Journal of Environmental Sciences Vol.16, No.5, pp.865—867, 2004

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2004)05-0865-03 **CLC number**: X703 **Document code**: A

Estimation of runoff and sediment yield in the Redrock Creek watershed using AnnAGNPS and GIS

Tsou Ming-Shu[1], ZHAN Xiao-yong[2,*]

(1. HydroGeoLogic Inc. 12343 Hymeadow Dr., STE 3B, Austin, TX 78750, USA; 2. Kansas Geological Survey, 1930 Constant Ave., Campus West, University of Kansas, Lawrence, KS 66047, USA. E-mail: xyz@ku.edu)

Abstract: Sediment has been identified as a significant threat to water quality and channel clogging that in turn may lead to river flooding. With the increasing awareness of the impairment from sediment to water bodies in a watershed, identifying the locations of the major sediment sources and reducing the sediment through management practices will be important for an effective watershed management. The annualized agricultural non-point source pollution(AnnAGNPS) model and newly developed GIS interface for it were applied in a small agricultural watershed, Redrock Creek watershed, Kansas, in this pilot study for exploring the effectiveness of using this model as a management tool. The calibrated model appropriately simulated monthly runoff and sediment yield through the practices in this study and potentially suggested the ways of sediment reduction through evaluating the changes of land use and field operation in the model for the purpose of watershed management.

Keywords: annualized agricultural non-point source pollution(AnnAGNPS); GIS; sediment yield; runoff

Introduction

Sediment has been identified as a significant threat to water quality and channel clogging that in turn may lead to river flooding. Particle size of sediment can lead to different impacts on reservoirs and river systems. Increased suspended (fine) sediment can be destructive to aquatic ecosystems by reducing light penetration, reducing oxygen delivery to fish eggs in the gravel, and deteriorating water quality. In addition to this, nutrients, heavy metals, and organic contaminants attached to the fine sediment would contribute to lake eutrophication and toxicity to aquatic organisms that live in or feed on bottom sediments (Novotny, 1994). On the other hand, coarse sediment would reduce flow capacity in rivers, which can lead to floods when storm events occur. Erosion from cropland, stream banks and beds, mining sites, and urban areas are some main sources of sediment. With the increasing awareness of the impairment from sediment to water bodies in a watershed, identifying the nature and location of the major sediment sources will be the first step to a successful sediment-control strategy. The annualized agricultural nonpoint source pollution model (AnnAGNPS) is a watershed-evaluation tool, which has been developed by the U. S. Department of Agriculture-Agriculture Research Service (USDA-ARS) and Natural Resources Conservation Service (USDA-NRCS; Cronshey, 1998). It can evaluate runoff, sediment, and chemicals (nutrients and pesticides) responses of a watershed for different land use and agricultural-management practices. With the aid of this model, estimating the amount of sediment and further locating the source of sediment can be easily accomplished. Furthermore, the proper land use and best-management practices (BMPs) for the watershed can be explored through the modeling tool.

The Cheney Lake reservoir located in south-central Kansas supplies over 60% of the daily drinking water to the City of Wichita. Since the watershed relevant to the reservoir has intensive agricultural practices, it is important to identify and alleviate potential sources of pollution in the watershed to ensure water quality within the drinking standard. The objective of this study is to serve as a pilot study for estimating sediment yield of the Cheney Lake watershed by applying AnnAGNPS in a sub-watershed, Redrock Creek watershed, so as to assess the viability of this approach for the whole watershed. The AnnAGNPS model and GIS approach will be briefly described in the following section, model input data and results are presented subsequently.

1 AnnAGNPS model and GIS

AnnAGNPS is a continuous-simulation, watershed-scale computer model for use in evaluating agricultural nonpoint-source pollution. It can simulate quantities of runoff, sediment, nutrients, and pesticide yield on a daily, monthly, or yearly basis according to user's specification. Nutrients related to soluble and attached nitrogen, phosphorus, and organic carbon and any number of pesticides are provided. Outputs can be specified at any desired source location such as specific cells, reaches, feedlots, or point sources.

