

An integrated GIS-AnnAGNPS modeling interface for non-point source pollution assessment

Huaguo Xiao

Abstract

AnnAGNPS (*Annualized Agricultural Non-point Source*), a continuous simulation and distributed pollution model, is widely applied in evaluating non-point source pollution and watershed management practices. However, the complexity of required input data and modeling procedure keep it from being an efficient modeling tool. An integrated GIS interface was developed to facilitate organizing and preparing the input data, running the model, and visualizing modeling and management results. The interface is operated in ArcGIS 8.x environment as a new command bar that was developed with Microsoft Visual BASIC 6. It consists of three major components: topographic data processing, soil and land use related data manipulation, model output visualizing.

Introduction

Nonpoint source pollution (NPS) is a widely concerned water quality issue. Due to the NPS nature and the limitation of experiments and field measurements, NPS management is highly dependent on the spatial simulation. Spatial simulation is an important technique of using models to deal with the NPS pollution problems associated with spatial uncertainty. Numerous models such as USLE (Wischmeier and Smith 1978), AGNPS (Young et al. 1987 and 1989), HSPF (Johnson et al 1980), ANSWERS (Beasley et al 1980), SWAT (Arnold et al. 1995) have been developed to aid in understanding parts of the NPS system and evaluating/identifying watershed management, land use, pollution control and conservation practices.

The application of NPS models to assess water quality requires efficient acquisition, storage, manipulation, visualization, analysis, and interpretation of model input and output data. Because GIS is powerful to store, manipulate, retrieve, and display spatial and non-spatial data, integration of GIS with NPS models can facilitate and reduce burden of the task of compiling necessary data for watershed modeling, interpreting and visualizing of model results. Moreover, the integration can enable decision-makers to determine critical area and to perform various “what-if?” scenarios of alternative management strategies. Currently many NPS models have been integrated with GIS (Engel and et al 1993; Arnold et al. 1995; Liao and Tim 1997; He et al 2001).

Objectives

Annualized Agricultural Nonpoint Source (AnnAGNPS) designed by U.S. Department of Agriculture (USDA ARS and NRCS), is a continuous and distributed simulation model widely used for watershed assessment. It expands the capabilities of its predecessor AGNPS which is a single event model. The newest version is 3.2 and can be downloaded for free from web site (<http://www.sedlab.olemiss.edu/agnps.html>). This model has an extensive input data requirement (up to 400 input parameters of 34 data categories). Preparing input data is very time-consuming and difficult without visualization support. Therefore, a user-friendly GIS integrated system was desired to reduce the complexity, time, and labor involved.

There're some GIS interface existed for AnnAGNPS model. The original AnnAGNPS package provided an ArcView 3.x interface (USDA ARS and NRCS). Some other researchers have also developed ArcView 3.x interface for it (Tsou, Misgna and et al

2001; Srivastava, Day and et al, 2001). The specific objective of this research was to develop a handy and user-friendly, integrated ArcGIS 8.x interface for this model.

