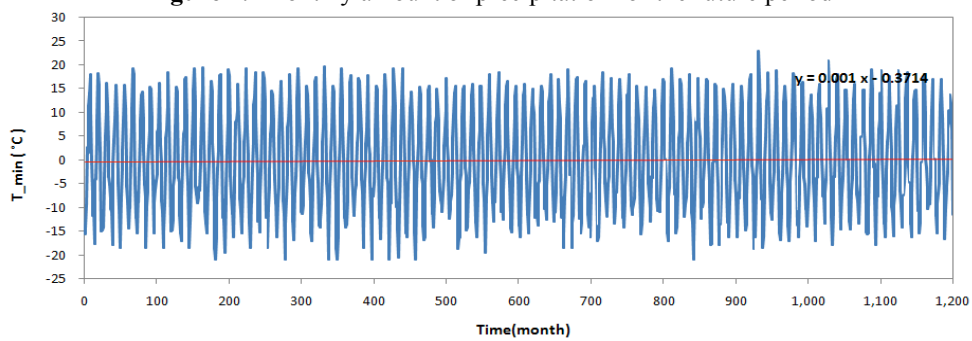


Figure 3. Monthly lowest temperature for the future period

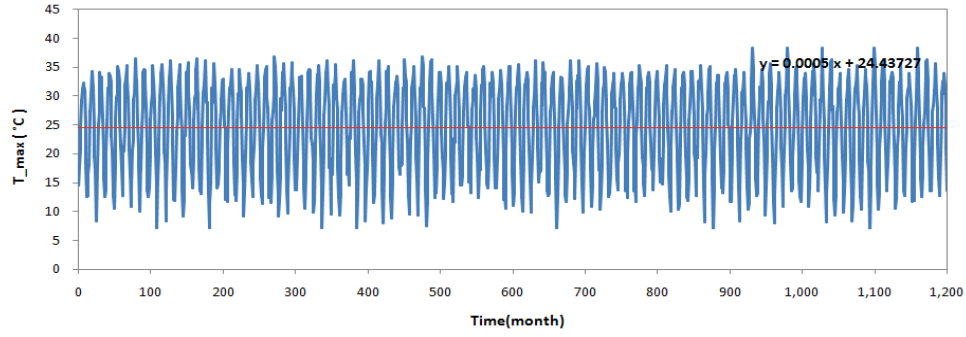
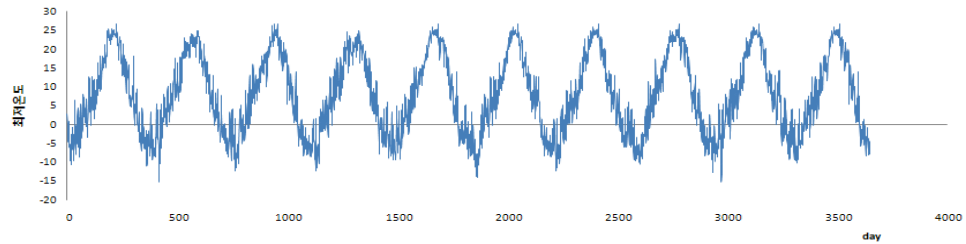
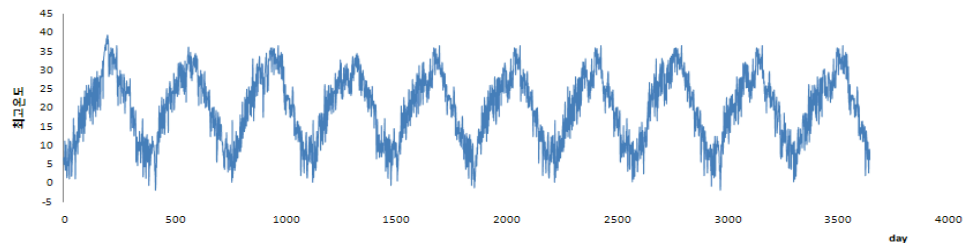


