EFFECT OF IRRIGATION ON STREAM FLOW IN MOUNTAINOUS SMALL WATERSHED OF SOUTH KOREA

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Abstract- This study examined change of stream flow with and without agricultural reservoirs which may include rice paddy fields. For this purpose a modified BROOK90 has been used to simulate stream flow under the some environmental change scenarios. Seven years (from 2000 to 2006) of historical weather data and daily discharge records has been considered. This research shows that management of land use is important as a measure to ensure environmental flows as well as proper operation of the reservoir.

Keywords- Irrigation, Agricultural reservoir, Rice paddy field, Stream flow, Mountainous watershed.

I. INTRODUCTION

Water balance of mountainous small watersheds is expected to be vulnerable under the environmental change such as climate change, land use change, and so on. These areas are without any external water inflow from other watersheds and they have the low storage capacities of the groundwater bodies [1], [2]. Therefore the need for watershed management to ensure environmental flows has been raised in these areas [3]. Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater, estuarine ecosystems, the human livelihoods, and their variables [4].

Various measures for the maintenance of environmental flows have been proposed in previous research literatures. Change of tree species or crops was proposed to reduce evapotranspiration [5]. Conservative tillage or no tillage was reported to increase infiltration [6]. Construction of reservoirs and proper operation of them were proposed [7]. Also it has been suggested to use agricultural reservoir to ensure environmental flows [8].

This study focused on the usage of agricultural reservoirs which highly exists in the mountainous watershed in South Korea. To take advantage of the reservoirs in order to maintain environmental flows, it is necessary to understand the processes that the water in the reservoirs contributes to stream flow. The object of this study is to try and find out more about the processes. To this end, this research examined the change of stream flow with and without reservoirs which may include rice paddy fields.

II. DETAILS EXPERIMENTAL

2.1. Study area

The study area is Guryang stream watershed located in the central mountainous part of South Korea (Fig. 1).

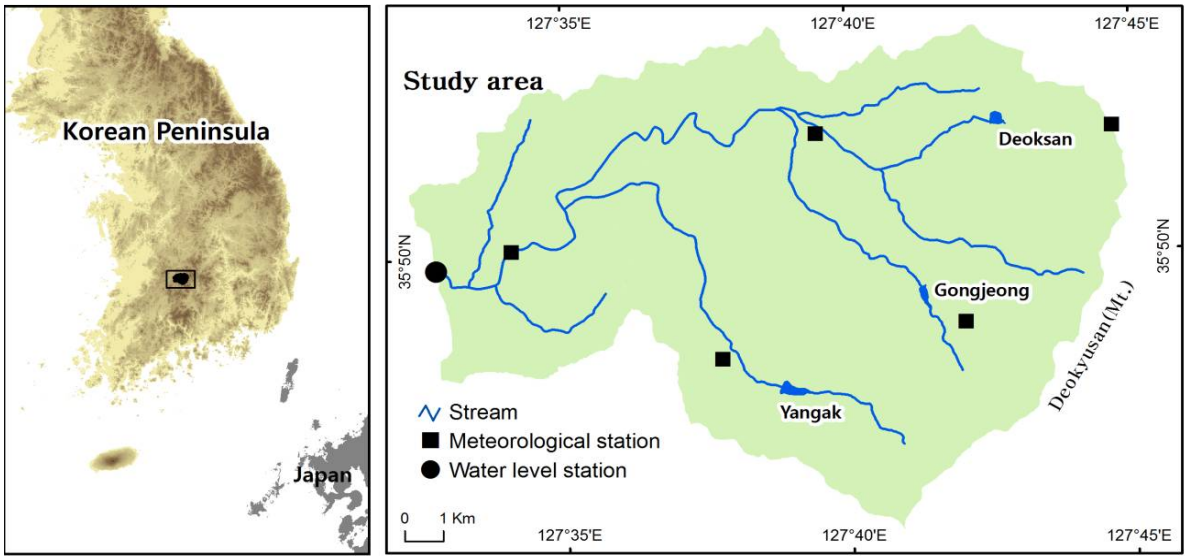


Fig.1. The location of the study area at South Korea

According to the land cover map developed by the Korean Ministry of Environment in 2001, the study area is comprised of 67 % forested land, 27 % agricultural land, and 6 % other land cover types. There are three major agricultural reservoirs in the region; the Deoksan reservoir which was constructed in 1981, the Yangak reservoir built in 1991, the Gongjeong reservoir created in 2002, with the original design storage capacity of 1,591,000 m^3, 3,280,000 m^3, and 3,262,000 m^3, respectively.