Interface Development and application procedure

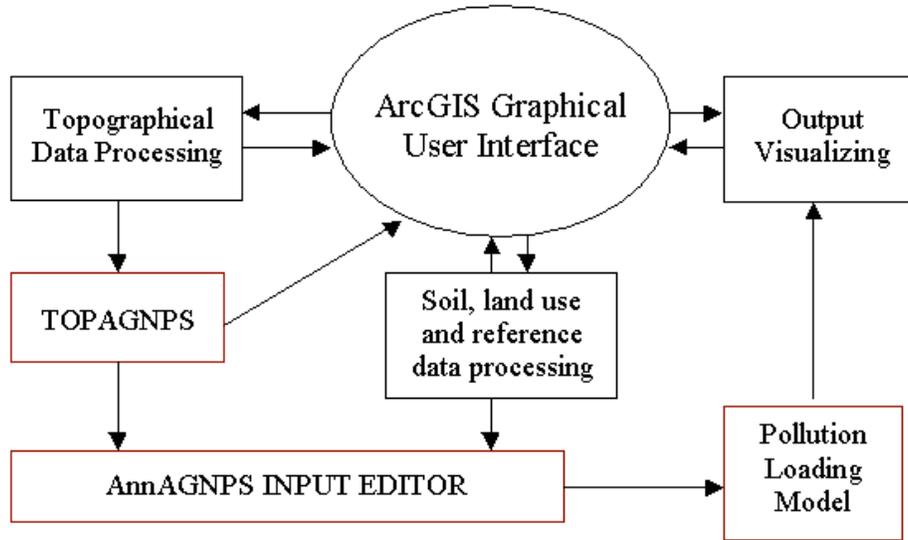


Figure 1 Schematic diagram of the interface architecture (Dark red box showing AnnAgNPS modules)

The interface, based on ArcGIS 8.2 and AnnAGNPS 3.2, was designed as an ActiveX dll by using Microsoft Visual Basic 6.0 and ArcObjects. It includes three major components: topographic data processing; soil, land use and reference data processing; and output visualizing (Figure 1). The interface is very user-friendly, and each tool or dialog is either self-explained or assisted with a help button or tooltip. To date, only the first component and portion of the second component have been finished.

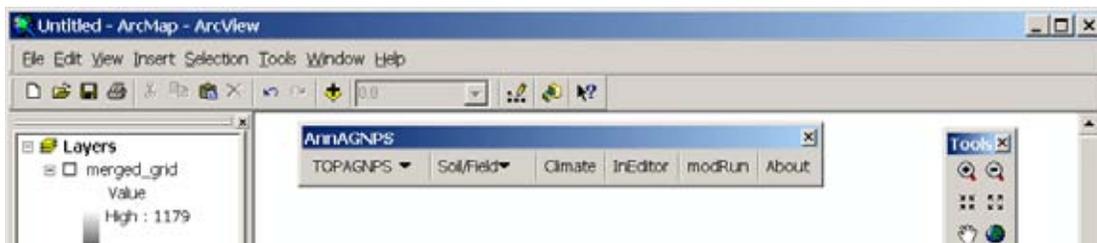


Figure 2 The AnnAGNPS command bar in ArcMap GUI

The interface was developed as a command bar with dropdown menus and buttons in ArcGIS GUI (Figure 2). To use this interface, ArcGIS Spatial Analyst extension must be installed and licensed. One should firstly install the AnnAGNPS package into a root folder in a drive (eg. F:\) and copy paste the folder *\AGNPS_Watershed_Studies* which is located in *\AGNPS* folder to the root folder in the same drive. Now, one should have folder structure as shown in Figure 3. If likes, one can rename “OR_Mission_Creek” to his specific watershed name, but the sub-folders should not be renamed. Secondly, the user can load interface to ArcMap. Start up ArcMap, and click Tools>Customize.... Press “add from

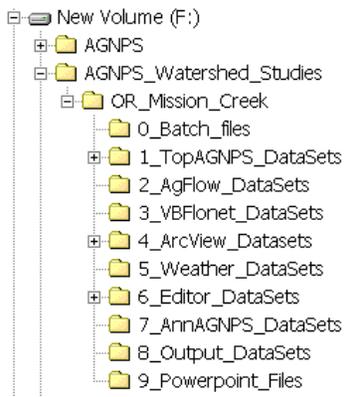


Figure 3 Tree view of folders

file...” button. Navigate to find and open the dll file, and click OK when a message dialog displays. Close the customize dialog. If the AnnAGNPS command bar doesn’t show up automatically, right-click on any command bar and choose AnnAGNPS.

Topographic data is fundamental to AnnAGNPS model. In this model, TOPAZ (called as TOPAGNPS in this model) is used to analyze landscape topography from digital elevation models (DEM), identify and segment watershed and sub-catchments, and generate topographic input data (such as cell and reach data) together with AGFLOW for the AnnAGNPS model.

The first component of the ArcGIS interface is to help processing DEM data, finding watershed outlet, delineating watershed boundary and preparing input files of and launching TOPAGNPS (Figure 4).

