ASSESSMENT OF CLIMATE CHANGE AND LAND USE IMPACT ON BEHAVIOR OF STREAM DISCHARGE : USING SWAT

Jisun Choi[a] Hoyong Ahn[a] Jinsoo Kim[b] Chuluong Choi [a, CA]

[a] Department of Spatial Information Engineering, Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 608-737, South Korea

Tel : +82 51 629 6655; Fax +82 51 629 6653
E-mail : ssun33023@naver.com

[b] ZEN21, 2nd Floor, RNC Building, 981-1 Bangbae 3-dong, Seocho-gu, Seoul 137-848, South Korea

KEY WORDS : SWAT, Stream flow, Land Use/Land Cover, Climate change scenario, calibration/Validation

ABSTRACT: Modeling the effects of past and current land use composition and climatic patterns on surface Run-off, sediment provides valuable information for environmental and land planning. This study predicts the future impacts of urban land use and climate changes on surface Run-off within the Hoeya River Basin, South Korea, between 2050 and 2059 Using Soil and Water Assessment Tool (SWAT). For the future LULC map, it has been drawn based on a storyline of RCP 4.5 and 8.5 scenarios with a current LULC map (2000) used as a baseline. Future climate patterns examined include the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP). Such changes will have significant implications for water availability and nutrient transport regimes in the Hoeya River Basin. Urbanization was the strongest contributor to the increase of surface runoff and water yield, replacement of desertscrub/grassland.

INTRODUCTION

Since are climate and LULC change not only considered a major factor to greatly influence the streamflow in the basins but also are known for the significance of their impacts on water sources, the separate and combined impacts of these two are of widespread concern and a great challenge to researchers and policy makers (Liu et al., 2011). For a recent few years, special report on emission scenario (SRES) used in the Intergovernmental Panel on Climate Change (IPCC) 4th assessment report (AR4) (IPCC, 2007) has been widely applied to investigate hydrological response to climate change (Moradkhani et al., 2010). IPCC is thinking about containing a new future climate prospect with various technical developments applied in the IPCC AR5 of 2014 and for this, it has adopted a new scenario called, representative concentration pathway (RCP). This study focuses on examining how future climate and/or LULC change (urbanization) underlying the RCP scenarios (4.5 and 8.5) would affect streamflow in the Hoeya River Basin, South Korea.

METHODS

Study area

For study area, the 218.34 km2 Hoeya River Basin (E 129°06′23″~129°21′03″, N 35°20′49″~35°30′40″) located in Ulsan metropolitan city in Korea was selected (Fig. 1). The elevation ranges from 1 m to 837 m, the average elevation is 133.9 m above sea level, the average slope is 24.15° and more than 70% of the basin area is mountains. The climate is extremely seasonal: summer is hot and humid with frequent heavy precipitation associated with the East-Asian Monsoon and winter is cold and dry due to the influence of the Siberian air mass (Jung et al., 2011).

Data preparation

Topographic and soil data : Topographic data used in this study include elevation, slope, aspect and flow direction and accumulation. Those have been created with digital evaluation model (DEM) of 10m interval grid provided by the Korea Ministry of Environment (KME) (Fig. 2a). 1/25,000 soil map by the Korea Rural Development Administration (KRDA) was adopted (Fig. 2b).

Land-use and land-cover (LULC) : Hoeya River Basin is considered to have a very rapid urbanization along with the population growth. LULC was provided by the Korea Water Management Information System (WAMIS).

LULC in 2000 was adopted to SWAT model calibration and validation and used to see future LULC change (Fig. 2c).

