

HENRY

Hydraulic Engineering Repository

Ein Service der Bundesanstalt für Wasserbau

Conference Paper, Published Version

Ramalingam, V. P.; Singh, J.; Altinakar, M. S.

A Gis-Based Decision Support System for Integrated Management of Agricultural Watersheds

Zur Verfügung gestellt in Kooperation mit/Provided in Cooperation with:
Kuratorium für Forschung im Küsteningenieurwesen (KFKI)

Verfügbar unter/Available at: <https://hdl.handle.net/20.500.11970/109969>

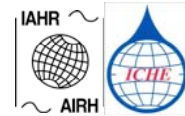
Vorgeschlagene Zitierweise/Suggested citation:

Ramalingam, V. P.; Singh, J.; Altinakar, M. S. (2010): A Gis-Based Decision Support System for Integrated Management of Agricultural Watersheds. In: Sundar, V.; Srinivasan, K.; Murali, K.; Sudheer, K.P. (Hg.): ICHE 2010. Proceedings of the 9th International Conference on Hydro-Science & Engineering, August 2-5, 2010, Chennai, India. Chennai: Indian Institute of Technology Madras.

Standardnutzungsbedingungen/Terms of Use:

Die Dokumente in HENRY stehen unter der Creative Commons Lizenz CC BY 4.0, sofern keine abweichenden Nutzungsbedingungen getroffen wurden. Damit ist sowohl die kommerzielle Nutzung als auch das Teilen, die Weiterbearbeitung und Speicherung erlaubt. Das Verwenden und das Bearbeiten stehen unter der Bedingung der Namensnennung. Im Einzelfall kann eine restriktivere Lizenz gelten; dann gelten abweichend von den obigen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Documents in HENRY are made available under the Creative Commons License CC BY 4.0, if no other license is applicable. Under CC BY 4.0 commercial use and sharing, remixing, transforming, and building upon the material of the work is permitted. In some cases a different, more restrictive license may apply; if applicable the terms of the restrictive license will be binding.



A GIS-BASED DECISION SUPPORT SYSTEM FOR INTEGRATED MANAGEMENT OF AGRICULTURAL WATERSHEDS

Ramalingam V.P.¹, J. Singh² and M.S. Altinakar³

Abstract: *This paper presents a GIS based Decision Support System (DSS) for Integrated Management of Agricultural Watersheds to preserve water quality by optimizing land-use and implementing best management practices. Called DSS-IWM, the decision support system integrates the Annualized Agricultural Non-Point Source Pollution (AnnAGNPS) model for modeling of watershed processes, CCHEID model for simulating flow and transport in the dendritic drainage network, and two separate modules for analyzing the economic and environmental impact of the management scenarios. For a user-defined scenario, the non-point source surface runoff, sediment yield and pollutant quantities computed by the AnnAGNPS model provide the loadings for the CCHEID model that simulates unsteady flow hydrodynamics, sediment transport and stream morphodynamics, and pollutant transport and water quality. The performance of the management scenarios are evaluated based on their economic and environmental impact calculated with economic and environmental modules. This paper will focus on the user-interface aspects of DSS-IWM. Specifically, we discuss the organization of this decision support system, describe how model integration is achieved, review various options available for visualizing results, explain the components considered for performing economic and environmental analysis, and finally demonstrate how management scenarios are compared. Readers are referred to Altinakar et al. (2010) for a case study performed using this system and the description of the economical and environmental modules.*

Keywords: *CCHEID; AnnAGNPS; GIS; Integrated Watershed Management; Best Management Practices; Decision Support System; GUI; VBA.*

INTRODUCTION

The application of Geographical Information System (GIS) in watershed management has grown substantially over the recent years, and a number of GIS-based tools are available for watershed management. The ability of GIS to integrate spatial and non-spatial data makes it a perfect candidate to analyze and understand the watershed process in a holistic manner. The GIS software also offers the possibility to develop and incorporate custom built tools,

1 Research Associate, National Center for Computational Hydroscience and Engineering, University of Mississippi, MS 38677, USA, Email: vitjay@ncche.olemiss.edu

2 Research Scientist, National Center for Computational Hydroscience and Engineering, University of Mississippi, MS 38677, USA, Email: singh@ncche.olemiss.edu

3 Associate Director and Research Professor, National Center for Computational Hydroscience and Engineering, University of Mississippi, MS 38677, USA, Email: Altinakar@ncche.olemiss.edu

interfaces, and complete applications to help watershed managers and decision makers to make informed decisions based on numerical simulation of what-if scenarios.