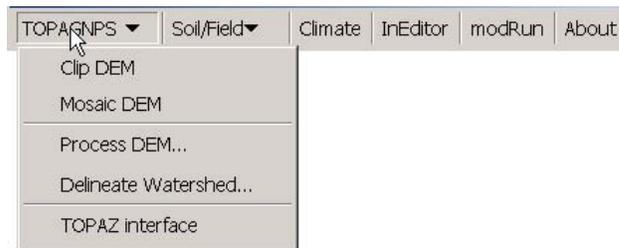


Figure 4 TOPAGNPS dropdown menu

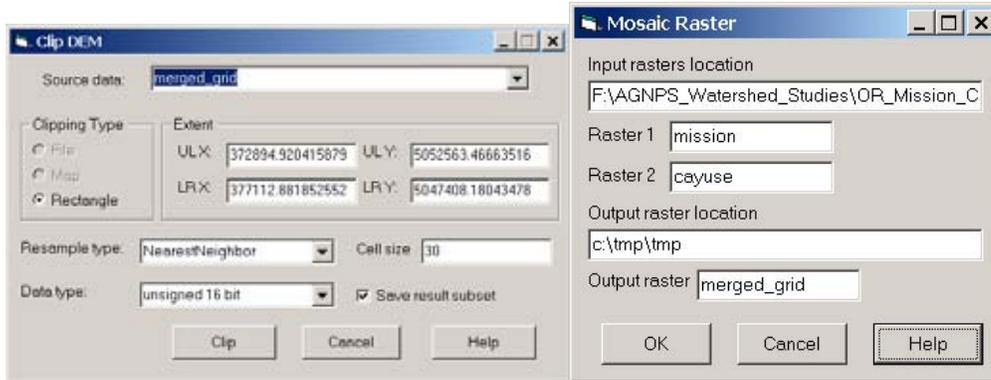


Figure 5 The clip DEM and mosaic DEM dialogs

The clip DEM and Mosaic DEM tools (Figure 5) are to make easier for those who work either with big-sized grid layers and don't have to manipulate the whole area or with small-sized grid layers and the target watershed is larger than one layer extent. After the grid layer(s) is/are clipped or mosaiced, the result can be added to the working ArcMap

