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WaterBase: Open Source Software for Integrated Water Resources Management

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Abstract

Water resources management is of increasing importance everywhere, as water demands increase, while its quantity and quality is constantly threatened. Environmental modeling has proven very effective in assisting management decisions, but it needs well trained people, good sound tools, and outputs that can be explained effectively to the people and communities involved. The WaterBase project aims to support integrated water resources management, particularly but not exclusively in developing countries, by providing (a) free, open source tools, (b) resources such as data, case studies, and training material, and (c) a community of people to assist each other and share experience. Tools produced so far are based on the river basin modeling tool SWAT. MWSWAT is an interface between SWAT and the open source GIS MapWindow, and is specifically designed to use freely available GIS data for anywhere in the world, as well as local data when available. SWATPlot and SWATGraph are a pair of tools supporting the rapid extraction and display of results from SWAT. Tools are open source, so as well as being free they are adaptable by anyone. They may be extended, or easily translatable to languages other than the original English.

Keywords: integrated water resources management, WaterBase, SWAT

1 Introduction

The WaterBase project (http://www.waterbase.org) of the United Nations University is aimed in particular, though not exclusively, at developing countries. Predictive modelling and decision support for water management in developing countries are plagued with a number of related problems such as: lack of money, lack of expertise, inadequate training capacity, and dependence on experts from other countries. At the same time water resources are under increasing pressure and aquatic ecosystems are being damaged by actions of people who lack the resources to explore the consequences of decisions before they are made. WaterBase aims to improve this situation by providing (a) tools for decision support, (b) resources such as web sites, documentation, training material, and case studies, and (c) a community of partners who can advise and support other partners, and who can contribute to the tools and resources.

2 Open source software

Software is considered open source once it complies with the following characteristics (OSI, 2008):

1. The source code of the product is available.
2. The licence allows unlimited redistribution of the product .
3. The licence permits the creation of license-free derived work.
4. The licence does not limit how, where or by whom the product can be used .

These characteristics make it free in the sense of not costing anything, and also free in the ways that you can use it, adapt it or extend it. Free of cost is the most obvious characteristic, and perhaps the most important for many people, but the freedom from license restrictions, and its consequences, are also very important:

1. It prevents *vendor lock-in*. If you buy proprietary software from a company, it can be difficult to break the connection with the company (the *vendor*). Changing to a different product will cost money not only for the product but also in training and data migration. If the company produces a new version (and they will - that is how they stay in business) you have to pay for it or find and change to an alternative. If you need new features you have to persuade the company to provide them, and pay, or else, again, find an alternative. Changing to a new open source product has the same problems of retraining and data migration (in part - see below) but is less likely to be necessary. Open source software is generally very responsive to user feedback, but also provides you with the alternative of changing or extending it yourself. You might achieve this personally, or with the help of colleagues, or even by hiring someone to do it for you.
2. Open source software generally uses and supports open standards. This makes it easier to interoperate between applications, and makes it easier to migrate data if you need to. (For open standards relevant to GIS, see the Open Geospatial Consortium (OGC, 2008).)
3. You get free support too. The free software movement operates to a large extent through networks of people who continuously interact on the internet. There is a regular exchange of requests for help or information and answers to those requests. (This also happens for proprietary software, but not to the same extent.)
4. It is reliable. This is perhaps surprising, but true. The code is read by a lot of people, and bugs get fixed quickly. The open source Apache is the most popular web server across the world, and regularly shows as the most reliable. (http://www.netcraft.com).
5. Total costs of ownership are lower, especially in developing countries. Total cost of ownership for software includes the indirect costs of installation, maintenance, training and administration. Whereas licence costs typically reflect North American or European prices, indirect costs reflect local prices.

There are also some dangers of open source software:

1. Proliferation of competing versions
2. Poor documentation
3. Projects can start in a flurry of enthusiasm and soon disappear
4. The software is written by experts and can be difficult for non-experts to use

These problems can be guarded against by careful selection of what software you use: only some open source projects suffer from them. WaterBase certainly tries to void them. In particular it places emphasis on good documentation and on well-designed, intuitive interfaces.

3 MWSWAT

The WaterBase project's first tool is MWSWAT, an interface to SWAT using the open source GIS system MapWindow. In overall functionality it is close to, and essentially replaces, ArcSWAT.

There are a number of open source GIS systems available (OS GIS, 2005). WaterBase eventually chose MapWindow (http://www.mapwindow.com) for three reasons. First, and critical when choosing any open source project, it was under active development. Second, unlike most open source projects, it is native to Microsoft Windows, which is the operating system we expect most of our users to be currently using and accustomed to. Third, it had just been chosen by the Environmental Protection Agency (EPA) in the US as the basis for version 4 of BASINS (EPA-Basins, 2005), which gave us confidence in its future support. There were also technical issues to be considered, such as whether MapWindow, could support watershed delineation, and how easy it was to write an extension for it, but technical problems can often be overcome, while the basic issue of whether your chosen GIS system will still be available and supported in 5 years time is the most important issue.