2.2. Water balance calculation

In this study, a modified BROOK90 has been applied to calculate water balance, including stream flow under the some environmental change scenarios. The BROOK90 is a physically-based, deterministic and process-oriented parameter hydrological model [9]. It is a one-dimensional model designed to study the processes of daily evaporation and soil water movement, with provision for stream flow generation by different flow paths. This model allows the leaf area index (LAI) to vary throughout the year, despite being a lumped hydrological model. This model uses relative LAI between 0 and 1. The value is an array of ten pairs of DOY (day of the year). The relative LAI is a multiplier of the maximum LAI [10].

However, the original model is not able to simulate the water balance for agricultural reservoirs and rice paddy fields due to without parameters related to irrigation system [11]. Therefore the BROOK90 was modified as shown in Fig. 2. The modified model can simulate the water balance in a reservoir and a rice paddy field. The module for reservoir simulation has been verified by the previous study [12]. This model consist of 4 steps; 1) the water flows into the reservoir from a back sub-watershed; 2) the water released from the reservoir; 3) the most of the water flows into the rice paddy field through a canal and a stream in the model, some water will directly reach the outlet; 4) the water in the rice paddy field will be evaporated, overflow discharge, and groundwater discharge after infiltration. Both overflow discharge and groundwater discharge are return flow. Return flow defined as surface and subsurface water that leaves the field following application of irrigation water [13].

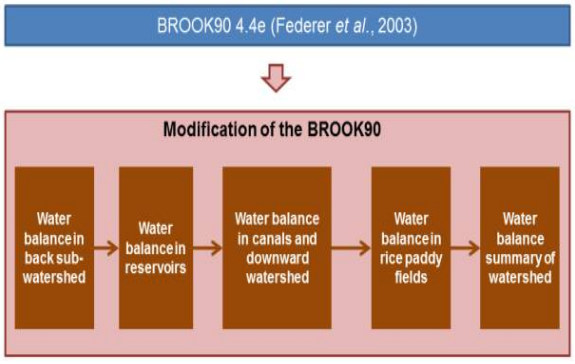


Fig.2. Concept of modified BROOK90 for this study.

2.3. Data

Seven years (from 2000 to 2006) of historical weather data and daily discharge records have been used in this research. The weather data was obtained from the Korean Meteorological Administration. The daily measured discharge data was collected from the WAter Management Information System (http://-www.wamis.go.kr). The data of the year 2000 was used to initialize the model. Three years of historical flow data covering the period from 2001 to 2003 have been applied for model calibration, while the next three years of data from 2004 to 2006 was used for model validation. The soil and canopy parameter of the model were derived from the national land cover map 2001 and national digital soil map, respectively.

III. RESULTS AND DISCUSSION

The overall R^2 of calibration period was 0.81, and the value of validation period was 0.91. Therefore the overall model performances were acceptable in the Guryang watershed. However, the model tends to markedly underestimate the discharge during the dry season (October to May).

Table 1 shows the simulated discharge from 2001 to 2006; the Case 0 shows the current water balance. The Case 1 presents the simulation results of the assumption that there are no reservoirs. The Case 2 display the simulation results of the assumption that there are no both reservoirs and rice paddy fields. The simulation results of the assumption that there are no rice paddy fields can be shown as the Case 3.

Table 1. Simulated discharge from 2001 to 2006

Simulation	Average discharge (mm)			
	Case 0	Case 1	Case 2	Case 3
Annual	892.1	899.8	995.8	994.2
Spring	103.0	103.7	124.6	125.9
Summer	648.8	654.4	742.2	721.4
Fall	92.1	91.6	98.3	100.4
Winter	48.2	50.2	48.7	46.4

In the simulation results of the Case 0, the average annual discharge was 892.1 mm/year. Seasonally, the average spring (March to May), summer (June to August), fall (September to November), and winter (December to February) discharges were 103.0 mm/season, 648.8 mm/season, 92.1 mm/season, 48.2 mm/season, respectively.

If there are no reservoirs, all the discharges are increased except the fall (Case 1). If there are no both reservoirs and rice paddy fields, all the seasonal discharges are decreased as well as the annual discharge (Case 2). If there are no rice paddy fields, all the discharges are increased except the winter (Case 3).

The figure 3 shows average daily stream discharge during the period from 2001 to 2006. The figure 3(a)

shows that stream flow reaches a little higher peak discharge in Case 1 (without reservoirs) than the Case 0 (the present). The figure 3(b) shows that the Case 2 also has higher peak discharges than the Case 0. In addition, the volume of the water discharged during the dry season tends to be smaller for the Case 2 than for the Case 0. The discharge in the Case 2 decreases in 126 days during the dry season compared with the Case 0. The decreases of the peak discharge did not clearly show in the Case 3 (no rice paddy fields) during the dry season which is non-irrigation period.

