Dam Construction Impacts on Stream Flow and Nutrient Transport in Kase River Basin

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1. Introduction

Presently, Kase River Basin in Saga Prefecture is facing a large scale environmental change. A new multi-purpose Kase River Dam has been constructed sequentially with an agricultural dam already built in the previous by MLIT (Ministry of Land Infrastructure and Transportation) Japan. Forest and agricultural areas have been changed from artificial coniferous forest and rice field to water area.

The impoundment of dam plays an important role in water supply and flood control. The impoundments modify the movement of water in the channel network by lowering the peak flow and volume of flood discharges. On the other hand, it contributes impact to water quality and quantity surrounding dam (Betnarek et al. 2001). Excessive dam constructions obstruct river flow, however, resulting in environmental degradation and decreased biodiversity (Berkamp, et al. 2008).

This study displays that dams can be a positive environmental instrument by decreasing downstream nutrient loading. The objective of this study is to illustrate the impact of dam construction on stream flow and nutrient loading from Kase River Basin. These estimates give a potential strategy to manage future downstream nutrient and water resources in Kase River basin.

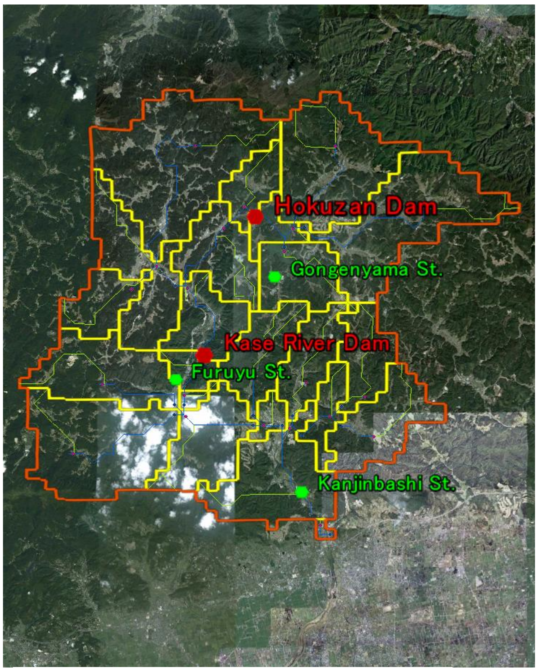

Fig.1 Watershed delineation in the watershed

2. Study area and model input data

Kase River Basin is located in the center part of Saga Prefecture. This basin consists of 3 cities including Saga City. Kase River flows through Saga Plain and pours into the Ariake Sea. The length of Kase River is about 57 km, with catchment area about 368 km^2. Kase River dam construction is started in December 1992 with the surface area of the reservoir 270 ha, and has started a first impounding in October 2010. Upstream of the new dam there is a dam called Hokuzan dam constructed in March 1957 for agricultural purpose only. Kase River Dam is an important water resources facility for Saga Prefecture. This prefecture has a big arable land and has a regional granary for supply rice in Kyushu Island, Japan.

ArcSWAT 2009 version of the SWAT model is used as a main tool in this study. This version integrates the newest version of Soil and Water Assessment Tool. This model was chosen because it was physically based and computationally efficient (Neitsch, 2002).

The SWAT was set up for the basin upstream area of 197.74 km^2 that accounts for 54% of the entire area of the Kase River basin in Japan. Fig. 1 shows the watershed is automatically delineated and divided by SWAT into 23 sub watersheds. The DEM was taken from Nippon-III 50 m grid elevation of digital map, land use map in 2007 obtained from the MLIT Japan, and detailed soil map was clipped from National Land Survey Division, Land and Water Bureau of MLIT`s website and used as the GIS input data for the model simulation. Hourly observed weather data (temperature, humidity, solar radiation) from Saga Meteorological Observatory were applied in order to calculate the potential evapotranspiration (PET) using Penman-Monteith`s method.