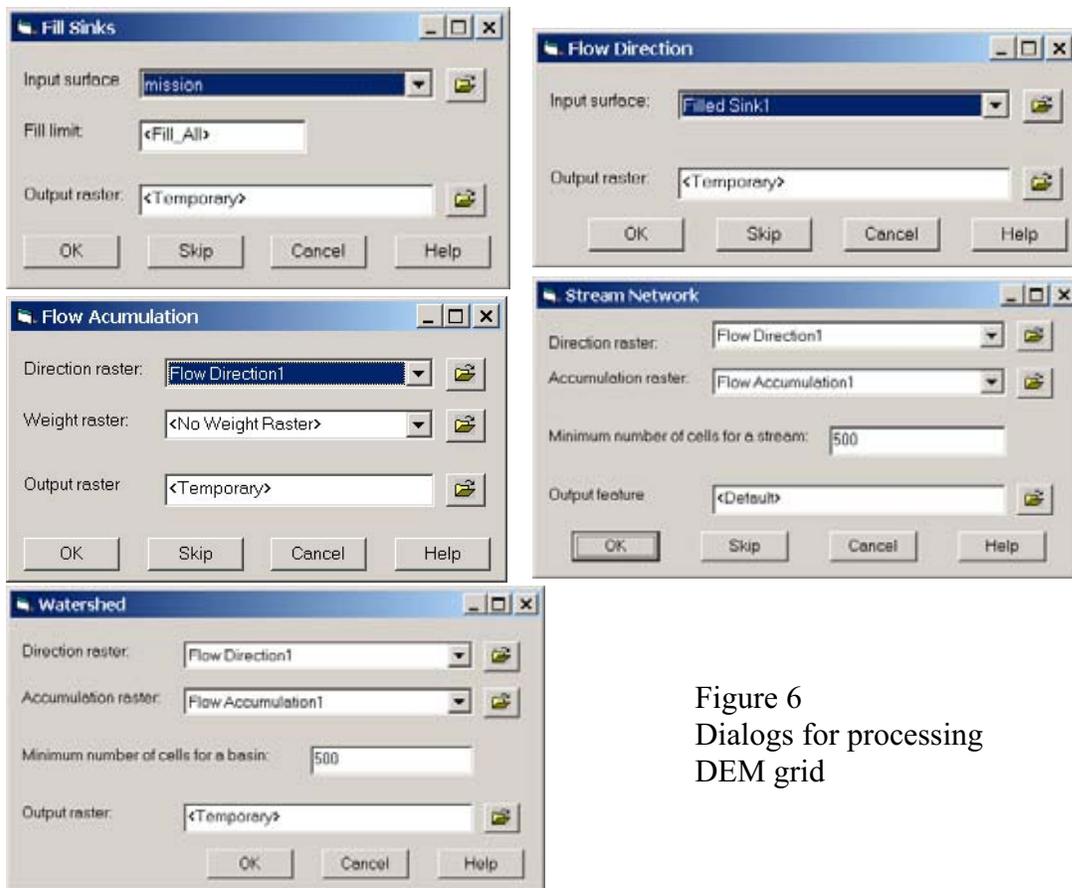


Figure 6 Dialogs for processing DEM grid

map document automatically.

