CHAPTER 4

WOCAT: A STANDARD METHODOLOGY FOR DOCUMENTING AND EVALUATING SOIL AND WATER CONSERVATION

Godert W.J. van Lynden
ISRIC World Soil Information, Wageningen, The Netherlands

Hanspeter Liniger,
Centre for Development and Environment, Institute of Geography, Bern, Switzerland

INTRODUCTION

The World Overview of Conservation Approaches and Technologies (WOCAT) programme was started in 1992 by a group of soil and water conservation specialists. It has since developed a global network of institutions and individuals involved in soil and water conservation (SWC). WOCAT's mission is to provide tools that enable soil and water conservation specialists to share their professional knowledge. Such tools can help them to identify appropriate technologies and approaches and support them in field planning and implementation.

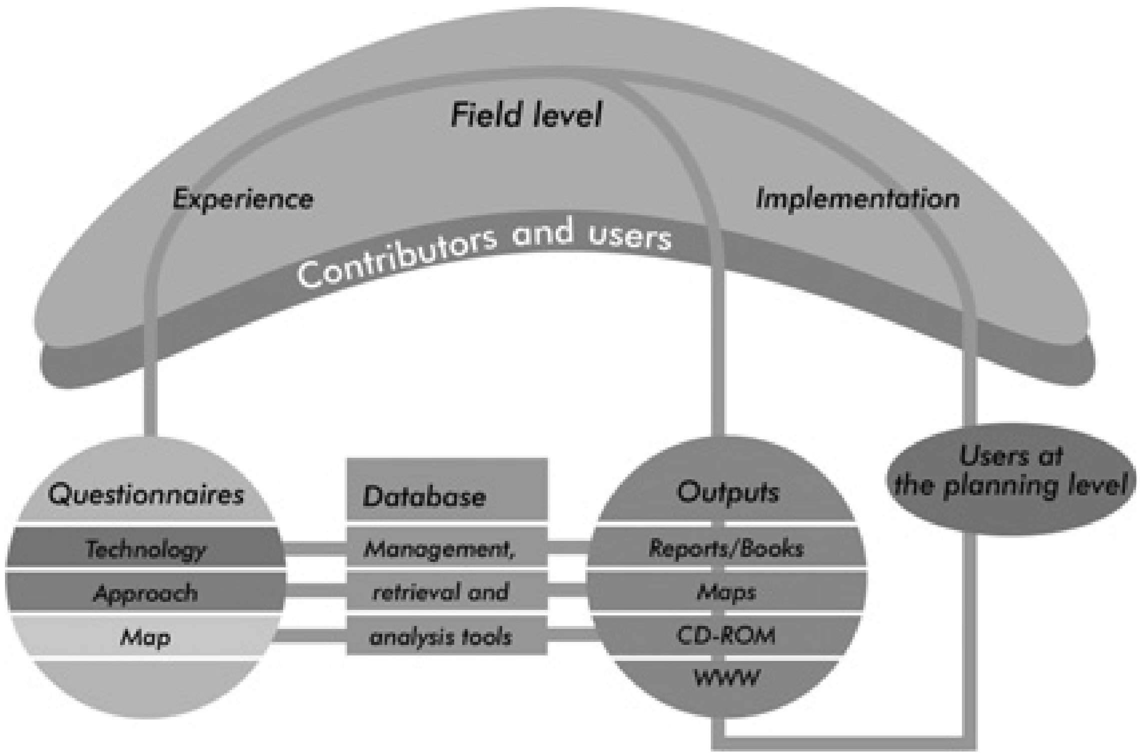
WOCAT is a global network of soil and water conservation specialists. It is organized as an international consortium coordinated by an international management group, and is supported by a secretariat based at the Centre for Development and Environment, Bern, Switzerland. A wide range of international and donor organizations in the field of sustainable agriculture and environment are represented in the network. These include FAO, ICIMOD, United Nations Environment Programme (UNEP), the Swiss Agency for Development Cooperation (SDC), DANIDA, the International Atomic Energy Agency (IAEA), the Regional Land Management Unit (RELMA) and national partner institutions in more than 35 countries. The latter consist of government departments, universities and NGOs. Recently, collaboration has started with commercial companies; a prominent one being Syngenta, the United Kingdom.

