ASSESSMENT IMPACTS OF CLIMATE CHANGE ON ANNUAL FLOW IN RIVER BASIN IN THE FUTURE CASE STUDY: NAKDONG RIVER BASIN IN KOREA

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Abstract: *Climate change has not only significantly influenced to hydrology process during the last decades but will continue to influence in the future. Its impacts effected significantly on the water resource supply and management in regions in general and especially in small basin. In this study, the main objective is to investigate how the streamflow on river basin will be effected by climate change in annual streamflow, and particularly in terms of the climate change of seasons on different periods in the future in the Nakdong basin, which were based on using hydrological model as the Soil and Water Assessment Tools (SWAT) model. After model was calibrated and validated with observation using monthly streamflow, the future of climate data as three benchmark periods simulated were 2010–2039, 2040–2069 and 2070–2099 were then used as input to the SWAT model to simulate the corresponding future streamflow, then these results are compared with baseline period (1980-2009). Results showed that annual mean streamflow increased for all periods; the significant change is revealed in period of 2040-2069 by comparing with baseline period (1980-2009). However, the streamflow on seasons were determined differences that the streamflow was mainly increased in summer (Jun-Aug) while decreased in autumn (Sep-Nov), which can be cause of more extreme events by flooding in summer and drought in autumn. The results also showed more vulnerable and challenge water resources supply and management in the future in region. In addition, the study can also provide useful support for the sustainable water resources management strategies and policy in river basins.*

Key words: Climate change; SWAT model; Streamflow; Nakdong, Korea.

1. INTRODUCTION

In the last few decades, the effect of increasing greenhouse gas concentrations influenced to climate in global. Recently, the research of Jung et al [7] trends of mean and extreme precipitation in Korea. Changes in precipitation are more speculative than temperature projections, especially for smaller regions. Although the regional distribution is uncertain, precipitation is generally expected to increase worldwide, especially in higher latitudes [4-5]. Global warming is also projected to alter potential evaporation. The most immediate effect will be an increase in the ability of air to absorb water as temperature rises. Budyko (1982) estimated that potential evapotranspiration would increase by four percent for every degree Celsius increase in temperature. The changes in precipitation and temperature are more large variable projections especially for smaller basins as change from 6.6% to 9.3% in precipitation, and increase from 0.8 ºC to 3.2 ºC in temperature in the future in Chungju basin [2], a variation of summer rainfall in Korea [8].

Climate change is a major force altering the hydrological process over a range of temporal and spatial scales. The disasters from climate related natural phenomena such as floods, droughts, landslides etc. cause devastating effects. All climatic processes are likely to intensify that was not only the average climatic conditions change, but also their variability and frequency which include severity of extreme events such as floods, heat waves, and droughts. Climate model projections show an increase in the global mean near-surface air temperature

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[6]. This is likely to lead to a more vigorous hydrological cycle, with changes in precipitation and evapotranspiration rates that are regionally variable. These changes will in turn affect water availability and runoff and thus may affect the discharge regime of rivers. There are several of researches that realized that climate change is change in different spatial in river basin and it is main cause to the effects on the flow routing time, peak flows and volume [10], surface runoff change [9], hydrology effect [11]. Therefore, the impact of climate change on the hydrological regime is an important aspect of water resources management, water quality management, and safe surface water withdrawals in the region. Many studies have focused on assessment and analysis of climate change impacts for water resources on annual average in current time. In this study focus to determine impacts of climate change on streamflow in mean annual and seasons in the future which is a need to classify clearly the definition of the variability, especially the forecasting for disaster as flooding and droughty and control in water resource‘s planning and management in study area.

2. Study Area and Data Descriptions

The Nakdong River basin is situated in the monsoon region of South Korea (35–37° N, 127–129° E) (figure 1). This region is characterized by heavy rainfall in the monsoon season in early summer from June to August. This is one of four major river systems in Korea, serves as an important water resource for the southeastern area. The river drains an area of 23,817 km2 and length of the main stream is over 525 km. The annual mean precipitation across the river basin is about 1200 mm, but more than 60% of the annual rainfall is concentrated during the summer season (June–August). The mean air temperature is 2.2°C during the coldest month (January) and 25.9°C in the warmest month (August). Currently, about 7 million people reside within the basin and more than 13 million people intake a drinking water from the river.