A watershed is divided into subwatershed cells for the spatial variability of soils, land use, and topography in AnnAGNPS. Runoff events can be caused from rainfall, snowmelt, and irrigation. Soil erosion from fields is estimated based on the revised universal soil loss equation (RUSLE; Renard, 1997). The estimation of sediment yield leaving fields to the stream networks is based on the delivery ratio calculated through the hydro-geomorphic universal soil loss equation (HUSLE; Theurer, 1991), which includes the calculation of eroded particle-size distribution, runoff rate, and peak runoff rate.

AnnAGNPS requires over 400 separate input parameters of 34 data categories(e.g., climate, land characterization, field operations, chemical characteristics, and feedlot operations). Because of the complexity of data requirements, a user-friendly interface was developed to directly link with a Geographic Information System(GIS, ESRI ArcView) and a database management system(Microsoft Access) to facilitate data preparation, manipulation, and analysis as well as output display and interpolation.

The GIS interface for AnnAGNPS was developed as an ArcView extension. This extension with ArcView is an integrated and interactive modeling environment to facilitate the use of the AnnAGNPS for watershed water-quality analysis. The interface consists of three major components: inputs for topographic data, inputs for soil and land-use related data, and output display. The first component is designed to assist in delineation of watershed boundary, outlet selection, TOPAGNPS(Garbrecht, 1995) input-data preparation, and execution of TOPAGNPS. The second component serves as an operating tool to organize and/or control soil data and land-use (field) information in appropriate formats. The last component initiates the AnnAGNPS, processes output files, and displays results in ArcView. Further detail for this GIS interface is provided in Misgna *et al*.(Misgna, 2003).

2 Model input data

The Redrock Creek watershed is a small agricultural watershed with a drainage area of 53.19 m^2(Fig.1) and over 75 percent of crop land. The average annual precipitation in the watershed is 28.7 inches per year. The climate information required for AnnAGNPS includes daily precipitation, maximum and minimum temperature, dew-point temperature, sky cover, and wind speed. The information can be obtained through national weather services.

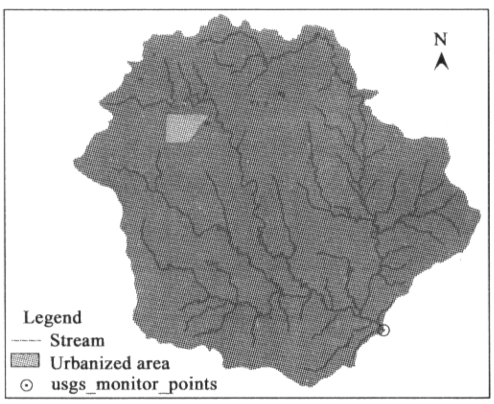

Fig.1 Redrock Creek watershed

The input data required by AnnAGNPS also include topography, soil and land-cover data, and field-management data. The topographical parameters such as slope, slope length, slope-shape factor, aspect/flow direction, and so on are derived from a digital elevation model(DEM) at a scale of 1:250000 from the U.S. Geological Survey. Soil textures are mainly classified to nine categories, which vary from clay loam to sandy loam. The related soil parameters for AnnAGNPS are acquired and derived from the soil survey geographic database(SSURGO) that is the most detailed level of soil database available. The land-cover data was derived from 1997 LANDSAT image. Crop operation and field-management data were prepared based on field investigation and databases.

Given the availability of the newly developed GIS interface for AnnAGNPS, it can aid to delineate modeling grid cells in the study area, and assign the dominant soil and land use to each modeling cell. Besides, the GIS interface can retrieve field-management data from the standard database and prepare them in model input formats.