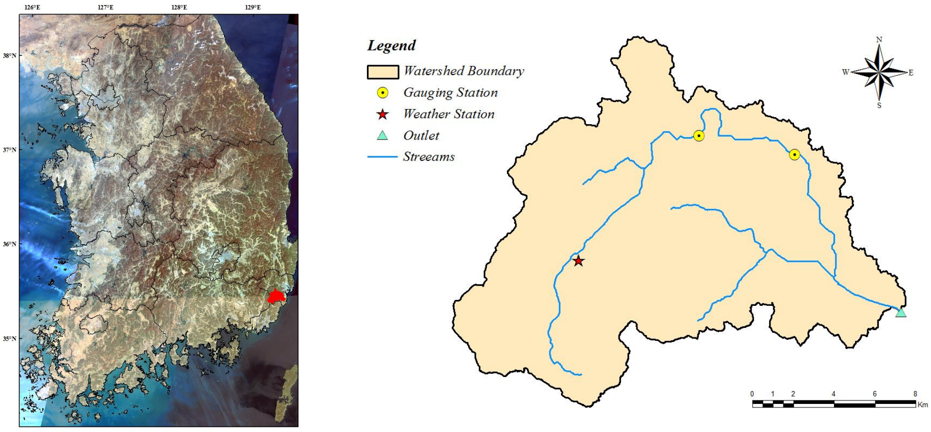

Figure 1 The location of Hoeya River Basin in South Korea and hydro-meteorological stations.

Hydro-meteorological data : Meteorological inputs are precipitation, temperatures, solar radiation, wind speed, and relative humidity. Such daily data was gained from Woongsang weather station in the basin, managed by Korea Meteorological Administration (KMA). In addition, climate data (2011~2100) of a regional climate model (12.5-km spatial resolution) which have been simulated by RCP 4.5 and 8.5 was adopted as future climate data (Table 1). Since such data would not include wind and solar radiation, it has been individually created from WXGEN weather generator model in SWAT. Water level and streamflow were used as hydrological data, which were observed from 2007 and 2008 by Suckchun and Mangyang gauging station.

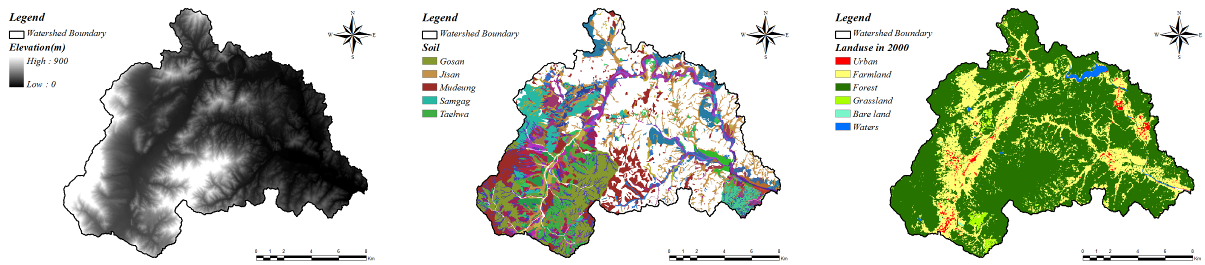

Figure 2 Datasets used in this study. (a) DEM, (b) soil map, (c) LULC in 2000.

LULC change model

Among various LULC change models, urban growth model with LR applied was selected. For the future LULC map, it has been drawn based on a storyline of RCP 4.5 and 8.5 scenarios with a current LULC map (2000) used as a baseline. According to the storyline of RCP 4.5 scenario, the population growth would decrease, the economy would be on a constant rise and a solid land-use regulation would be established so that the environmental preservation could be properly valued. On the contrary, the storyline of RCP 8.5 scenario says that the growth of population would have urban demand increased with relatively low economic development and the society would concentrate on development more than the environmental preservation (Van Vuuren et al. 2011).

The hydrological model

The SWAT model : Hydrological modeling was performed using the Soil and Water Assessment Tool (SWAT) extension for ArcGIS mapping analysis software. SWAT is a physically based, continuous-time, semi-distributed model that operates on a daily time step and is able to predict the movement of water in complex watersheds with varying soils, land use and management conditions over long-term periods.