Figure 1. Location of study area, river systems

Spatial data used in this study include a digital elevation model (DEM90x90m), land use, and soil map (scale of 1:25.000). The meteorological data history during 1980-2009, and future climate data for (2010-2099) from climate change simulation, the A2 scenario was used in this study which include daily data of precipitation, maximum and minimum temperature, solar radiation, humidity, win speed at six teen weather stations in Nakdong river basin. The streamflow data at stations were included annual and monthly data during (1995-2009). All the data are available and obtained from the Water Management Information System (WAMIS), Korea.

3. Methodology

The impacts of climate change on hydrological characteristics of the basin are assessed through hydrology models. In this study, the Soil and Water Assessment Tools (SWAT) model is used to assess the impact of climate change on treamflow in Nakdong river basin. The SWAT model is a continuous time model that operates on a daily time step. It is physically based and can operate on large basins for long periods of time (Arnold et al., 1998). The hydrologic cycle is based on the water balance equation.

$$SWt = SW_0 + \sum_{i=1}^{t} (Rday - Qsurf - Ea - Wdeep - Qgw) \quad (1)$$

where SWt is the final soil water content (mm H_2O) SW0 is the initial soil water content on day i (mm H_2O), t is the time (days), Rday is the amount of precipitation on day i (mm H_2O), Qsurf is the amount of surface runoff on day i (mm H_2O), Ea is the amount of evapotranspiration on day i (mm H_2O), Wdeep is the amount of water into the deep aquifer on day i (mm H_2O), and Qgw is the amount of return flow on day i (mm $_{H2O}$). SWAT simulates various processes that include hydrology, weather, erosion and sedimentation, soil temperature, plant growth, nutrients, pesticides, and land management. Streamflow simulation was the main focus in this study. The basic SWAT model inputs are included time-series data as rainfall, maximum and minimum temperature, radiation, wind speed, relative humidity; and spatial data as land use/land cover, soil, and elevation Digital Elevation Model (DEM). All of study approach is shown in figure 2 below:

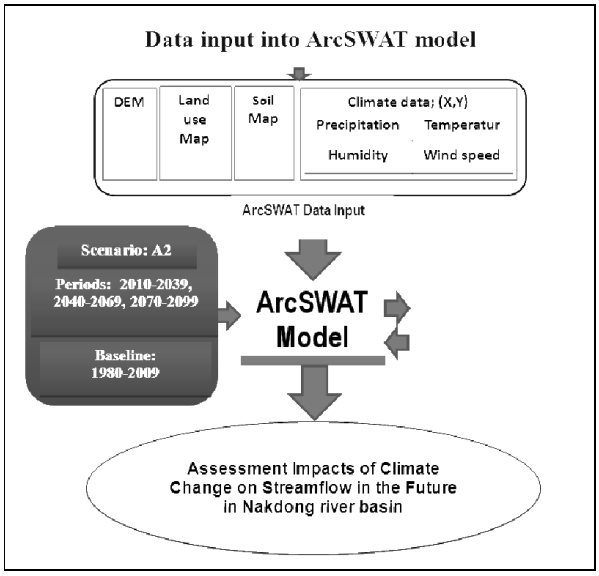

Figure 2. Flowchart for study method

The implement was included steps. First, SWAT model was set up, calibrated and validated. Next, the future periods of climate change were input into ArcSWAT model. In this study, the climate change data that were obtained by collection is based on available data. In specific, the data obtained from the GCM of ECHO-G under three different GHG emission scenarios as A2, B1, A1B for period of 2010-2099. However, in this study is only climate change scenario of medium-high emission (A2) that was selected for assessing in corresponding with developing countries like Korea. On the other hand, under A2 scenario is also divided under three benmak of (2010–2039), (2040–2069) and (2070–2099) in order to advantage in comparison and assessment. Finally, ArcSWAT model was run for each of the climate period to simulate the streamflow. And then, results of streamflow were obtained from the model output under the different climate change periods in order to evaluate impacts by climate change on streamflow in the mean annual and the seasonal variations in study region.