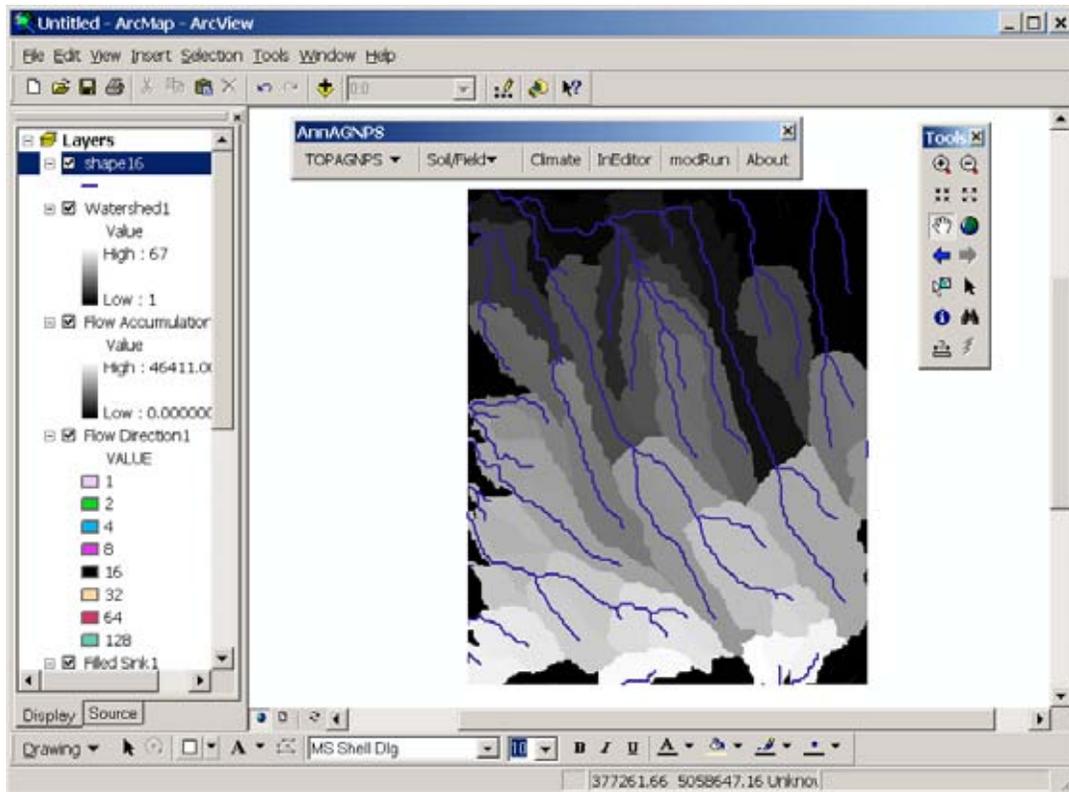


Figure 7 Streams and watersheds Derived from Mission Creek DEM data

“Process DEM...” is a series of procedures that help users extract stream network and watershed data from the DEM (Figure 6). This is done by removing all sinks (or areas of internal drainage) contained within it, calculating the direction of flow out of each cell into one of its eight neighbors, creating a Grid of accumulated flow to each cell, determining stream network and optionally determining watershed based on the user-specified number of cells. The result grid of each step will be automatically added to the working map document. Each dialog has a help button which provides a brief help message of how to use that dialog and what value should be chosen for each control box. The skip buttons are to be used when one wants to skip a step. Default values are set on the dialog to make the procedure simpler. They can be changed based on user’s demand. The stream network and watersheds derived from Mission Creek DEM data in AnnAGNPS package are shown in Figure 7.

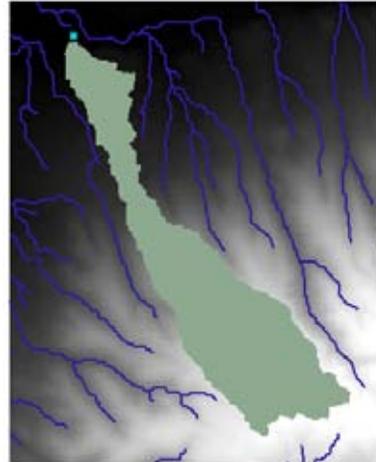
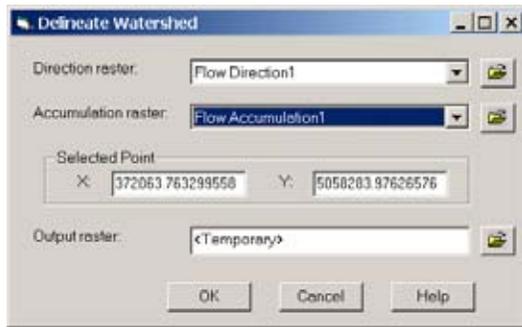


Figure 8 Delineate watershed dialog (left) and derived watershed based on a user-specified outlet (right)

Watershed boundary for a specific outlet on the stream network can be delineated automatically by using “Delineate watershed...” item. Simply zoom in to the outlet area, draw a point on the outlet location, and then click this tool item to start up the dialog (Figure 8). Because this item depends on the result layers of “processing DEM...”, it must be run after “processing DEM...”.

Next step is to create TOPAZ input files (DEDNM.inp, DNMCNT.inp, and NTGCOD.inp) and run TOPAZ by clicking “TOPAZ interface” item. The TOPAZ dialog

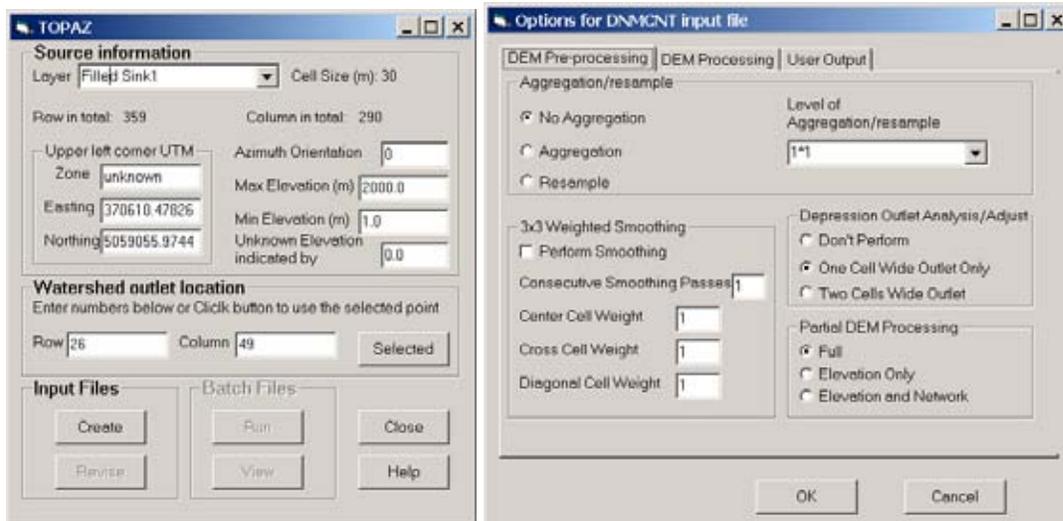


Figure 9 TOPAZ interface dialog (left) and dialog for modifying DNMCNT parameters (right)