Model calibration validation : The model was calibrated automatically for streamflow at the sub-basin level during 2007 years based on daily observed streamflow at gauging stations along Hoeya River Basin, while the model was validated during 2008 year. The most sensitive SWAT parameters were selected for model performance (calibration and validation), which included as follows: BLAI, CANMX, CN2, ESCO, GWQMN, SOL_AWC, and SOL_Z.

Establish scenarios and examination : Three different scenarios were established as follows to assess the separate and combined impacts of the future climate change and/or LULC change under the RCP 4.5 and 8.5 scenarios on streamflow in the Hoeya River Basin, Korea. According to each scenario, streamflows in the basin from 2050 to 2059 were simulated.

(1) Scenario 1: In order to analyze only the impact of future climate change on streamflow, the streamflow under each climate change scenarios (RCP 4.5 and 8.5) for the future periods (2050-2059) is simulated on the assumption that the future LULC is preserved to be constant by the current LULC (2000).

(2) Scenario 2: To analyze only the impact of future LULC change on streamflow, the streamflow for the future periods (2050-2059) is simulated with LULC for the future periods (LULC in 2050), on the assumption that climate condition for the future periods are the base periods (2000-2009).

(3) Scenario 3: In order to analyze the combined impact of future climate and LULC change, the streamflow under each climate change scenarios (RCP 4.5 and 8.5) and future LULC for the future periods (2050-2059) are simulated.

RESULTS

Future LULC change for each scenario

Basically, it was predicted that a urban would be expanded from a farmland located on both sides of the Hoeya River Basin. In particular, a peculiar urban growth is found on the right region and it shows that the growth will reach the limit by the end of 2050. Add to this, RCP 8.5 scenario turned out to have a quicker urban growth than RCP 4.5 scenario.

Calibration and validation

Daily values of simulated streamflow were compared with observation to calibrate the SWAT model. During the validation, the simulated value of the model is slightly higher than the observed value. These results suggest that the calibrated model can describe the streamflow in the Hoeya River Basin and assure that the calibrated model with the set of optimized parameters can be applied to experiment response of the basin′s streamflow to climate and LULC changes.

Impacts of climate and/or LULC change on streamflow

Scenario 1

Between RCP 4.5 and 8.5 scenarios have a difference, it is shows a distinct change in the pattern that wet season (July to September) streamflow reduce, dry season (November to April) streamflow increase. Although there is some variation among RCP 4.5 and 8.5 scenarios, the general pattern is increases in spring and winter flow and decreases in summer and autumn flow (Fig. 3a).

Scenario 2

There had appeared much little change in streamflow comparing to the results of simulation from scenario 1 but still, Figure 3b proves that change in monthly, seasonal, and annual streamflow are significantly affected by LULC change. The general pattern is increases in spring and summer flow and decreases in autumn flow. In the winter, streamflow hardly increases or decreases and, a reason for this is because except for a little snowfalls, the winter in basin does not have precipitation frequency (Fig. 3b).

Scenario 3

Monthly streamflow increased from November until April to July from September until reduced under RCP 4.5 and 8.5. The ranges of relative changes in seasonal streamflow under RCP 4.5 and 8.5 in the future periods in spring and winter than in other seasons were larger (Fig. 3c).