4. Results Analysis and Discussion

4.1. Model calibration and verification

The climate data under periods of (1995–2004) and (2005-2009) input into SWAT model to simulate streamflow, then they were used to compares between simulated monthly streamflow with the observed streamflow values at the outlet of the river basin. The results showed good consistency between the simulated and measured monthly streamflow at outlet of the basin with the Nash-Sutcliffe coefficient of efficiency (E_{NS} = 0.68 for calibration, and 0.72 for validation), the coefficient of determination (R^2 = 0.78 for calibration, and 0.83 for validation), as showed in Figure. 3, and Figure. 4. Finally, the results simulation in the future of streamflow for benchmark periods (2010–2039), (2040–2069) and (2070–2099) compared with streamflow of baseline period as (1980-2009).

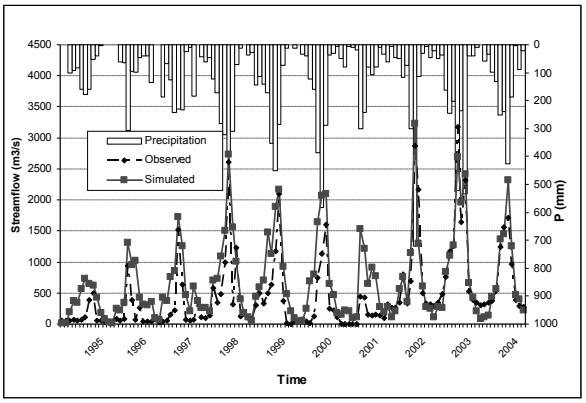

Figure 3. Comparision of observed and calculated monthly streamflow for calibration period from 1995 to 2004

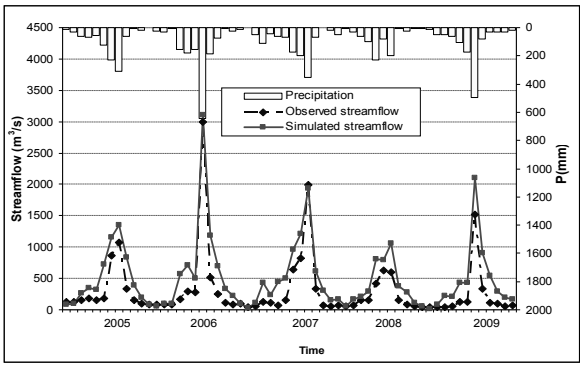

Figure 4. Comparision of observed and calculated monthly streamflow for validation period from 2005 to 2009

4.2. Impacts of climate change on mean annual and seasonal streamflow

In mean annual streamflow, the results were determined most increasing trend for three benchmark periods in the future with corresponding increase +1.4% in (2010-2039), increase +2.2% in (2040-2069), and increase +0.7% in (2070-2099). The changing in seasonal streamflow showed that there are quite different characteristics for the changes of seasonal streamflow in the future such as the magnitude of autumn streamflow decreased for all of three periods in future as -3.1%, -3.7% and -3.5% in periods 2010-2039, 2040-2069 and 2070-2099, respectively while the streamflow being increased during of summer +4.4%, +5.8% and +2.8% in periods 2010-2039, 2040-2069 and 2070-2099, respectively. The results show that its impacts of climate change on surface streamflow can be more extreme events of flood and drought in the future as shown Figure 5.

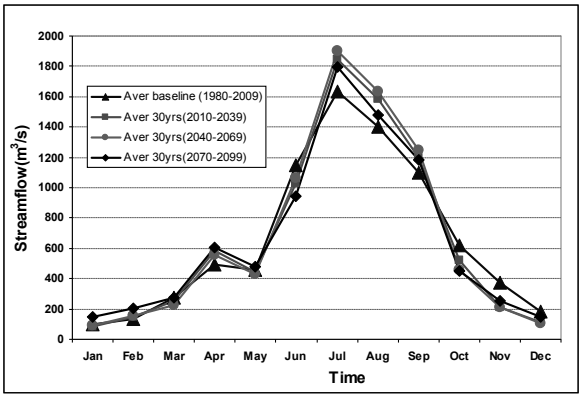

Figure 5. Showed the results of comparison for month streamflow under different periods to relative baseline period Jindong station