The Decision Support System (DSS) presented here, DSS-IWM, takes advantage of the features and the flexible environment offered by GIS software. It is built as an extension of the ArcGIS software provided by Environmental Systems and Research Institute (ESRI). Even though there are other GIS-based watershed management systems, the DSS-IWM presented here is the only system to integrate AnnAGNPS and CCHE1D models using GIS, for the purpose of watershed management. The description of AnnAGNPS model can be found in Bingner et al. (2003), and the validation and successful applications of CCHE1D model are described in Wu et al. (1998) and Wang et al. (2002).

The features of DSS-IWM are presented in the following sections. In Section 1 we describe the overall organization and features of this system. Section 2 discusses model integration, best management practice (BMP) options, output options available, and economic and environmental modules. Finally, in Section 3, we describe how alternative management scenarios are compared.

1. ORGANIZATION OF DSS-IWM

The DSS-IWM was developed using Visual Basic for Applications (VBA) language and Arc Objects, for ArcGIS version 9.0 and above. It can be installed and used on any computer with ArcGIS 9.x software and Windows operating system. Figure 1 shows the four principal analysis options available to the user for creating and comparing management scenarios when Decision Support System for Integrated Watershed Management (DSS-IWM) is installed. During setup, the tool creates a parent folder called “DSS-IWM_Scenarios” under C: drive of the computer. All scenarios created by the user are stored under this folder.

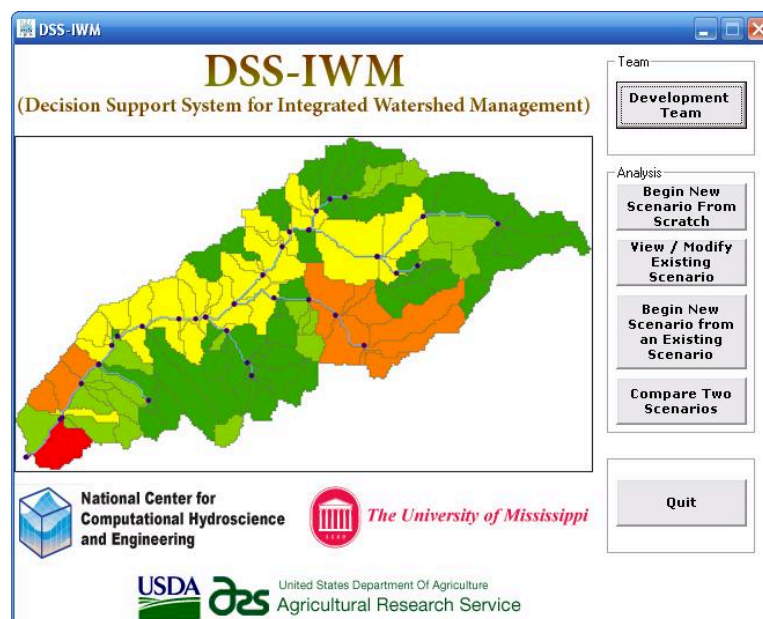


Fig. 1. DSS-IWM window, which provides access to four principal analysis options.

A set of seven input files are required to *Begin New Scenario From Scratch*. The land use and soil maps are available from USDA-NRCS databases. The stream network and subwatersheds are extracted from a digital elevation model (DEM) using TOPAZ in CCHE1D ArcVIEW interface, which also provides the shape files of nodes. A detailed description of the preparation of these data layers can be found in CCHE1D User's Manual (Vieira and Wu, 2002). The AnnAGNPS input data which contains information regarding the soil, land use, crops, field operations, and feedlots is prepared using the input editor of AnnAGNPS. The climate data for the watershed can be generated using the Climate-Data generator (GEM) program (Johnson et al., 2000). The land use text file, created using ArcGIS, contains the representation of subwatershed boundaries in ASCII format. Finally, the CCHE1D input file is created by using the CCHE1D ArcView interface. If water quality needs to be simulated, the initial condition file, background concentration file, water quality parameter file, and output definition file are also required. When all the above files are created for a watershed, the user inputs these files into the tool and initiates a new scenario under a chosen name.

When *Begin New Scenario From Scratch* option is selected, the DSS-IWM automatically creates a new scenario folder under the parent folder, creates a new ArcMap document, and automatically launches ArcGIS. The name of this folder follows the following format: "Scenario_name-iwm-date", and all the input and output files for this scenario, including the newly created ArcMap document, are stored under this folder. Keeping all files under one directory optimizes file management tasks and allows the user to transfer a scenario to any other computer and readily access information. The *View/Modify Existing Scenario* option allows users to select an existing, previously-created ArcMap document for a scenario and continue with the analysis. In this case no new scenario folders are created. The option *Begin New Scenario From An Existing Scenario* allows users to create a new scenario from an existing scenario. Here, a new scenario folder is created according to the new name given by the user, and the contents of the existing scenario are copied in to this newly created folder. The copied ArcMap document is renamed to reflect the newly created scenario. Figure 2 shows the tool-bar structure of DSS-IWM when a scenario is created or reopened.