3 Results and discussion

The runoff volume in AnnAGNPS is estimated using the Soil Conservation Service(SCS) method which has a single parameter, curve number(CN). The CN has been tabulated by the SCS on the basis of soil type and land use, which represents the normal antecedent moisture condition. Thus, in order to obtain accurate estimations of runoff, the CN is an important factor to be assigned. In this study, the CN was assigned based on standard handbook but adjusted to incorporate local conditions in the model calibration, which includes the effect of crop operation and variation of soil type and land use.

The model was calibrated based on monthly mean stream flow data from a USGS gauging station(Latitude 37°54′10″, Longitude 98°00′48″ NAD27) in the year of 1997. It was then verified with the stream data in 1998 and presented as an accumulated plot as shown in Fig.2. The model predicted lower runoff than observed data and the deviation is around 10 percent. As pointed out by Yuan *et al*.(Yuan, 2001), AnnAGNPS tended to under predict runoff. This may be due to the assumption of a triangular hydrograph and some approximations of model parameters. Therefore, the 10 percent deviation is within the reasonable range.

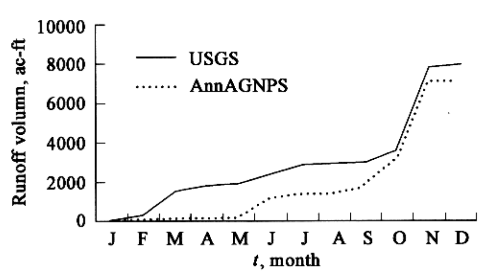

Fig.2 Comparison of USGS observed and AnnAGNPS simulated runoff

Soil erosion and sediment delivery are related to runoff events in the AnnAGNPS simulating process. The RUSLE is used to estimates sheet and rill erosion within a field (modeling grid cell). Sediment deposition before entering the stream, i.e. the edge of the field, is estimated based on a delivery ratio of sediment from the erosion to the stream through the HUSLE, which is related to the peak runoff. As indicated by Kuhnle *et al*. (Kuhnle, 1996), the decrease in cultivated land reduces the soil erosion and more importantly diminishes the peak flow rate and runoff amount which in turn lower the sediment yield to the channel and thus to the outlet. Thus, runoff is an important factor to the sediment yield.

As shown in Fig. 3, the simulated curve of sediment yield basically follows the trend of runoff in Fig. 2 except a few months during the middle of the year, which may be due to some additional effects of land cover and soil disturbance. Also, RUSLE was derived from long-term average annual soil loss estimates (Yuan, 2001), so the prediction may not have sufficient accuracy for monthly sediment yield. Given the 10 percent deviation of runoff estimation, the sediment-yield estimation has around 20 percent deviation for the simulated result in 1998 and thus is considered acceptable for practical applications based on the current model setup.

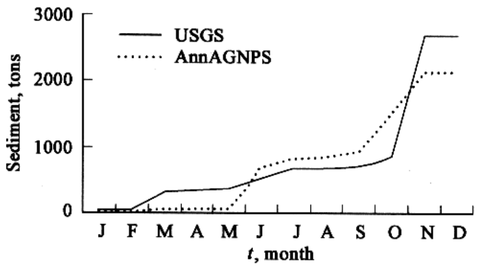

Fig. 3 Comparison of USGS observed and AnnAGNPS simulated sediment yield

The most important feature for using this model as a management tool is the capability of identifying the areas for contributing the amount of runoff and sediment to the outlet. The distribution of contributing ratios to the outlet can be displayed and would be valuable for the watershed management. As shown in Figs. 4 and 5, the dark colored areas are the most critical areas that contribute largest amount of water and sediment to the outlet. With the aid of this feature, the model can be used to evaluate the effectiveness of reducing sediment yield by changing the land use or field operations through difference scenarios.

