Prediction of hydrologic impacts due to climate change scenarios in upstream catchment of Kase River basin

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1. Introduction

Global warming due to increasing concentration of greenhouse gases is likely to have a significant impact on precipitation, run-off processes and water resources (Arnell and Reynard, 1996; L. Cuo et al., 2015; Haddeland,I.,et al., 2012; Pervez and Henebry, 2015; Q.A. Zhang et al , 2010).

Meteorological Research Institute (MRI) and the Japan Meteorological Agency (JMA) projected climate change over Japan due to global warming using a high resolution Regional Climate Model of 20 km mesh size (RCM20) developed in MRI. Projection was made for 2081 to 2100 following a SRES-A2 scenario (Kazuo Kurihara et al., 2005) .

The objective of this study is to predict hydrologic impacts of climate changes under CC scenarios using 5 year average data (1991-1995). This study specially sought to: Predict the hydrologic impacts of climate change under scenario 1 (RCM20 under A2 scenario) and scenario 2 (Future temperature increase by 3 ºC).

2. Methods and Materials

Study area

Kase River is one of the major rivers in Saga Prefecture, which is originated in the Seburi Mountains of Mitsuse, saga city (altitude 912m) that flows through Saga Plain and pours into the Ariake Sea. In this study, upstream catchment is focused with catchment area of 225km² that covers 61% of entire area of the basin. The elevation ranges from 12.8m to above 1000m from sea level. The watershed is characterized in climatology as warm and temperate zone. Precipitation falls as a rain and the average annual rainfall is about 2376mm.Most of the precipitation (~58%) falls between June and September. The mean annual temperature in the river basin is 16.5ºC.The highest average monthly temperature is in July and August and lowest is in January. Upstream catchment is generally covered by more than 80% of dry evergreen forest; other area covers rice field, agriculture and buildings. Floods are normally experienced during the rainy season which has more intense rainfall caused by typhoons. The maximum discharge recorded at Kawakami head was 55 m³/s from 1991 to 1995 occurred in July.

A deterministic, fully-distributed and physically-based hydrological model MIKE SHE (DHI, 2014) was used as a main tool in this study area.

Topographic, land use , soil , hydrological and meteorological data required by the model were collected as follows: (1)The Digital Elevation Model (DEM) data with resolution of 5m were obtained from Geospatial Information Authority, (MLIT,Japan);(2) Landuse data of 1987 and 2009 were obtained from Ministry of Land and Infrastructure (MLIT,Japan) ;(3) Geological map were analyzed from geological map of Japan (AIST, 2003).After that the comparison was done with the soil map of japan based on reclassification and digital soil map of the world to obtain the name of the soil types at river basin (FAO, 2003);(4) The meteorological data from eight rainfall stations within the Kase River basin and some lower parts of the river basin were used as primary inputs which were taken from MLIT website, Japan : (5) Other climate data such as temperature were taken from Saga Meteorological Observatory; (6) Hydrological data from one station were taken from MLIT website, Japan (7) Ref .ET was calculated by Hamon method (1961) (C.-Y.Xu, V.P.Singh, 2001).

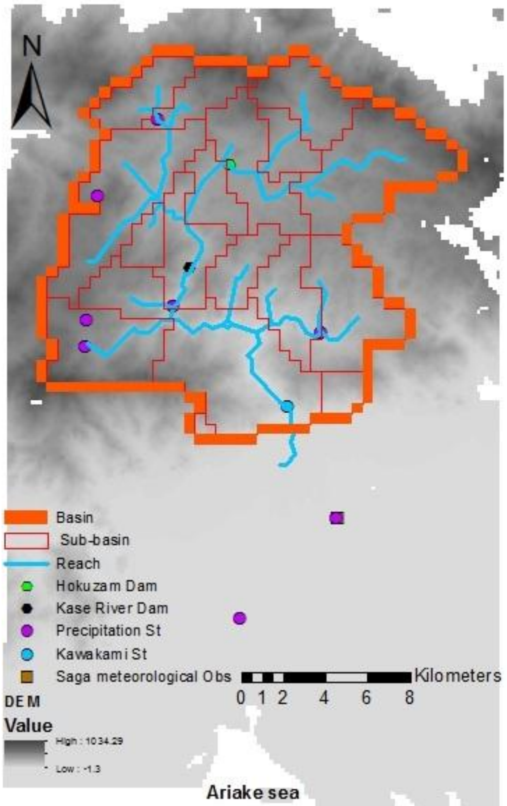

Fig.1 Watershed delination with discharge and Precipitation station in the upstream Kase River Basin

Model Calibration and CC Scenarios

The model was successfully calibrated in the station where discharge data was available. The average daily discharge data was measured at Kawakami station. Data from 5 year period (1991-1995) was used for the calibration effort. The Nash-Sutcliffe efficiency NSE =0.588 and R^2=0.68 suggests that the model can predict the runoff mechanism satisfactorily. Different scenarios were tested in the river basin to find out the impact of environment changes within the watershed.

