available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/agwat

ELSEVIER

Agricultural Water Management

Evaluation of Agricultural Nonpoint Source (AGNPS) model for small watersheds in Korea applying irregular cell delineation

Jaepil Cho [a,*], *Seungwoo Park* [b], *Sangjun Im* [c]

[a] *Biological and Agricultural Engineering, University of Georgia, 2329 Rainwater Road, Tifton, GA 31793-0748, USA*
[b] *Department of Landscape Architecture and Rural System Engineering, Seoul National University, San 56-1, Sillim-Dong, Gwanak-Gu, Seoul 151-742, Republic of Korea*
[c] *Department of Forest Sciences, Seoul National University, San 56-1, Sillim-Dong, Gwanak-Gu, Seoul 151-742, Republic of Korea*

ARTICLE INFO

Article history:
Received 1 February 2007
Accepted 8 November 2007
Published on line 27 December 2007

Keywords:
Agricultural Nonpoint Source (AGNPS)
Geographic Resources Analysis Support System (GRASS)
Irregular cell
Peak flow
Runoff
Sediment
Korea

ABSTRACT

The Agricultural Nonpoint Source (AGNPS) model was tested in two small agricultural watersheds in Korea. The model was calibrated for 412.5 ha located in the Balhan watershed. The rainfall amount distinguishing between antecedent moisture conditions (AMC) I and II was changed to calibrate the runoff volume. A validation was performed for 274.1 ha located in the Banwol watershed, with similar land use and soil characteristics as the 412.5 ha in the Balhan watershed. The input data were extracted from multiple GIS layers using the Geographic Resources Analysis Support System (GRASS)–AGNPS interface. The AGNPS model was modified to treat the undisturbed forest areas as irregular cells instead of the uniform cell division currently used by AGNPS. Simulated results from the irregular cell-based scheme (ICS) and the uniform grid scheme (UGS) of ANGPS were compared with the observed data. The ICS increased runoff volume and decreased peak flow rate and sediment yields from the watershed compared to the UGS. The ICS significantly reduced the number of cells in a watershed and provided better agreement for surface runoff and peak flow rate compared to the UGS.

1. Introduction

Nonpoint source (NPS) pollution transported by runoff from both urban and agricultural lands is the most significant source of water quality problems in the United States (USEPA, 2000). Agricultural sources are responsible for impairment of more than one half of the rivers and lakes in the United States (Novotny and Olem, 1994). NPS pollutants are generated over an extensive area of land and enter receiving water bodies in a diffused manner. Best Management Practices (BMPs) have been used to reduce or eliminate the losses of pollutants from diffuse sources into receiving waters (Line et al., 1999, 1994; Spooner et al., 1992).

Effectiveness of BMPs is site-specific, depending on land use, topography, and climatic factors. Therefore, it is not possible to extrapolate monitoring results to other ungaged watersheds (Dillaha, 1990). Modeling, however, can be used to predict the effects of BMPs, rank BMP alternatives, and select the most appropriate BMP for a particular situation, prior to BMP implementation. For this reason, NPS pollution models are increasingly being used in watershed-scale NPS analysis and Total Maximum Daily Load (TMDL) studies. Borah and

* *Corresponding author*. Tel.: +1 229 391 6854; fax: +1 229 386 3958.
E-mail addresses: jpcho@uga.edu (J. Cho), swpark@snu.ac.kr (S. Park), junie@snu.ac.kr (S. Im).
0378-3774/$ – see front matter
doi:10.1016/j.agwat.2007.11.001

Bera (2003) reviewed frequently used watershed-scale hydrologic and NPS pollution models including the Agricultural Nonpoint Source (AGNPS) model (Young et al., 1987).

The AGNPS model simulates runoff, sediment, and chemical transport from single storm events. Although AGNPS is a distributed model in the sense that watershed geometry is represented by uniformly distributed cells, its components are for the most part empirical and lumped. AGNPS uses the curve number (CN) and the Universal Soil Loss Equation (USLE) for estimating runoff and erosion from agricultural land, respectively. Even though the CN and USLE approaches are empirical equations derived from agricultural areas in the United States, AGNPS have been widely used and validated in different conditions, ranging from agricultural to forest areas in several countries (Grunwald and Norton, 1999; Hassen et al., 2004; Kim et al., 2004; Kusumandari and Mitchell, 1997; Lin, 1997; Lo, 1995; Nigussie and Fekadu, 2003; Perrone and Madramootoo, 1997; Rode and Frede, 1997).