Figure 4. Monthly highest temperature for the future period

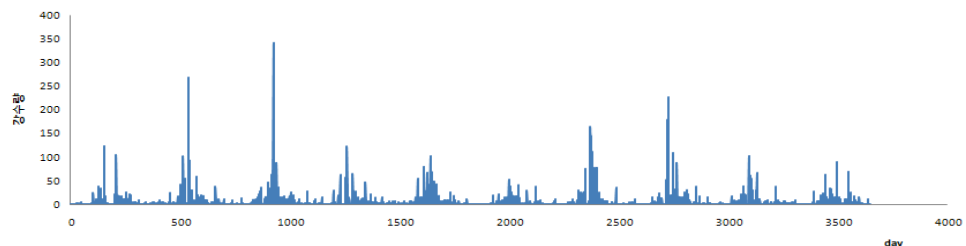
Daily climate model was simulated in application of NN-GA Technique to the monthly climate data simulated in accordance with the Artificial Neural Network Model. NN-GA Technique is a method presented by Kim, Soo-Jeon (2011) in a method to spatially downscaling the climate data. Daily climate data simulated according to NN-GA Technique are the lowest temperature, the highest temperature, amount of precipitation, relative humidity, wind velocity and the quantity of solar radiation. The simulation period of daily climate data is for 100 years (2000~2099), and in this study, the daily climate data for the period from 2090 till 2099 was used to examine the influence of climate change on the functions of wetland (Fig. 5).



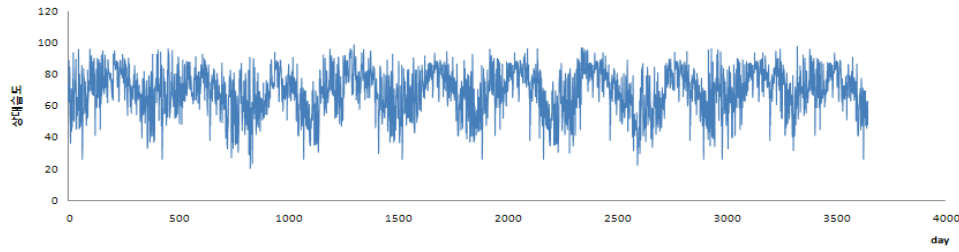
(a) Lowest Temperature



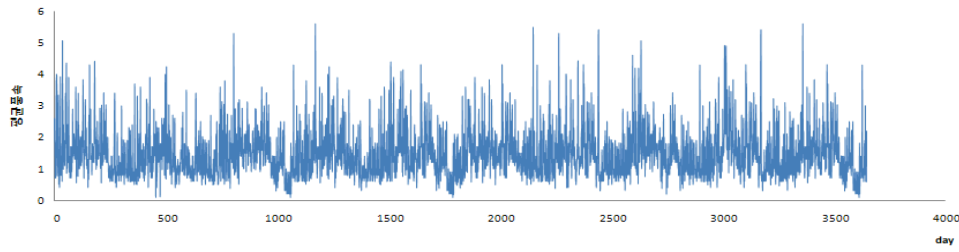
(b) Highest Temperature



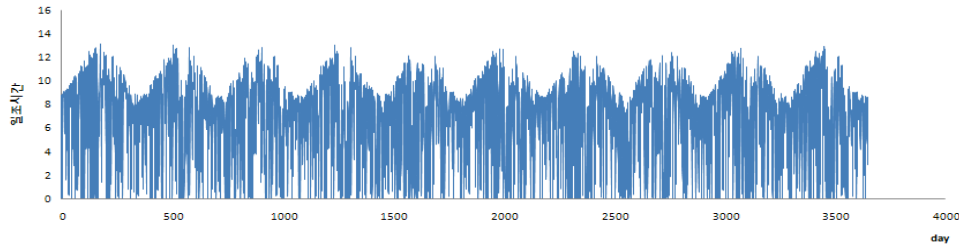
(C) Amount of Precipitation



(d) Relative Humidity



(e) Average Wind Velocity



(f) Duration of Sunshine

Figure 4. Daily Climate Data simulated according to NN-GA Technique (2090~2099)

4.3 Impact analysis of climate change on wetland functions

In this study, the functions of wetland were assessed to evaluate the influence of climate change on the wetland functions. Assessment of wetland functions was executed in comparison of the wetland functions at the present and in the future. HGM (Hydrogeomorphic Method), which was presented by the US Army Corps of Engineers, was applied to assess the wetland functions. HGM is a method to display the wetland function in Index of Function in comparison of the reference wetland and the wetland subject for assessment. The reference wetland is the present Upo wetland, while the target wetland is Upo wetland in the future. Index of Function, FCI) of wetland is calculated by each function of Table 1. And then, diverse variables are to be applied to calculate each Index of Function. Values of variables to be applied to calculation of Index of Function are calculated through comparison of the reference wetland and the target wetland. Here, the values of variables and Index of Function are distributed from 0 to 1. The formula of Index of Function) of each function is as in the Table 2 (Brinson et al., 1995).