As it happens, MapWindow does have a watershed delineation tool, using the Taudem software (Tarboton and Ames, 2001). In fact Taudem's use of the *Dinf* approach to slope directions, instead of the normal *D8*, promised better watershed delineation than found in the current ArcSWAT interface. MapWindow is also intended to be extensible through the use of "plug-in" architecture, so it was in fact technically suitable. So an interface for setting up SWAT was created based on MapWindow, and called MWSWAT.

4 Data sources

There is a considerable amount of data available on the web, and MWSWAT was designed from the start to take advantage of that. In particular it is delivered along with global data:

1. DEM maps: SRTM project (SRTM, 2004).
2. Land: Global Land Cover Facility (Hansen et al,1998).
3. Soil maps: FAO (FAO/UNESCO, 2003).
4. Precipitation and temperature data (NCDC, 2005).

The increasing availability of such data opens a number of possibilities for its exploitation beyond water resource management. Additionally, users should not be restricted to such data, because where local data exists it will generally be finer grained and more accurate. But at the same time they should not be prevented from doing some simulations even when there is no local data.

5 Design philosophy

Setting up a SWAT run is complicated. Generating a thousand input files is not unusual, and so there are a vast number of parameters to consider. The user can therefore easily get lost in the process, and we need to keep a balance between simplicity of the interface and access to everything the user might need to see and perhaps change. The first priority is therefore to try to create a simple model of the process that the users may have in their minds. We based the interface around three basic steps:

1. Watershed delineation.
2. HRU definition
3. SWAT setup and run

The main form just before Step 3 is illustrated in Figure 1.

Figure 1: MWSWAT Main Form

6 Watershed delineation

Watershed delineation uses a plug-in included in MapWindow. First the digital elevation (DEM) is chosen, and options to burn in existing streams, and/or to use a mask for the watershed, may be selected. Then the threshold (minimum area to be designated as drainage for a stream) is chosen. Finally outlets and inlets are selected, either from an existing shapefile, or by creating one interactively.

After the watershed delineation process is completed, all the layers are displayed in the MapWindow view A delineated watershed is illustrated in Figure 2 with all the subwatershed notation in place.