5. Discussion and conclusions

Climate change may seriously affect of regional water resources. Therefore, the objective of this study is focused on the using the SWAT (Soil and Water Assessment Tools) model to assess the impact of climate variability on surface hydrology in Nakdong river basin. The results from using of models in this study showed that. The impact of climate change analysis on streamflow suggested most increasing trend in mean annual streamflow of three benchmark periods in the future. However, the results indicated the hydrology regime being changed on streamflow, such as the high of peak flow and strong increasing in summer which is cause of flooding events while this was significant reduced winter that can be results of drought period in Nakdong river basin in the future. Climate changes impact of this kind will affect regional may result in more extreme events of flood and drought, water supply, water quality management, and security in the basin. The scenarios presented in this paper, and the simulated impacts on the hydrologic regime, raise questions over the availability of future water resources in the study area, particularly in terms of the magnitude of seasonal runoff. Using SWAT, the results obtained in this study could be useful for planning and management in different sectors in this region.

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Tóm tắt:

ĐÁNH GIÁ TÁC ĐỘNG CỦA BIẾN ĐỔI KHÍ HẬU TỚI DÒNG CHẢY TẠI LƯU VỰC SÔNG TRƯỜNG HỢP NGHIÊN CỨU: LƯU VỰC SÔNG NAKDONG-HÀN QUỐC

Biến đổi khí hậu không chỉ đã ảnh hưởng lớn đến quá trình thủy văn trong những thập kỷ qua mà sẽ còn tiếp tục tác động trong các thập niên tới. Tác động này đã ảnh hưởng một cách đáng kể đến việc cung cấp và quản lý nguồn nước cho khu vực nói chung, đặc biệt nó có tác động mạnh đến lưu vực sông nói riêng. Trong nghiên cứu này, mục đích chính làm thế nào để xác định sự thay đổi của dòng chảy năm trên lưu vực sông dưới ảnh hưởng của biến đổi khí hậu, đặc biệt chỉ ra ảnh hưởng này tới dòng chảy các mùa trong năm với các thời đoạn khác nhau trong lưu vực sông Nakdong. Để đánh giá những thay đổi này, mô hình thủy văn ArcSWAT đã được áp dụng để mô phỏng sự biến đổi khí hậu lên dòng chảy trên lưu vực sông. Sau khi mô hình được kiểm định với dòng chảy tháng đo đạc được tại trạm đo, dữ liệu khí hậu đầu vào được sử dụng cho mô hình ArcSWAT với ba giai đoạn là (2010–2039), (2040–2069) and (2070–2099) để mô phỏng dòng chảy tương ứng với các giai đoạn trên, sau đó được so sánh với giai đoạn chuẩn (1980-2009). Kết quả cho thấy dòng chảy trung bình năm đã tăng trong tất cả trong các giai đoạn và sự thay đổi đáng kể nhất đã thể hiện trong giai đoạn (2040-2069). Tuy nhiên, dòng chảy theo các mùa trong năm đã được xác định với sự thay đổi chủ yếu tăng mạnh trong mùa Hè từ tháng 6 đến tháng 8 trong năm, sự thay đổi này là nguyên nhân dẫn đến các trận lũ có thể xảy ra vào mùa Hè, ngược lại kết quả chỉ ra dòng chảy giảm mạnh vào các tháng mùa Thu từ tháng 9 đến tháng 11 tác động này là nguyên nhân chính dẫn đến hạn hán, thiếu hụt nước tăng mạnh vào mùa Thu của lưu vực trong những thập niên tới. Qua kết quả nghiên cứu cho thấy việc cung cấp và quản lý tài nguyên nước trong lưu vực đang đối mặt với thách thức lớn hơn dưới ảnh hưởng của biến đổi khí hậu trong tương lai. Ngoài ra, nghiên cứu này cũng cung cấp một phương pháp hữu ích trong chiến lược và chính sách quản lý bền vững tài nguyên nước trên các lưu vực sông.

Từ khóa: Biến đổi khí hậu, mô hình Arc SWAT, dòng chảy, sông Nakdong, Hàn Quốc.

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