Table 2. FCI Calculation for Each Function

	Functions	FCI Calculation
Hydrologic	Dynamic Surface Water Storage	$[V_{\text{FREQ}} \times \{(V_{\text{INUND}} + V_{\text{MICRO}} + V_{\text{SHRUB}} + V_{\text{TREE}})/4\}]^{0.5}$
	Long-Term Surface Water Storage	$(V_{\text{SURWAT}} + V_{\text{MACRO}})/2$
	Energy Dissipation	$[V_{\text{FREQ}} \times \{(V_{\text{MACRO}} + V_{\text{MICRO}} + V_{\text{DTREE}})/3\}]^{0.5}$
	Subsurface Storage of Water	$(V_{\text{PORE}} + V_{\text{WTF}})/2$
Bio-geochemical	Nutrient cycling	V_{PROD}
	Removal of Imported Elements and Compounds	$[\{(V_{\text{FREQ}} + V_{\text{SURFIN}})/2\} + \{(V_{\text{MICRO}} + V_{\text{SORPT}})/2\}]/2$
	Retention of Particulates	$[\{(V_{\text{FREQ}} + V_{\text{SURFIN}})/2\} \times \{(V_{\text{HERB}} + V_{\text{SHRUB}} + V_{\text{DTREE}} + V_{\text{MICRO}})/4\}]^{0.5}$
	Organic Carbon Export	$[\{(V_{\text{FREQ}} + V_{\text{SURFIN}} + V_{\text{SURFCON}})/3\} \times V_{\text{ORGAN}}]^{0.5}$
Plant Habitat	Maintain Characteristic Plant Communities	$(V_{\text{COMP}} + V_{\text{CANOPY}} + V_{\text{DTREE}})/3$
Animal Habitat	Maintain Spatial Structure of Habitat	$(V_{\text{STRATA}} + V_{\text{GAPS}})/2$
	Maintain Interspersion and Connectivity	$(V_{\text{FREQ}} + V_{\text{DURAT}} + V_{\text{MICRO}} + V_{\text{SURFCON}})/4$
	Maintain Distribution and Abundance of Invertebrates	$(V_{\text{SINVT}} + V_{\text{AQINVT}})/2$
	Maintain Distribution and Abundance of Vertebrates	$(V_{\text{FISH}} + V_{\text{HERP}} + V_{\text{BIRD}} + V_{\text{MAMM}})/4$

Values of Variables applied to FCI Formula are like in the Table 3.

Table 3. Estimation Variables in Upo wetland for FCI calculation

Variable	Definition	Value
V_{FREQ}	Frequency of overbank flow	1.0
V_{INUND}	Average depth of inundation	0.5
V_{MICRO}	Microtopographic complexity	1.0
V_{SHRUB}	Shrub and sapling density, biomass, or cover	1.0
V_{DTREE}	Tree density	0.5
V_{BTREE}	Tree basal area	0.5
V_{CWD}	Coarse woody debris	0.0
V_{REDVEL}	Reduction in flow velocity	1.0
V_{MACRO}	Macrotopographic relief	1.0
V_{PORE}	Soil water content	1.0
V_{WTF}	Fluctuation of water table	1.0
V_{SUBIN}	Subsurface flow into wetland	1.0
V_{GWOUT}	Groundwater contribution to streamflow	1.0
V_{SURFIN}	Surface inflow	1.0
V_{MICROB}	Surfaces available for microbial activity	1.0
V_{SORPT}	Sorptive properties of soils	1.0