Unlike agricultural areas in the United States, agricultural watersheds in Korea contain large areas of forest and paddy lands. Paddy areas cover around 61% of the nation's total cultivated area, and they reduce downstream flooding and sediment yield mainly due to their ability of retaining runoff water (Kang et al., 2006). The forested areas, which occupy a large portion of agricultural watersheds in Korea, have steep slopes, contain a variety of tree types, and remain undisturbed. Since undisturbed forest areas are an insignificant source of suspended solids to the streams, and inadequate hydrologic and water quality data are available in forest areas, the uniform grid scheme used by the current AGNPS model may not be appropriate for forest areas in Korea. These land use and topographic differences require site-specific calibration and/or modification of the AGNPS model prior to its application to Korean land use situations.

The goal of this study was to evaluate the applicability of the AGNPS model to small agricultural watersheds in Korea. The specific objectives were (1) to evaluate the AGNPS model for predicting hydrology and sediment yields using two different agricultural watersheds for calibration and validation and (2) to modify the AGNPS model to treat forested areas as irregular cells instead of uniform cells and evaluate the response of the model to the irregular cell approach.

2. Materials and methods

2.1. The study watersheds

Two small agricultural watersheds were selected for evaluating the AGNPS model in Korean land use conditions: Balhan (HS#3) for calibration and Banwol (WS#1) for validation. Fig. 1 shows the location of watersheds and the monitoring networks. The HS#3 watershed has a drainage area of 412.5 ha, with 49.7% paddy land, 31.8% forest, 14.6% cropland, and 3.9% farmstead. Hydrologic soil group B, which has moderately low runoff potential and above-average potential infiltration, occupies about 45.3% of HS#3, followed by groups C, A and D, which occupy 22.2, 18.4, and 14% of the watershed area, respectively. Soil group A has low runoff potential with high infiltration rates while group D has high runoff potential with very slow infiltration rates (USDA, 1972). The meteorological data were obtained from the weather station located within the Balhan watershed. Total precipitation and average temperature were 1218 mm and 13.34 °C, respectively, during the calibration period (from July 1996 to 1997). The length of the main stream to the outlet is approximately 1.63 km, and the average stream slope is 17.8 m/km.

The WS#1 of the Banwol watershed is 274.1 ha and has land use characteristics similar to those of HS#3, with 41.0% under paddy land, 28.6% forest, 21.6% cropland, and 8.8% farmstead. Soil characteristics of WS#1 are similar to those of HS#3, with 44.8, 34.6, 15.8, and 4.8% of hydrologic soil group B, C, A, and D, respectively. The observed data measured from April 1993 to September 1993 were used for the model validation. Its soil and topologic characteristics are similar to those of HS#3, with the exception of the shape of the watershed. HS#3 has a round shape, while WS#1 has an oblong shape.

Stream water velocity and the cross-sectional area were measured at various water levels to develop rating curves, which were used to calculate the discharge from measured levels. The constant-slope method, which connects the minimum value prior to the beginning of the storm hydrograph to the inflection point on the recession limb, was used for baseflow separation (Maidment, 1993). One grab sample was collected during a rainfall event for water quality analysis. Seven samples were taken among twenty storm events in HS#3. Another set of samples was taken from each of the eleven storms in WS#1. These sets of samples were analyzed for suspended solid concentration using the glass-fiber filter method, which measures the difference in weight between the pre- and post-filtered glass-fiber filtering paper (Ministry of Environment, 2001).

2.2. Data preparation

GRASS has been selected as an interface for a number of hydrologic models because the source code is open to the public (Ogden et al., 2001). The GRASS–AGNPS user interface within the WATERSHEDSS (Osmond et al., 1997) was employed for simulation of the AGNPS model in this study. Land use, soil, and topographic input parameters for AGNPS were derived using the GIS data. The thirteen GIS data layers that are required by the GRASS–AGNPS interface were created through spatial data manipulations including scanning, vectorizing, adding topology, converting data format, and rasterization processes. Topographic and land use-related GIS data layers were derived from the topographic map, while soil-related GIS layers were derived from the detailed soil map. Land use types were grouped into the five categories: forest, cropland, paddy, farmstead and water, based on the topographic map. Grid sizes of 100 m were chosen for both watersheds, based upon the preliminary test to consider the accuracy of data conversion from vector to raster format. Spatial distributions of soil and land use types were reasonably described in the 100 m grid size. Fig. 2 shows the spatial distribution of land cover for both the calibration and validation watersheds according to the selected grid size.