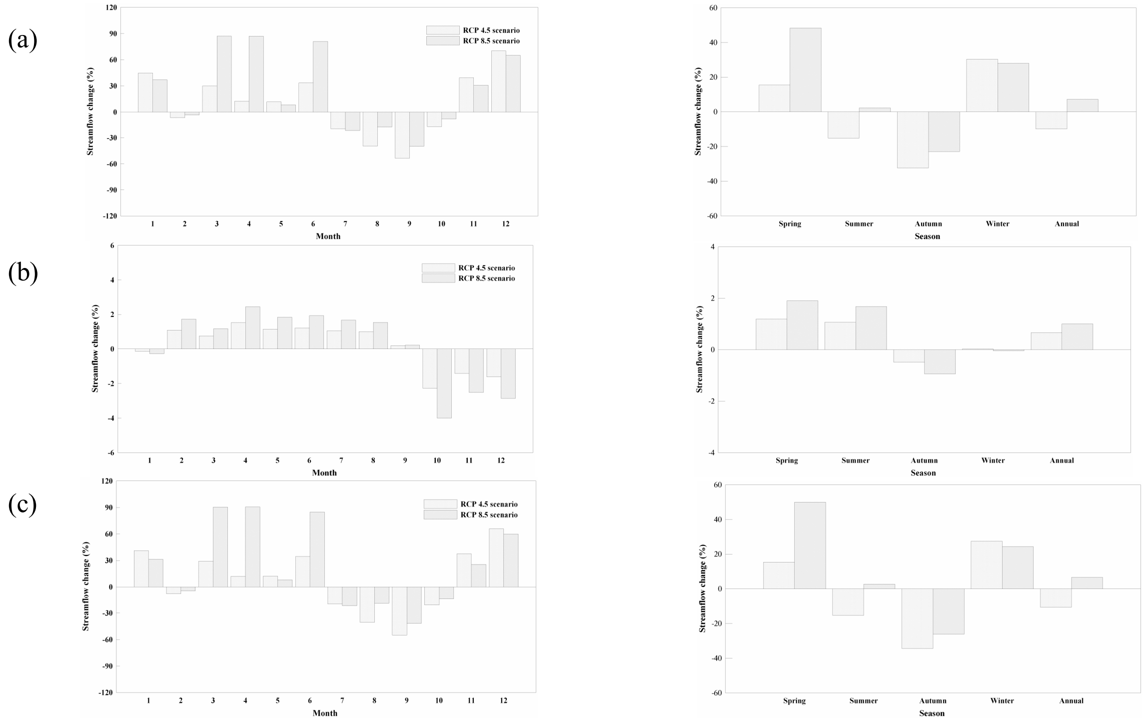

Figure 3 Changes in streamflow under scenario 1 (a), scenario 2 (b) and scenario 3 (c). The left is changes in mean monthly streamflow, the right is changes in mean seasonal and annual streamflow.

DISCUSSION & CONCLUSIONS

The major objectives of this study were to assess the separate and combined impacts of future climate change and/or LULC change under the RCP 4.5 and 8.5 scenarios on streamflow. Using the projected 2050 land use scenario, the simulated amount of daily flow would increase. This might be attributed to the fact that, according to the projection, there would be more urban areas in the HOEYA basin in the year 2050. Climate change would have a more prominent hydrologic effect than land use change if our environment became dry. When climate change was considered together with land use change, the impact on discharge was more apparent. These results implied that the projected land use change could increase the flow, which would be a welcoming relief under dry conditions, mitigating the drought impacts of climate change. On the contrary, if our climate became wetter, than the impending urbanization in the river basin would exacerbate the flow regimes, perhaps causing more floods.

ACKNOWLEDGEMENT

“This work was researched by the supporting project to educate GIS experts"

REFERENCES:

Jung, I.W., Bae, D.H., Kim, G., 2011. Recent trends of mean and extreme precipitation over South Korea. International Journal of Climatology 31, pp.359-370.

Liu, L., Liu, Z., Ren, X., Fischer, T., Xu, Y., 2011. Hydrological impacts of climate change in the Yellow River Basin for the 21st century using hydrological model and statistical downscaling model. Quaternary International 244, pp.211-220.

Moradkhani, H., Baird, R.G., Wherry, S.A., 2010. Assessment of climate change impact on floodplain and hydrologic ecotones. Journal of Hydrology 395, pp.264-278.

Van Vuuren, D.P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J.F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., Rose, S.K., 2011. The representative concentration pathways: an overview. Climate Change 109, pp.5-31.

IPCC, 2007. Climate Change 2007: The Scientific Basis, IPCC Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.