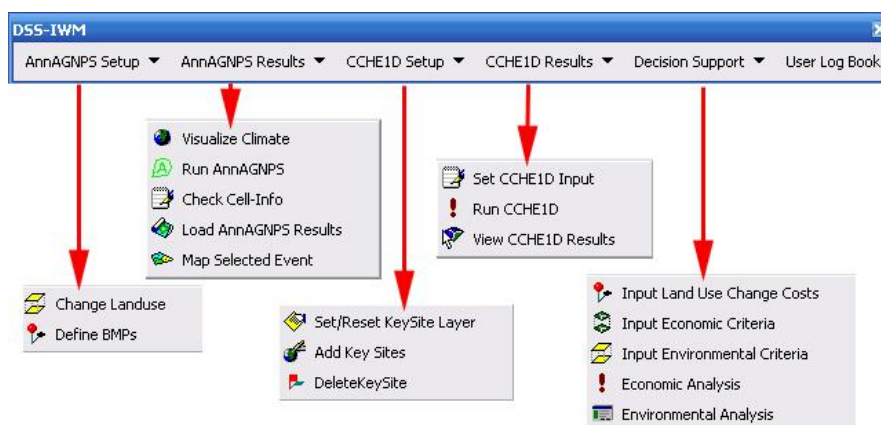


Fig. 2. DSS-IWM tool bar structure.

Finally, when *Compare Two Scenarios* option is selected the user is prompted to select ArcMap documents of two different management scenarios to be compared. A new ArcMap

document is created in a new sub folder with the generic name “Compare_givenname-date-Scenario1Name-Scenario2Name”, which is placed under the parent folder. This contains all the necessary file pointers to input and output files from both scenarios. The details of comparison module will be discussed in Section 4.

2. Coupled Simulation of Watershed and Drainage Network

Figure 3 shows the new ArcMap document that is created and launched for a new scenario. The selected shape files are automatically added to the new ArcMap document. The user creates a new management scenario in this ArcMap document. The shape files shown were delineated using CCHE1D for the Goodwin Creek Experimental Watershed located in the Bluff Hills of the Yazoo River basin in northern Mississippi, USA, which has a surface area of 21.3 km².

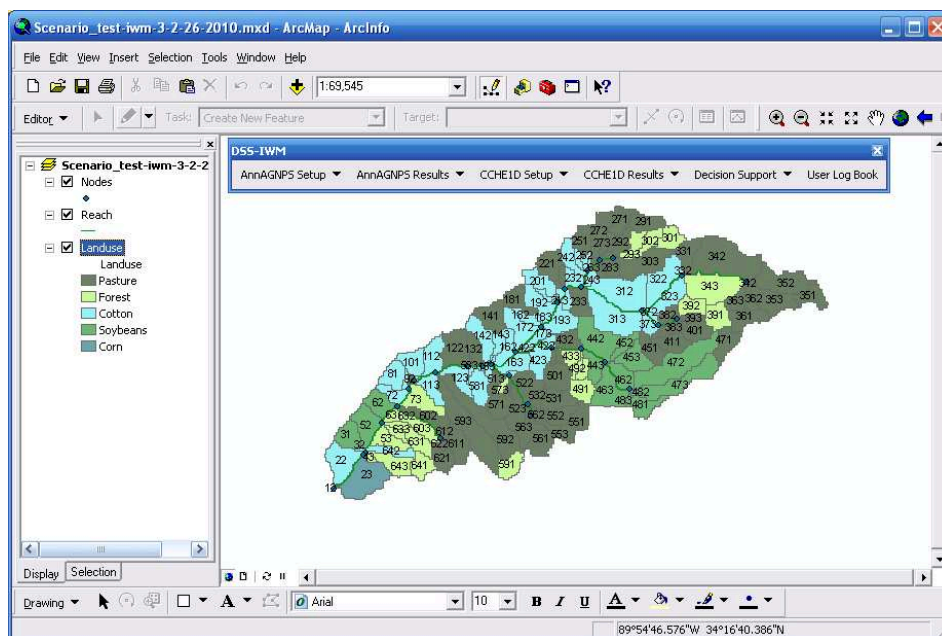


Fig. 3. ArcMap document created for defining/modifying a new scenario.