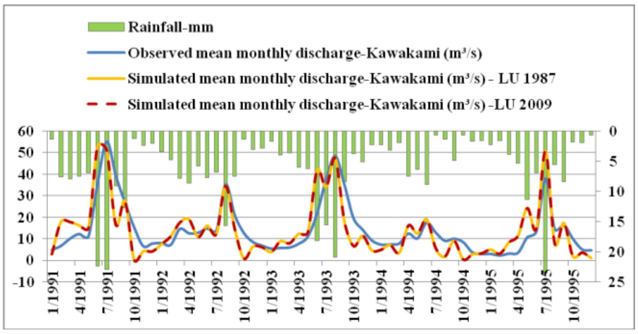

Fig.2 Rainfall-runoff process under LU Scenarios

3. Results and Discussion

LU Scenarios

In terms of land use changes, the major changes were increase in forest land and decrease in barren land. It resulted in an increase in mean annual evapotranspiration (1.54mm) whereas there was no significant changes in the surface flow and groundwater flow in Kase watershed. The increased ET could be a result of increased area of forest.

CC Scenarios

1) Scenario 1 (RCM 20 under A2 scenario)

Future Climate variability under scenario 1 caused an increase of 408.16mm in surface flow; 46.77mm in terms of base flow and interflow and a increase of 41.74mm actual ET.The increase in surface runoff may be mostly due to increase in precipitation. Therefore increase in future monthly temperature 3ºC from January-May, October to December and about 2ºC in summer resulted in significant increase of actual ET.

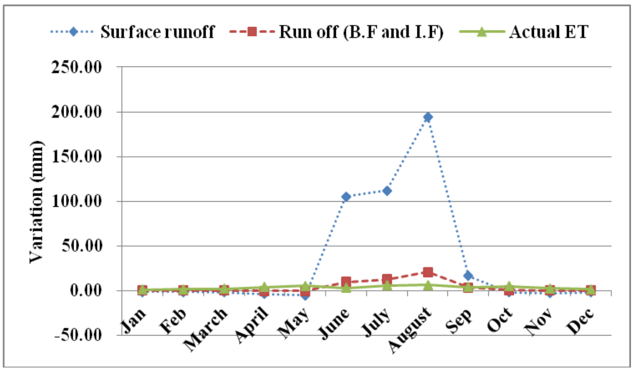

Fig.3 Change of hydrological components in Kase River for the future period (2100) under Scenario-1

2) Scenario 2 (Future Temperature increase by 3 ºC)

Future Climate variability under scenario 2 caused an decrease of 38.43 mm in surface flow; 2.25 mm in terms of base flow and interflow and an increase of 46.62mm actual ET.The decrease of surface runoff may be due to unchanged precipitation and increase temperature. Therefore increase in future average monthly temperature 3ºC in all month resulted in significant increase of actual ET.

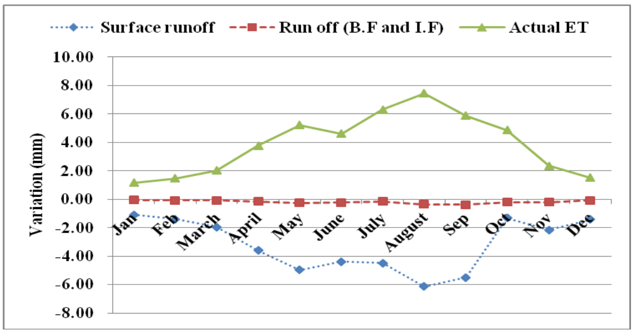

Fig.4 Change of hydrological components in Kase River for the future period (2100) under Scenario-2

4. Conclusions

(1) In the past 22 years, land use changes have occurred in this watershed. The major changes were the increase in forest land (3%) and decrease in barren land. A noticeable climate trend has occurred around 1994 in the study area: mean monthly temperature increased from 16 to 17.3ºC during 1991 to 1995 period. Increase in temperature and precipitation after 100 years has large impacts on river basin.

(2) The combined effect of these changes increases surface runoff and evapotranspiration.Changes in temperature and precipitation has increased surface runoff and evapotranspiration whereas increase in temperature has decreased surface runoff in the watershed. Climate variability played a dominant role in this watershed.

5. References

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