The figure shows a relatively reduction of peak discharge for storm water in both reservoirs and rice paddy fields. However, reservoirs seem to have an important role to reduce the peak discharge only during the dry season. The reduction of peak discharge during the wet season seems to relate to rice paddy fields. In addition, the results indicate that the water in rice paddy fields discharged into stream through lateral movement especially during the dry season.

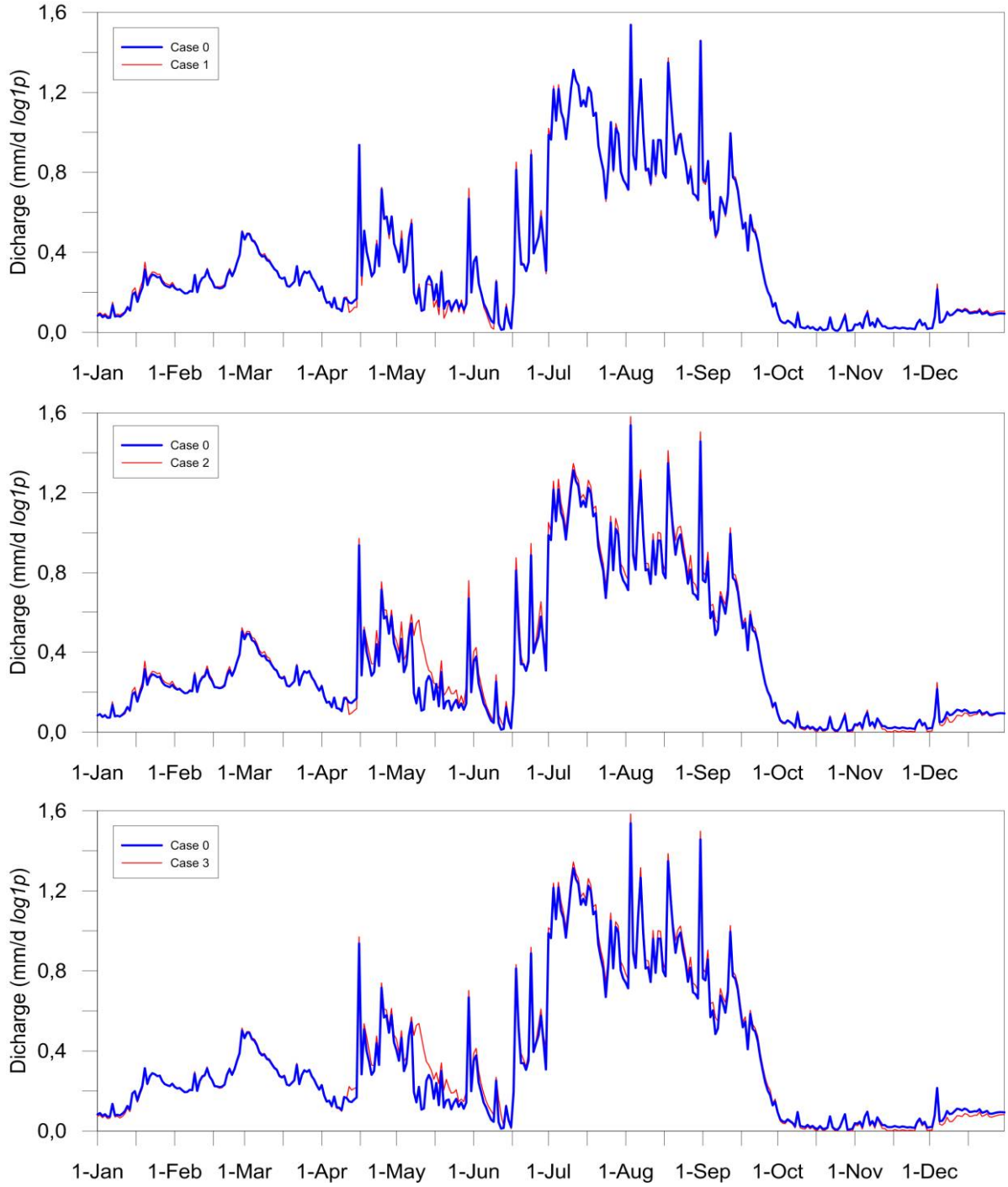


Fig. 3. Average daily stream discharge at the outlet of the study area between 2001 and 2006.

CONCLUSIONS

Change of stream flow was studied under the assumption that there is no irrigation system in the

study watershed and major conclusions are as follows:

1. Rice paddy fields are expected to contribute to the prevention of flooding by decreasing peak discharge.
2. The rice paddy fields are an important part of discharge processes in the study area with reservoirs. It means that management of land use is important as a measure to ensure environmental flows as well as proper operation of reservoir.
3. Finally, future researches such as comparison of runoff components are needed to raise understanding about effect of irrigation system on stream flow.

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