The coupled simulations of the watershed and the drainage network in response to a specified watershed management scenario are carried out by launching first the AnnAGNPS model, and then CCHE1D model. As mentioned earlier, the AnnAGNPS model output provides the loadings (surface runoff, sediment, nutrients, and agrochemicals) to the nodes of CCHE1D model. Since AnnAGNPS has to be executed first, the tool automatically prohibits users to run CCHE1D code before running AnnAGNPS code. In Sections 2.1 and 2.2 we discuss the options available to the users to create a new scenario.

2.1 AnnAGNPS

A watershed management scenario can be defined by changing the land use of a subwatershed and/or by defining a number of BMPs in a selected subwatershed. These two

options are available under the menu *AnnAGNPS Setup*. To change land use, the user selects one subwatershed and clicks on *Change Landuse* from the menu item shown in Figure 2. The dialog box shown in Figure 4 is displayed to allow the user to select a different land use from the dropdown list, which is automatically populated based on the land-use types available in the AnnAGNPS input file. The land use changes made by the user are updated in the AnnAGNPS input file. The user's actions are displayed under the menu item *User Log Book* from Figure 2 and in the land-use change history at the bottom of the window shown in Figure 4. These enable the user to back track the changes made, if he/she chooses to.

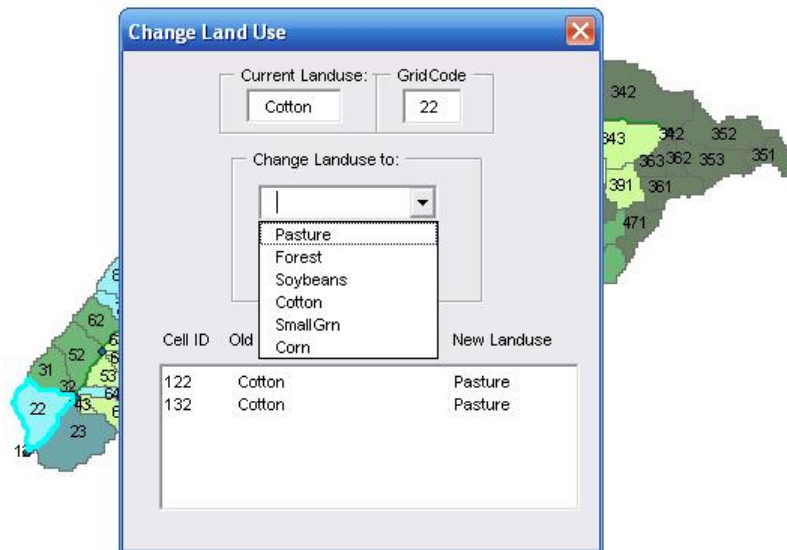


Fig. 4. Land use change options.

To apply one or more BMPs the user selects one subwatershed and clicks on the menu item *Define BMPs*. The user then selects one or more BMPs from the list of ten available BMP types and provides the necessary BMP parameters as shown in Figure 5. Due to the multi-page structure and size of this dialog box, only a limited part of the dialog box is displayed in Figure 5. The available BMPs are Buffer Strips (Riparian Forest Buffer, Riparian Grass Buffer, Tree Planting, and Vegetative Buffer Strips), Off-Stream Watering (Without fencing, With Fencing, Fencing and Rotation grazing), Poultry, Barnyard, and Animal Waste management.

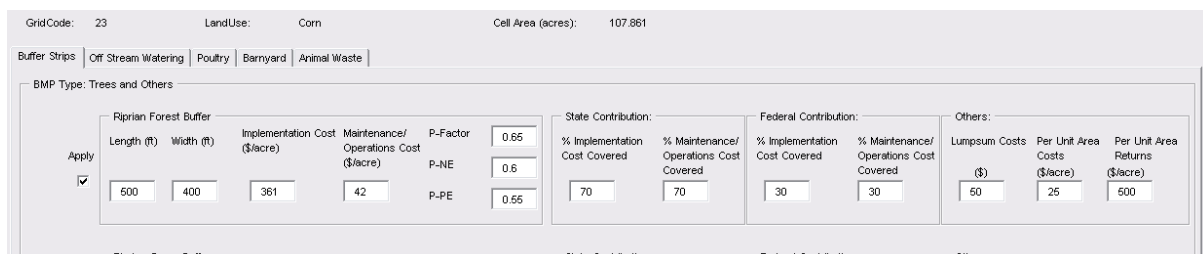


Fig. 5. Best Management Practice options currently available in DSS-IWM.