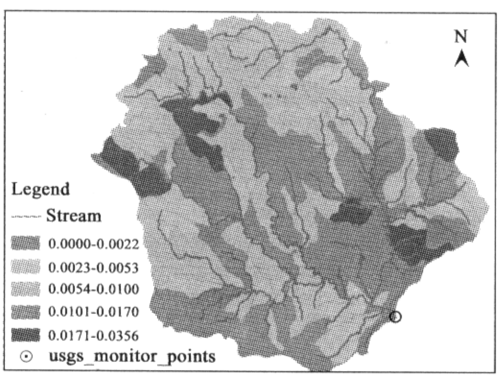

Fig. 4 The distribution of runoff contributing ratios to the outlet

4 Conclusions

The GIS modeling interface was very efficient and effective in preparing input data, model calibration, and output display, and the model appropriately simulated monthly runoff and sediment yield through the practices in this study. Curve number is the only parameter to the runoff estimation in the model so its value would significantly affect runoff and sediment yield in further. Sediment yield is also sensitive to land cover and field operation. Thus, more accurate field information would definitely provide better estimation of sediment yield.

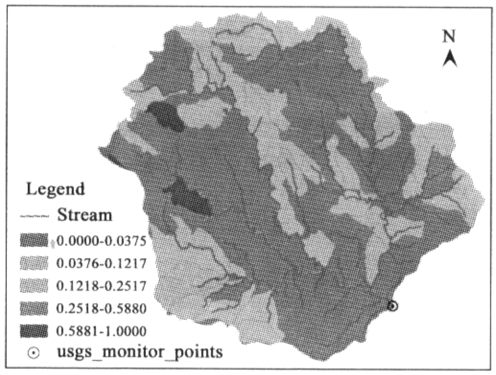

Fig. 5 The distribution of sediment-yield contributing ratios to the outlet

The BMPs within the watershed can be evaluated through tracking the critical areas in the watershed based on the current condition and further changing the land use and field operation for improvement. This process can be conducted through various "what-if" scenarios to ultimately reach the goal of better managing the watershed and controlling the water quality into the reservoir.

References:

Cronshey R G, Theurer F G, 1998. AnnAGNPS-non point pollutant loading model[C]. In: Proceedings first federal interagency hydrologic modeling conference. 19—23 April 1998, Las Vegas, NV.

Garbrecht J, Martz L W, 1995. Advances in automated landscape analysis[C]. In: Proceedings of the first international conference on water resources engineering (Espey W. H., Combs P. G. ed.). American Society of Engineers, San Antonio, Texas, August 14—18, 1995, Vol. 1. 844—848.

Johnson G L, Daly C, Taylor G H *et al*., 2000. Spatial variability and interpolation of stochastic weather simulation model parameters[J]. J Appl Meteor, 39: 778—796.

Kuhnle R A, Binger L B, Foster G F *et al*., 1996. Effect of land use changes on sediment transport in Goodwin Creek[J]. Water Resources Research, 32 (10): 3189—3196.

Novotny V, Olem H, 1994. Water quality: Prevention, identification, and management of diffuse pollution[M]. New York: Van Nostrand Reinhold. 1054.

Milligan C R, Pope L M, 2001. Occurrence of phosphorus, nitrate, and suspended solids in streams of the Cheney Reservoir watershed, south-central Kansas, 1997—2000[R]. U. S. Geological Survey, Water-Resources Investigations Report 01—4199.

Misgna G, Tsou M S, Zhan X, 2003. User's manual for AVAnnAGNPS[R]. Kansas Geological Survey Open-File Report 03—24.

Renard K G, Foster G R, Weesies G A *et al*., 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)[M]. U. S. Department of Agriculture, Agriculture Handbook No. 703.

Theurer F G, Clarke C D, 1991. Wash load component for sediment yield modeling[C]. In: Proceedings of the fifth federal interagency sedimentation conference. March 18—21. 7—1 to 7—8.

Yuan Y, Bingner R L, Rebich R A, 2001. Evaluation of AnnAGNPS on Mississippi Delta MSEA watersheds[J]. Trans of ASAE, 44(5): 1183—1190.

(Received for review September 11, 2003. Accepted November 10, 2003)