shows up (Figure 9). Choose or input information of source DEM data for each control box and one can accept the default values if some information is unknown. A brief help message is provided for each input box. The location of the outlet for input file is defined as row and column numbers of DEM. One can input these numbers or just simply press “Selected” button to enter a graphically selected outlet. Click Create button to create the

default input files. To simplify the procedure, it is recommended that input files are saved in the sub-folder *\1_TopAGNPS_DataSets*. The user can also adjust DNMCNT.inp parameters by choosing options through the user-friendly dialog (Figure 9) either in the first run of generating default files or after the default files created. After input files are ready, the TOPAZ along with AGFLOW can be executed by pressing Run button. The user will be reminded to open corresponding batch file located under sub-folder *\0_Batch_files*. Follow the response message to run the TOPAZ programs and TOPAZ output files will be automatically saved to right location under the folders shown in Figure 3. The user may need to close the TOPAZ output windows to proceed during the running process.

The results from 'TOPAZ interface' will be used for clipping soil and land use coverages or as input files for AnnAGNPS 'Input Editor'.

The second major component of this interface is for preparing soil, land use and related reference data. It will help extract soil, land use coverages, retrieve or derive soil parameters from available database such as Soil Survey Geographic Database (SSURGO) and State Soil Geographic (STATSGO) Database (STATSGO). Up to date, only the GIS operation portion of this component has been done. The database query, retrieval and manipulation functions are waiting for implementation. Thus, only the finished portion (Figure 10) is introduced here.



Figure 10 Soil/Field dropdown menu

The 'Clip Tool...' item is a procedure to clip soil and land use coverage (Figure 11) by utilizing the watershed segmentation coverage *subwta.arc* generated by TOPAGNPS interface described above. To use this

item, the user need to input the path and name of *subwta.arc* or press the open file icon to input it interactively. The result dataset of each step will be automatically added to the current map document.

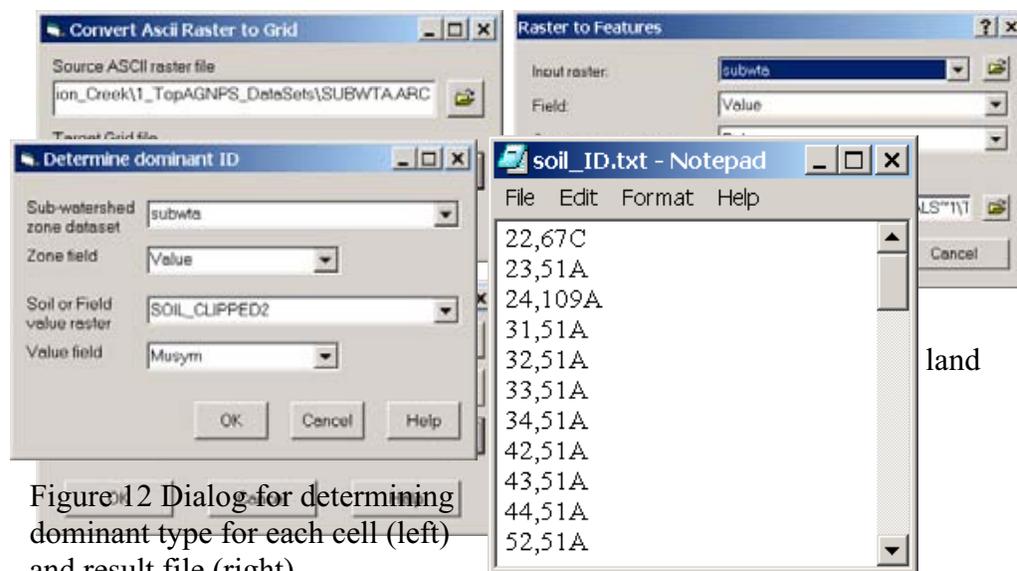


Figure 12 Dialog for determining dominant type for each cell (left) and result file (right)