V _{HERB}	Roughness factors	1.0
V _{SHRUB}	Shrub density, biomass, or cover	1.0
V _{SURFCON}	Surface hydraulic connections with channel	1.0
V _{ORGAN}	Organic matter in wetland	1.0
V _{COMP}	Species composition for tree, sapling, shrub, and ground cover strata	1.0
V _{CANOPY}	Canopy cover	1.0
V _{STRATA}	Number and attributes of vertical strata of vegetation	1.0
V _{PATCH}	Vegetation patchiness	1.0
V _{GAPS}	Canopy gaps	0.5
V _{SINVT}	Distribution and abundance of invertebrates in soil	1.0
V _{LIMVT}	Litter invertebrates	1.0
V _{AQINVT}	Distribution and abundance of invertebrates in aquatic habitats	1.0
V _{FISH}	Distribution and abundance of resident and migratory fish	1.0
V _{HERP}	Distribution and abundance of herptiles	1.0
V _{BIRD}	Distribution and abundance of resident and migratory birds	1.0
V _{MAMM}	Distribution and abundance of permanent and seasonally resident mammals	1.0

Like in the Table 3, the calculated variables were applied to the formula of Index of Function. As a result, the Index of Function by each function of wetland in consideration of Climate Change was calculated as in the Table 4.

Table 4. FCI of Each Function for a Target wetland

	Functions	FCI
Hydrologic	Dynamic Surface Water Storage	0.775
	Long-Term Surface Water Storage	1.000
	Energy Dissipation	0.791
	Subsurface Storage of Water	1.000
	Moderation of Groundwater Flow of Discharge	1.000
Bio-geochemical	Nutrient cycling	1.000
	Removal of Imported Elements and Compounds	0.833
	Retention of Particulates	0.816
	Organic Carbon Export	1.000
Plant Habitat	Maintain Characteristic Plant Communities	0.833
	Maintain Characteristic Detrital Biomass	1.000
Animal Habitat	Maintain Spatial Structure of Habitat	0.833
	Maintain Interspersion and Connectivity	1.000
	Maintain Distribution and Abundance of Invertebrates	1.000
	Maintain Distribution and Abundance of Vertebrates	1.000

5. Conclusions

The Index of Function for wetland function was calculated in application of the values of variables calculated in consideration of climate change. As a result, it was analyzed that the function of wetland is changing due to the influence of climate change. Variables which were changed due to the climate change are the average depth of inundation, tree

density, tree basal area and canopy gap, and it was calculated that the values of Index of Function using these variables were changed (Table 4). Such results are the values calculated assuming that the entire Index of Function of the present Upo wetland is 1.0, displaying that the wetland function of Upo Wetland has been reduced due to climate change. However, the result of this study is the one that has considered the climate change for variables from the hydrological aspect. Accordingly, the ecological aspect was not considered. Therefore, it is considered that the studies in consideration of climate change from the ecological aspect in addition to the hydrological aspect should be carried out more diversely in the future in order to more accurately examine the influence of climate change on the wetlands.

Acknowledgements. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MEST) (No.2011-0028564)

References

- Kim, S.J., 2011: Impact of Climate Change on Water Resources and Ecological Habitat in a River Basin. Ph.D. Dissertation, INHA University.
- Brinson, M.M., Rheinhardt, R.D., Hauer, F.R., Lee, L.C., Nutter, W.L., Smith, R.D., and Whigham, D., 1995: A Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands. Wetland Research Program Technical Report WRP-DE-11, US Army Corps of Engineers.
- Dawson, T.P., Berry, P.M., and Kampa, E., 2003: Climate change impacts on freshwater wetland habitats. *Journal for Nature Conservation*, **11**, 25-30.
- Erwin, K.L., 2009: Wetlands and global climate change; the role of wetland restoration in a changing world. *Wetland Ecology Management*, **17**, 71-84.
- Ministry of Construction and Transportation, 2004: The report of channel improvement plan (Topyeongcheon).
- Mortsch, L.D., 1998: Assessing the Impact of Climate Change on the Great Lakes Shoreline Wetlands. *Climate Change*, **40**, 391-416.
- Withey, P., and van Kooten, G.C., 2011: The Effect of Climate Change on Wetlands and Waterfowl in Western Canada; Incorporating Cropping Decisions into a Bioeconomic Model. Resource Economics & Policy Analysis Research Group, Department of Economics, University of Victoria.