The BMPs are defined by P-factors (describing the efficiency of BMP; see Bingner et al., 2003), area of BMP, implementation and maintenance costs, state and federal contributions, and other costs. Referring to Figure 5, the P-Factor reflects the overall efficiency, P-NE reflects the total nitrogen reduction efficiency, and P-PE reflects the total phosphorous reduction efficiency. If more than one BMP is applied, the P-Factors are combined and updated in the AnnAGNPS input file. After the user has created a certain management scenario, the AnnAGNPS model is ready to execute. Also, the user defined parameters for BMPs are recorded and displayed in the *User Log Book*.

The results from AnnAGNPS can be visualized in map, chart, or in table format. For example, the menu item *Map Selected Event* allows users to map the minimum, maximum, or the instantaneous values for a selected parameter. Figure 6 shows the dialog box for creating a map, and the map created for the selected parameter. The ability to spatially visualize the results allows users to envision the impact of the new management scenario.

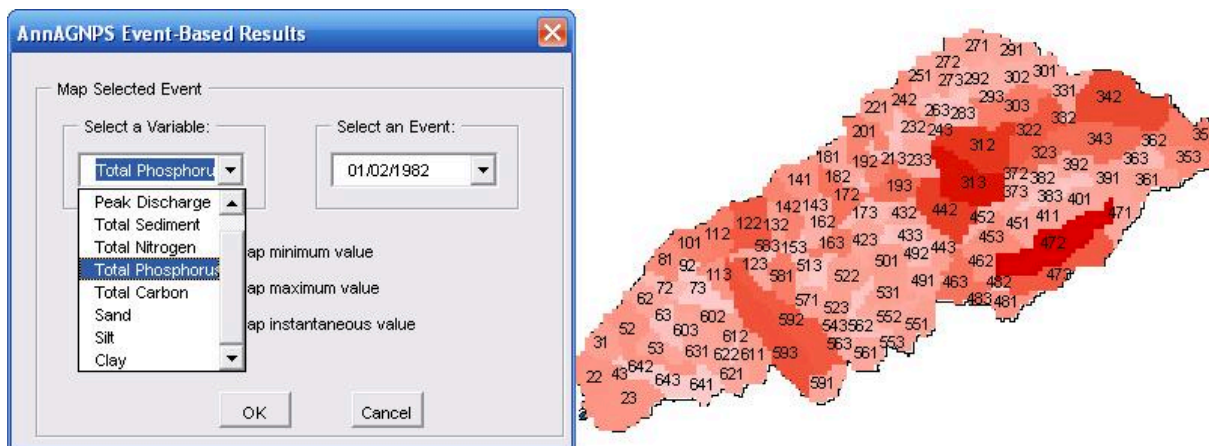


Fig. 6. Dialog box to create maps, and total phosphorus yields displayed in map format.

2.2 CCHE1D

Under *CCHE1D Setup* menu, the user is able to define monitoring points at selected key locations along the stream network where simulation results are recorded as a function of time for further analysis. *CCHE1D Setup* menu is enabled even before executing AnnAGNPS model, and the user is able to define monitoring points before, during, or after the execution of AnnAGNPS, but the user cannot execute CCHE1D model until AnnAGNPS is executed and at least one monitoring point is defined. To define a monitoring point, the user selects a node of the stream network and clicks *Add Key Sites* menu item. All selected monitoring points are displayed in a new point shape file in the current ArcMap document. To remove a monitoring point, the user can select the point and click *Delete Key Site* from the menu item. The dialog box and the node shape file with selected monitoring sites are shown in Figure 7. All user actions regarding the monitoring points are recorded in the *User Log Book*.

After creating monitoring points, the user should *Set CCHE1D Input* as shown in menu item

from Figure 2. When *Set CCHE1D Input* is executed the output files at the outlet of each subwatershed from the AnnAGNPS are changed into the boundary conditions files for the CCHE1D, and the user defined monitoring points are updated for CCHE1D simulation. The menu item *Run CCHE1D* is enabled at this time, and the user is able to launch the execution of CCHE1D model. By selecting *View CCHE1D results* after execution, the results for each monitoring point can be displayed in a chart format as shown in Figure 8. The user can create a chart for a monitoring point, for a selected parameter, and for a specific time range. The results can also be exported to bitmap image format, or text format.