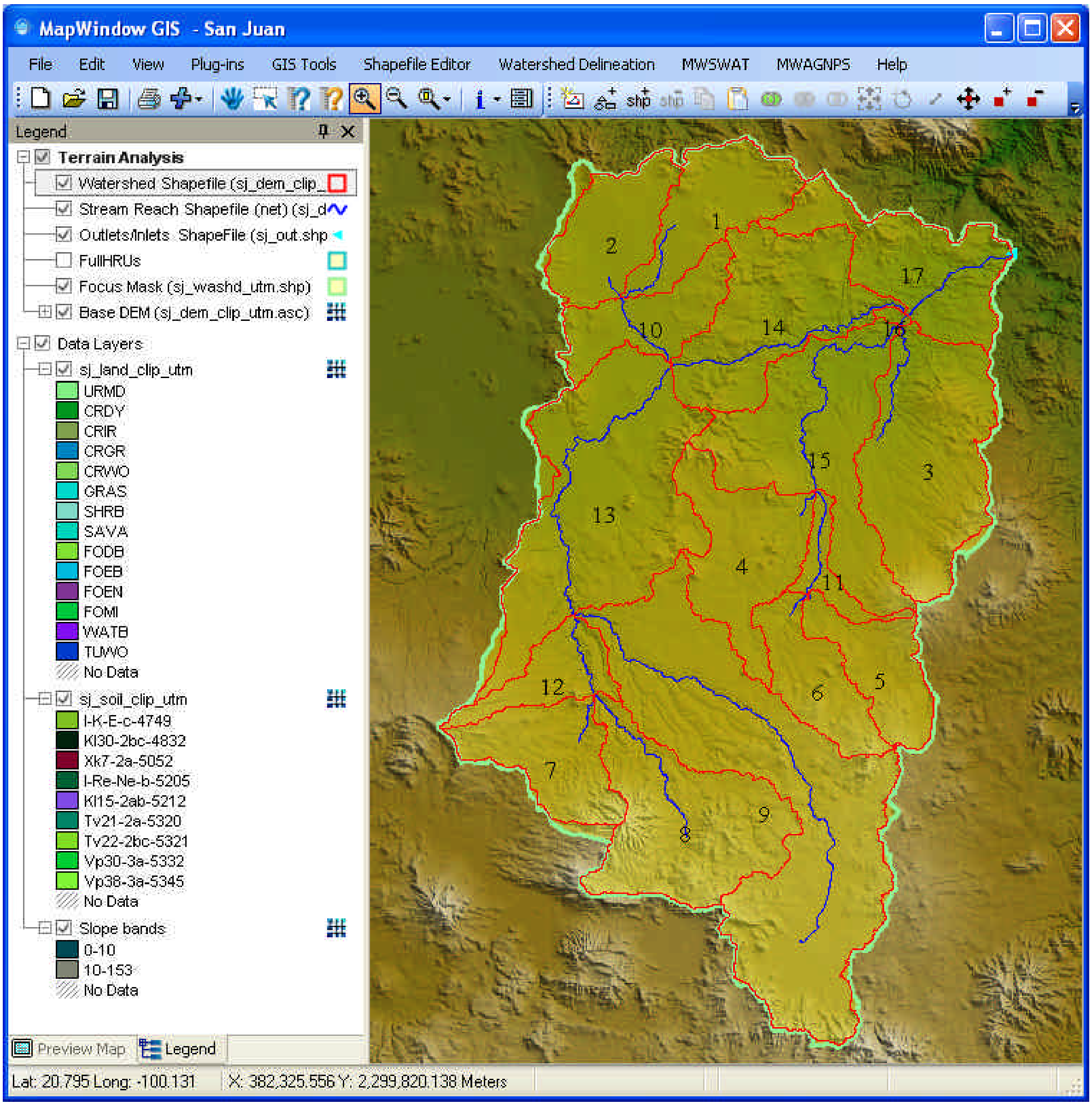

Figure 2: Delineated Watershed

7 HRU creation

SWAT uses the Hydrological Response Units (HRUs) as the basis for its modeling. HRUs may be formed per sub-basin (where a sub-basin is the area that drains into a reach of the stream network), or as a division of a sub-basin based on a particular combination of landuse, soil, and slope range. The Create HRUs form allows users to first select the landuse and soil maps, together with database tables (lookup tables), which relate the categories used in these maps to SWAT landuse and soil categories.

Then users can select intermediate slope percentages so as to form bands of slopes. At this point the maps are read. Then the user can choose singe HRUs (i.e. one per sub-basin) or multiple HRUs. In the second case the user removes small HRUs, either by a selecting a minimum area, or by selecting minimal percentages for landuse, soil and slope. Users may optionally subdivide landuses into others, and may choose to exempt some landuses from the thresholds.

8 SWAT Setup and run

The final step is to read the meteorological data, write the SWAT files in the proper format and run the model. The SWAT Setup and Run form allows the user to select weather sources (currently weather stations, plus precipitation and temperature gauges), to choose the period of simulation, and make a number of other choices.

Users can also choose to make detailed edits to the input files using the SWAT Editor, can run SWAT itself, and can save the output from the latest SWAT run. In brief, this form is the main control of the model itself. It is fully based on the current SWAT development and if required can be modified to keep pace with future changes.

9 Displaying SWAT output

Decision support is a vital component of any modeling system, and a first step is convenient extraction and display of data. SWATPlot is a tool that allows users to select (a) a SWAT run (b) an output file (reach, hru, basin, or water) (c) a sub-basin or hru and (d) a variable for display. Each such selection constitutes a *plot*. Several such plots may be selected, along with sets of observed data covering the same period as the SWAT runs, each set forming another plot. The plots may then be saved (for future use or further analysis) and displayed in a tool SWATGraph, each plot forming a line in a graph or columns in a histogram. Thus comparisons of different runs, or of model outputs against observed data, can be accomplished with a few mouse clicks. SWATPlot is shown in Figure 3 and a display from SWATGraph in Figure 4.