land

AnnAGNPS model subdivides watershed into

homogenous cells with respect to soil type, land use, and land management. In other words,

soil, land use and land management data within each cell is represented by a dominant type. The ‘dominant ID’ menu item in this component can automatically extract and assign dominant type to each cell. Startup this item (Figure 10) and choose proper datasets and fields, press ok button to run it (Figure 12). Two temporary tables will show up and the user is requested to save the result in a text file. The result file is a comma-delimited text file with the cell ID in the sub-watershed as first column and soil or field ID as second column (Figure 12). This file can be directly imported by AnnAGNPS Input Editor. The current version of ArcGIS may not support a feature dataset as a source of zone dataset. If this is true, the user should convert the zone dataset into a raster (grid) dataset before using this menu item.

There are a few more buttons on the command bar such as ‘climate’, ‘InEditor’, ‘modRun’ (Figures 2, 4 and 10). These buttons are to help user interactively startup corresponding AnnAGNPS modules. Click any of these buttons; an open file dialog will display (Figure 13). Navigate to locate the corresponding batch files in the subfolder \0_Batch_files. The title of dialog window reminds the user which file should be opened. Follow the message displayed to finish executions.

The Climate button helps launch the *Climate Generator* and *Complete Climate* in AnnAGNPS package. Climate data for the user’s watershed will be interactively generated for the *Pollution Loading Model* which is the core of AnnAGNPS model.

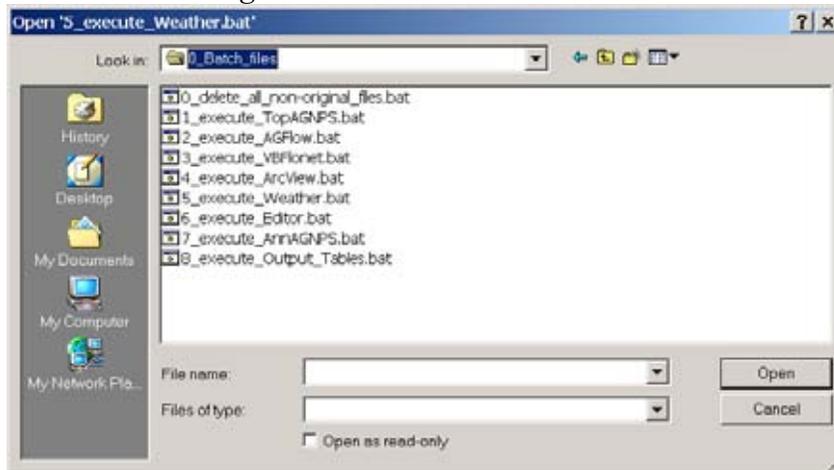


Figure 13 Dialog for opening batch file

The Input Editor provided by AnnAGNPS package is for preparing the AnnAGNPS input file. Start it up from the command bar by clicking InEditor button. Then one can create or modify an AnnAGNPS file and enter basic information about the watershed. Import cell data (i.e. AnnAGNPS_Cell.dat) and reach data (i.e. AnnAGNPS_Reach.dat) which are generated by TOPAZ interface and located under folder \2_AgFlow_DataSets. And also import the text files of soil, land use IDs generated by ‘Dominant ID’.

After the AnnAGNPS input files and climate data are ready, one can launch the *Pollution Loading Model* and *Output Processor* by clicking modRun button. Model results are saved as text files in the folder 7_AnnAGNPS_DataSets and 8_Output_DataSets.

The visualization of model outputs is important for a user to interpret them. This is planned as a major component in this ArcGIS interface. Future work will focus on that.

Discussion and concluding remarks

AnnAGNPS is a very effective tool for watershed simulation and management. However, the preparation process of its input data is tedious and time-consuming. Its modeling procedure is confusing. Therefore, a user-friendly GIS interface is desired to reduce the tedious task of data collection and organization, especially for a beginner.