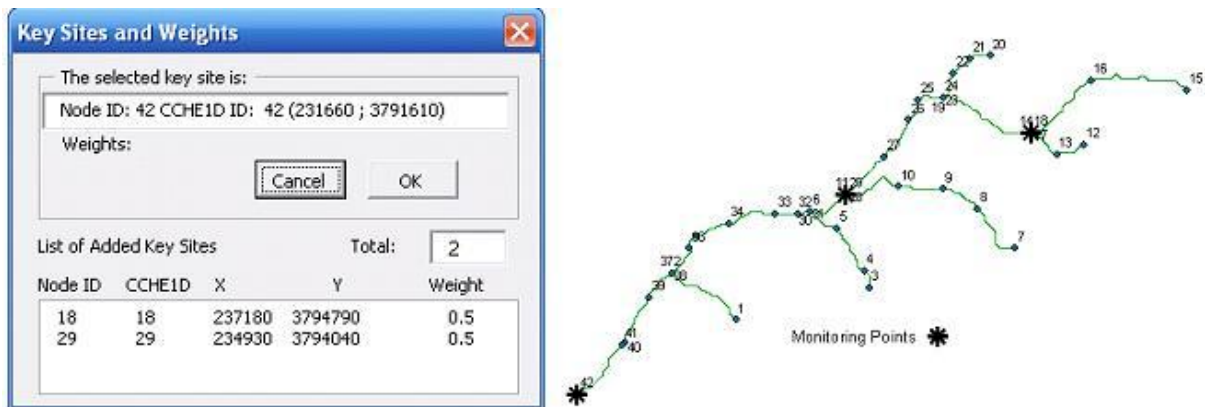


Fig. 7. Dialog box to add key sites and key site nodes in new shape file.

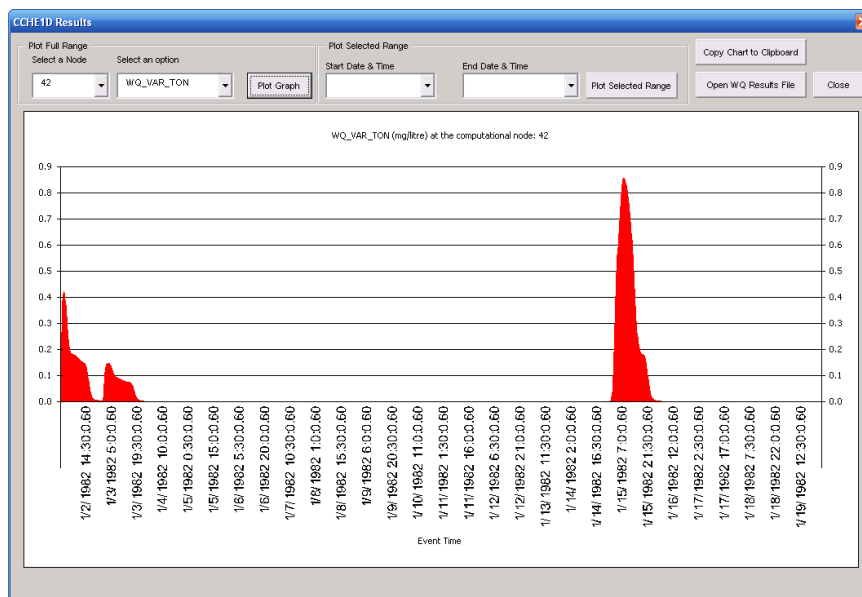


Fig. 8. CCHE1D results in chart format.

3. Economic and Environmental Modules

We describe here how the user is able to perform economic and environmental analysis, and detailed computational procedures of these modules can be found in Altinakar et al. (2010).

The menu item *Decision Support* shown in Figure 2 allows the user to input parameters and perform economic and environmental analysis. The steps involved are discussed next.

3.1. Economic Analysis

The economic analysis module contains an updated version of the module suggested by Qi (2006). To perform economic analysis, the user should enter the land use change costs, and the crop information such as crop type, yield, price, and crop production costs for each subwatershed. The menu items *Input Land Use Change Costs* and *Input Economic Criteria* in Figure 2 is used to define these values. The menu item *Economic Analysis* is enabled after all values are entered. The economic analysis is performed using specified data and the BMP information defined by the user. The economic analysis is designed to capture all important gains, returns, and costs from the point of view of the farmer, state and federal institutions. The analysis computes area, original land use, current land use, land-use change costs, crop area, crop type, crop returns, crop production cost, total BMP area (if applicable), BMP implementation cost, BMP maintenance cost, state contribution in BMP implementation and maintenance cost, federal contribution in BMP implementation and maintenance cost, lump sum cost, per unit cost, per unit return, net return, state cost, federal cost, and other costs for each subwatershed, and also provides a overall summary for the entire watershed. Figure 9 displays the results from the economic analysis when the menu item *Economic Analysis* is selected. The user is able to export these results to spread sheet format, and the land use change costs and crop information are recorded in *User Log Book*.