Daily observed discharge data were taken by the Ministry of Land Infrastructure and Transportation (MLIT) (2007-2008) for the analysis.

Data on the nutrient parameters before and after dam impoundment were collected by MLIT during November 2008-March 2011. The period of water quality data before impoundment from November 2008 to October 2010 represent the time when the water had not exist in the reservoir yet, and due to available data, Furuyu point represents the point sources to downstream riverine nutrient.

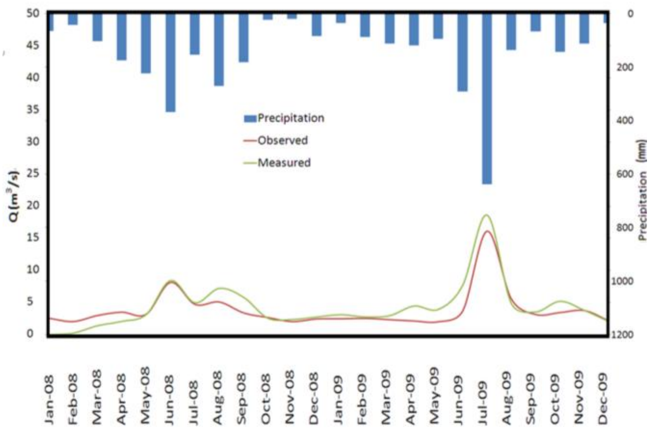

Fig.2 Simulated and observed discharges in Furuyu outlet

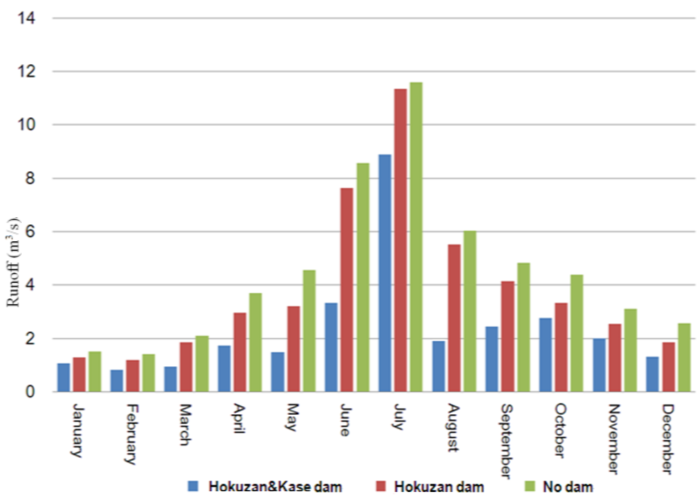

Fig.3 Simulation of average annual runoff for 2008-2009 at Furuyu outlet under the scenarios

3. Model calibration and dam scenarios

Available data from January to December, 2008 were used for the calibration and the daily stream flows in 2009 at the Furuyu station located just in the downstream of the new dam were applied for validation. Prior to calibration, 4 most sensitive parameters: CN2, GWQMN, Alpha_BF, and Sol_AWC, were selected and adjusted manually based on previous SWAT research in Japan for mountains area. Fig. 2 shows the calibration and validation results for flow at the watershed during 2008~2009. Although there were some discrepancies between the observations and simulations, overall the simulated daily flows coordinated well with the observed flows (R^2=0.86 and Nash-Sutcliffe (1970) NSI=0.84).

The set of scenarios tested the impact of the existence or nonexistence of reservoirs in the watersheds. The scenarios were carried out with Hokuzan dam but no Kase River dam, with both Hokuzan dam and Kase River dam, and with all the dams in watershed disappeared, i.e., no dams.