An integrated ArcGIS interface is being developed. The most important portion has been finished and was demonstrated. This interface is totally mouse and menu/toolbar driven and requires minimal user interaction while providing full flexibility for changing input parameters. Because it is programmed by COM technology through MS Visual Basic and ESRI ArcObjects, this interface is transferable between platforms such as Windows NT/2000/XP. The interface is also fully modular and function modules can be easily added or removed.

Acknowledgement

Appreciation is presented to Dr. Wei Ji for reviewing and providing valuable suggestion to this paper. Appreciation is also presented to Dr. Mingshu Tsou, Dr. Xiaoyong Zhan and Girmay Misgna in Kansas Geological Survey for helpful discussion about AnnAGNPS model. Thanks to Dr. Xiaoyong Zhan, Dr. Mingshu Tsou for testing some interface programs and providing helpful feedback.

References

- Arnold, J. G.; Srinivasan, R.; Muttiah, R. S., and Griggs, R. H. 1995. Watershed modeling and GIS with SWAT and GRASS. SWAT user's manual. Temple, TX: Blackland Research Center, Texas Agricultural Experiment Station.
- Beasley, D. B.; Huggins, L. F., and Monke., L. F. 1980. ANSWER: A Model for Watershed Planning. Transactions of ASAE. 23(4):938-944.
- Engel B.A. ; Srinivasan R. ; Arnold J. ; Rewerts C., and Brown S.J. 1993. Nonpoint source (NPS) pollution modeling using models integrated with geographic information systems (GIS). Water Science & Technology. 28(3-5):685-690.
- He, C.; Shi, C.; Yang, C. and Agosti, B.P. 2001. A windows-based GIS-AGNPS interface, Journal of the American Water Resources Association 37, 395-406.
- Johson, R. C.; Imhoff, J. C. and Davis, H. H. 1980. User's Manual of the Hydrologic Simulation Program Fortran (HSPF). Environmental Protection Agency, Technical Report No EPA-600/9/80-015.
- Liao, H.-H. and Tim, U.S. 1997. An interactive modeling environment for non-point source pollution control, Journal of the American Water Resources Association 33, 591-603.
- Srivastava, P.; Day, R.; Robillard, P. and Hamlett, J., 2001. AnnGIS: Integration of GIS and a continuous simulation model for non-point source pollution assessment. Transactions in GIS. 5(3): 221-234.
- Tsou, M.; Misgna, G.; Zhan, X. and et al, 2001. Modeling procedures for using AnnAGNPS Arcview extension. Open-File Report 2001-57, Kansas Geological Survey.
- USDA ARS and NRCS. AGNPS Web Site <http://www.sedlab.olemiss.edu/agnps.html>.
- Wischmeier, W. H. and Smith, D. D. 1978. Predicting rainfall erosion losses. Agriculture Handbook, 537. U. S. Dept. Agr., Washington, D. C.

- Young, R. A.; Onstad, C. A.; Bosch, D. D., and Anderson, W. P. 1987. AGNPS, Agricultural Non-Point-Source Pollution Model: A Watershed Analysis Tool. Conservation Research Report 35 ed. Washington, D.C. U.S. Department of Agriculture, Agricultural Research Service.
- Young, R. A.; Onstad, C. A.; Bosch, D. D., and Anderson, W. P. 1989. AGNPS: A nonpoint-source pollution model for evaluating agricultural watersheds. *Journal of Soil and Water Conservation*. 1989 Mar-1989 Apr 30; 168-172.

Author information

Huaguo Xiao, current Interdisciplinary Ph D student majored in Geosciences and Computer Networking in University of Missouri-Kansas City. Mailing address: Lab for GIS and Remote Sensing, Department of Geosciences, University of Missouri-Kansas City, Rm 420 FH 5110 Rockhill Rd, Kansas City, MO 64110, USA. Tel: 816-2355917, 816-2351334. Fax: 816-2355535. E-mail: hx502@umkc.edu