The screenshot shows a window titled "Economic Analysis" with a sub-header "Economic Analysis for each Subwater Shed". It contains a table with the following columns: Grid Code, Total Cell Area (acres), Orig. Land Use, Curr. Land Use, LU Change Cost(\$), Crop Area (acres), Crop Type, and Crop R. The table lists 23 grid codes with their respective land use and crop information. Below the table is a summary section titled "Economic Analysis for the entire Water Shed:" with a table showing: Total Net Return to Farmer (\$), Total State Costs (\$), Total Federal Costs (\$), and Total Other Costs (\$).

Grid Code	Total Cell Area (acres)	Orig. Land Use	Curr. Land Use	LU Change Cost(\$)	Crop Area (acres)	Crop Type	Crop R.
25	72.278	Cotton	Cotton	0	72.278	corn	
27	157.861	Corn	Corn	0	157.861	Soybeans	
31	43.589	Soybeans	Soybeans	0	43.589	Cotton	
33	2.446	Cotton	Cotton	0	2.446	corn	
35	6.445	Cotton	Cotton	0	6.445	corn	
43	5.782	Forest	Forest	0	5.782	Pasture	
52	60.047	Soybeans	Soybeans	0	60.047	Cotton	
53	36.919	Forest	Forest	0	36.919	Pasture	
62	44.924	Soybeans	Soybeans	0	44.924	Cotton	
63	12.677	Forest	Forest	0	12.677	Pasture	
72	28.911	Cotton	Cotton	0	28.911	corn	
73	52.263	Forest	Forest	0	52.263	Pasture	
81	42.477	Cotton	Cotton	0	42.477	corn	
82	3.114	Cotton	Cotton	0	3.114	corn	
83	3.336	Cotton	Cotton	0	3.336	corn	
92	4.893	Pasture	Pasture	0	4.893	Forest	
93	0.89	Pasture	Pasture	0	0.89	Forest	
101	41.365	Cotton	Cotton	0	41.365	corn	
102	1.234	Cotton	Cotton	0	1.234	corn	
112	52.485	Cotton	Cotton	0	52.485	corn	
113	36.503	Cotton	Cotton	0	36.503	corn	
122	73.613	Cotton	Cotton	0	73.613	corn	
123	36.695	Cotton	Cotton	0	36.695	corn	

Economic Analysis for the entire Water Shed:			
Total Net Return to Farmer (\$)	Total State Costs (\$)	Total Federal Costs (\$)	Total Other Costs (\$)
1460620.191699	1835.169877534	796.501376886	4591.36622

Fig. 9. Economic analysis window.

3.2. Environmental Analysis

The *Environmental Analysis* menu item is enabled when the user defines the upper and lower limits for the water quality parameters to be analyzed using the menu item *Input Environmental Criteria*. With the given lower and upper limits, the analysis can be performed by selecting the menu item *Environmental Analysis* and defining the start date and end date of the period of analysis in the dialog box. Figure 10 displays the results from the

environmental analysis. The results corresponding to different water quality parameters are displayed in separate tabs for all the selected key sites. The results window displays the upper limit, lower limit, starting data, ending date, total loading, total amount above the upper limit, total amount within the lower and higher limits and their percentages. The user is also able to export the results to spread sheet format.

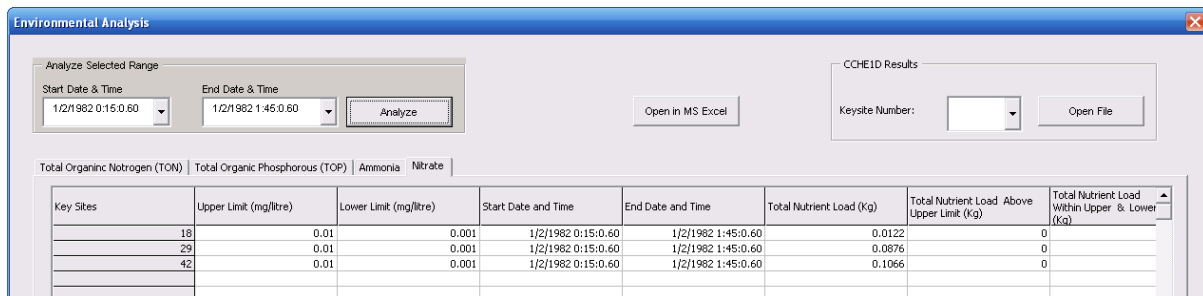


Fig. 10. Environmental analysis window.

4. Comparing Scenarios

The DSS-IWM allows the user to compare results of a pair of previously analyzed watershed management scenarios, one against the other, in order to select the best one. The scenario comparison module is launched by clicking the *Compare Two Scenarios* button on the main dialog box shown in Figure 1. This launches the module for comparing scenarios as discussed in Section 1, and the new ArcMap document displays the *DSS-IWM Compare* tool bar shown in Figure 11.