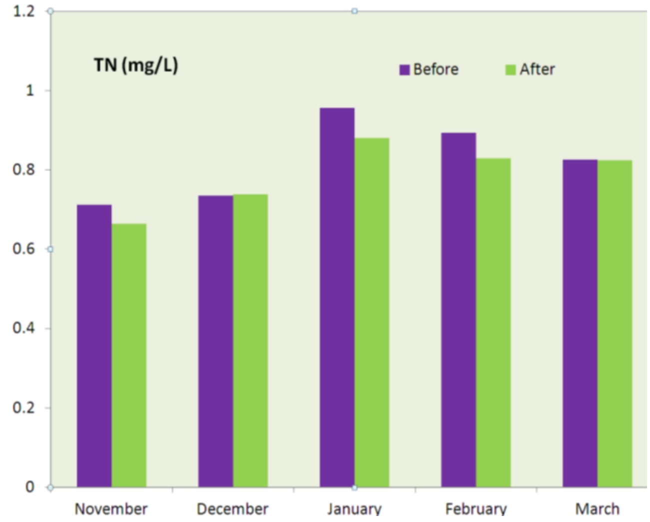

Fig.4 TN concentration in Furuyu outlet (2008-2011)

4. Result and Discussion

As predictable, the presence of dams resulted in significant reductions in annual flow in the watershed. The results also showed that the existence of Hokuzan dam and Kase River dam in the watershed caused greater reductions in stream flow than the only Hokuzan dam did.

These dams seem to result in decrease of annual discharge by up to 29.3% from the disappeared dam scenario. The decrease of stream discharge from this alteration may be attributed to the fact that dams those divert water to offstream uses such as irrigation and urban uses (multi-purpose), especially out of basin diversions, will reduce the total downstream flow (Collier et al, 1995). Excessive dams and floodgate operations have change dramatically the flow regimes and shift peaking time (J. Xia, et al. 2005).

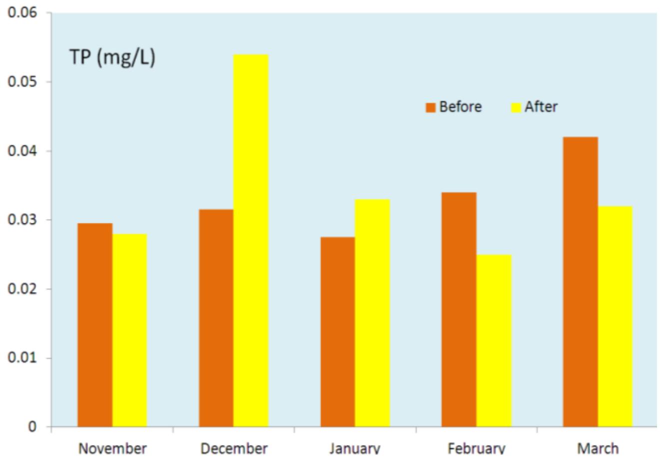

Fig.5 TP concentration in Furuyu outlet (2008-2011)

These effects on decrease of annual stream flow by increased number of dams in the watershed are particularly strong in the wet period from June to July, because precipitation is abundant in the wet period and temperatures are high enough to support high evaporation. Therefore, as shown in Fig. 3, the stream flow rates decreased substantially for the period. Decreases in discharge also occur in the periods after the wet period. The quite lower decrease in discharge in the August–September period is resulting from hot temperatures in those months.

Dams' impoundments have an obvious effect on downstream nutrient transport (Fig.4 and Fig.5). The presence of Hokuzan dam and Kase River dam results in decreasing of total nitrogen at Furuyu point, just downstream after the Kase River dam. The Furuyu`s TN showed a decrease tendency up to 7.85%, but the TP showed average 18.45% decrease in November, February, March, and 29.2 % increase in December and January.

5. Conclusions

(1) Excessive dams in Kase River basin has changed dramatically the stream flow regimes
(2) The presence of Hokuzan dam and Kase River dam results in mainly reducing the nutrient transport in Kase River basin.
(3) Dams can be a positive environmental instrument by decreasing downstream nutrient loading.

References

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