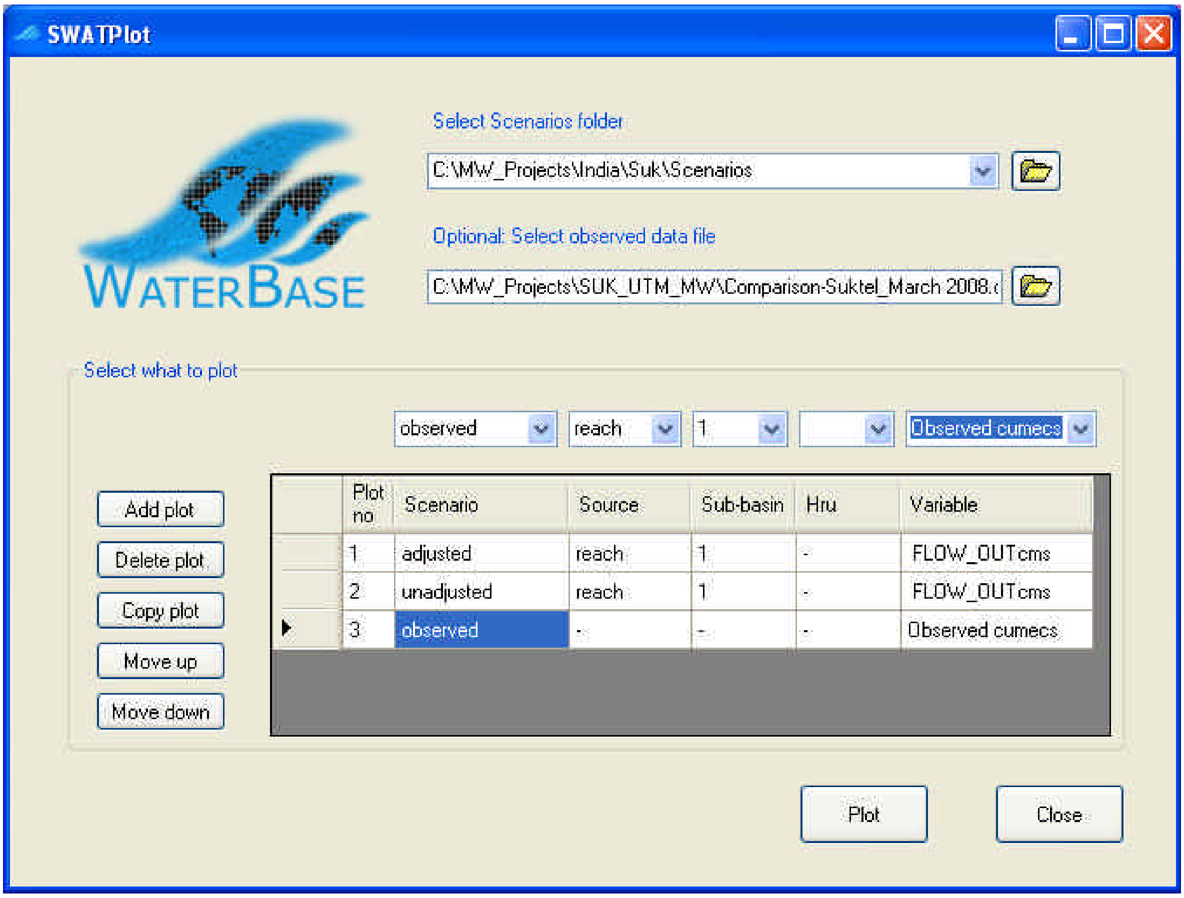

Figure 3: SWATPlot

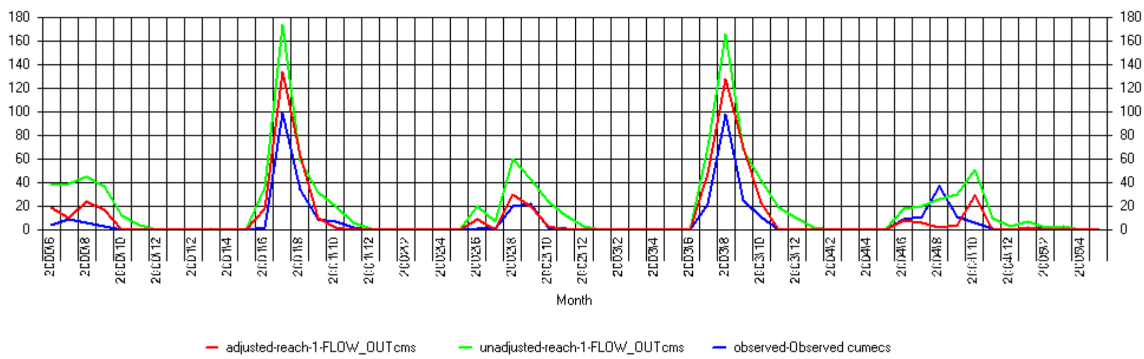

Figure 4: SWATGraph Display

10 Conclusions and further work

MWSWAT has been available since December 2007. SWATPlot and SWATGraph were added in mid-2008. Immediate technical plans are the support for the event-based model AGNPS, which can model the effect of storms, and for more decision support, such as sub-basins coloured according to user-chosen characteristics such as sediment output.

MWSWAT is the first of, we hope, many tools to support IWRM. A concurrent objective is to form a community of partners who are interested in using and/or contributing tools and other resources to the project. Partner organizations may be government departments, universities and research institutes, or even private companies. In particular partners can provide requirements for new tools and extensions or changes to existing ones. The existence of an active collection of users and developers will also be a critical factor in finding donor organizations to support the project financially. As a step towards this the Google group waterbase (http://www.google.com/groups/waterbase) has been established.

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