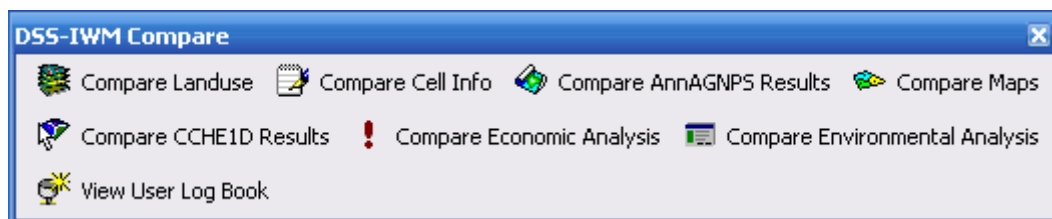


Fig 11. DSS-IWM Compare tool bar.

The menu items *Compare Land Use* and *Compare Maps* will both generate two map layers displaying the results, one for each scenario. The user can toggle between these two maps to see the differences. The menu item *Compare AnnAGNPS Results* will create two charts of time series of a selected result in the same window, each showing the results for a user selected subwatershed from one of the scenarios. The menu item *Compare Cell Info* shows AnnAGNPS results in table format from two scenarios, in two different tabs. The *Compare CCHEID Results* will display results similar to Figure 8, but contains two separate tabs corresponding to the two different scenarios. The menu items *Compare Economic Analysis*, *Compare Environmental Analysis*, and *View User Log Book* are displayed in different windows, with separate tabs in each window corresponding to different scenarios.

CONCLUSIONS

The DSS-IWM tool can be used to analyze any small to medium size agricultural watersheds. It provides the user with a user-friendly, decision-making platform to easily set up watershed scenarios by changing land uses and/or installing BMPs, and to analyze their outcome based on coupled numerical simulations of watershed and the drainage network using AnnAGNPS and CCHE1D, respectively. Developed within the framework of ArcGIS software from ESRI, the custom built graphical user interface (GUI) provides methods to change input parameters, view the results in different formats, and export results to different formats in a user friendly fashion. This system can be used by watershed managers and decision makers, who are not necessarily specialized in watershed and channel network modeling, but have a good understanding of watershed processes. By defining and testing various watershed management scenarios, or by modifying a pair of existing AnnAGNPS and CCHE1D input files, users can quickly create several scenarios, compare their outcomes, and make decisions to select the most optimum one. DSS-IWM can also be used for Total Maximum Daily Load (TMDL) analysis.

ACKNOWLEDGEMENTS

This work is part of the research project sponsored by the USDA-ARS Specific Research Agreement 58-6408-7-236 (monitored by the USDA-ARS National Sedimentation Laboratory) and the University of Mississippi.

REFERENCES

- Altinakar, M.S., Singh, J., Ramalingam, V.P., Sadeghi, A.M., McCarty, G.W., Hively, D. and Sexton, A.M. 2010. Integration of Watershed model AnnAGNPS and Stream Network model CCHE1D for the development of a new GIS-Based BMP Planning Tool. World Environmental & Water Resources, Providence, Rhode Island, May 16-20, 2010.
- Bingner, R.L., Theurer, F.D., and Yuan, Y. 2003. AnnAGNPS Technical Processes (Version 3.3), USDA-ARS National Sedimentation Laboratory, Oxford, MS 38655.
- Johnson, G.L., Daly, C., Taylor G.H., and Hanson, C.L. 2000. Spatial Variability and Interpolation of Stochastic Weather Simulation Model Parameters. *J. Appl. Meteor.*, 39, 778-796.
- Qi, H. 2006. "Integrated Watershed Management and Agricultural Land-use Optimization under Uncertainty", Ph.D. Thesis, the University of Mississippi, MS.
- Vieira, D.A.N., and Wu, W. 2002. One-dimensional Channel Network Model CCHE1D Version 3.0 – User's Manual. National Center for Computational Hydroscience and Engineering, University of Mississippi, Oxford, MS.
- Wang, S.S.Y., Wu, W., Hsia, H.M., and Cheng, C.C. 2002. Simulation of Flood and Sediment Routing in Ping-Chang River and Pu-Tze River of Taiwan Using CCHE1D Model. *Proceedings of the Fifth International Conference on Hydroscience and Engineering*, Warsaw, Poland.
- Wu, W., Vieira, D.A.N., and Wang, S.S.Y. New Capabilities of the CCHE1D Channel Network Models", *Proceedings of ASCE's Joint Conference on Water Resources Engineering and Water Resources Planning and Management*, Minneapolis, MN, 1998.