Although much is known about soil and watershed conservation, this knowledge tends to be scattered and not easily accessible. This is recognized as one of the reasons why soil degradation continues in many parts of the world, despite decades-long efforts and large investments in soil and watershed conservation. WOCAT is contributing to overcoming this problem by documenting and disseminating knowledge. The aim is to enable practitioners to learn from each others' experiences and to provide a source of reliable information over many geographic and subject areas. The information gathered helps to identify research needs and suggests how ongoing practices can be improved.

METHODOLOGY

WOCAT has developed a set of three comprehensive questionnaires to capture information about soil and water conservation technologies and field-level approaches. The questionnaires are quite complex and so WOCAT runs training courses to show how to use them and the associated database. Participation in these training courses leads on to identifying what data trainees will collect to contribute to WOCAT.

FIGURE 1
The WOCAT process



The three types of questionnaires cover technology, approaches and mapping. These questionnaires are the main tools for collecting, recording and analysing data in a systematic and standardized manner. The technologies questionnaire asks about field activities. Technologies may be technically ideal but their successful implementation often depends on a wide range of non-technical issues. The approaches questionnaire therefore asks about factors such as required skills and technical knowledge, required and available resources, socio-economic and cultural aspects, and perceptions and acceptance by land users. The standard WOCAT definitions of important terms are given in Box 1.

Patterns of soil degradation vary at all spatial levels from the village to the global scale. The map questionnaires are designed to gather geographic information. They ask about planning issues and aim to build up a spatial overview of degradation and conservation in defined areas. This questionnaire complements the technologies and approaches questionnaires.

Responses to the mapping questionnaire show that although patterns of degradation have been mapped in many areas, there are hardly any maps on conservation achievements. Such maps are needed to identify where soil and watershed conservation measures have been effective and where they are most needed and could be effectively implemented.

BOX 1

WOCAT DEFINITIONS

Soil and water conservation (SWC) refers to local-level activities that maintain or enhance the productive capacity of the land in areas affected by, or prone to, degradation. These include activities that prevent or reduce soil erosion, compaction and salinity; conserve or drain soil water; and maintain or improve soil fertility. The WOCAT methodology was originally designed to focus mainly on soil erosion and fertility decline in erosion-prone areas. Since then it has evolved to cover other types of land degradation, such as salinization and compaction.

SWC technologies are agronomic, vegetative, structural and management measures that control land degradation and enhance productivity in the field.

SWC approaches are ways and means of support that help to introduce, implement, adapt and apply SWC technologies on the ground.

Source: WOCAT questionnaires (WOCAT, 2003a; 2003b; 2003c).

The information gathered from the questionnaires is entered into a database. WOCAT's database now includes more than 300 technology case studies and more than 200 approaches from 40 countries (some of which have still to be completed and validated). The information can then be fed back in various forms to users at the field or planning levels.

WOCAT has gathered information from more than 35 countries. It has collected most information from Africa (60 percent) and Asia (30 percent), and only a few case studies from Latin America. It has recently started to gather information from Europe. The database mainly comprises individual case studies. Efforts are under way to collect a number of these case studies into a synthesized and generalized description of specific technologies and approaches.

The WOCAT methodology has been tested and developed based on the needs and requests of collaborating institutions – most of whom are WOCAT users. Participants at national and regional workshops have evaluated the practicality and usefulness of WOCAT's questionnaires, database and outputs. The methodology has been tested and revised continuously since the first questionnaires were developed in 1994. Since 1998, the emphasis has been on collecting and using the data. The more than 30 national training workshops that have been held since 1999 have confirmed that the current questionnaires serve their purposes well, although some collaborators feel they are too complex.

USES OF WOCAT

WOCAT disseminates its information via its Web site, on CD-ROMs, in articles and at workshops. All of WOCAT's tools, data and outputs are accessible via the Internet at www.wocat.net. The database can be searched for a specific technology or approach or for specific conditions in which these are applied. Another facility enables a technology or approach to be evaluated. Some of the information is presented as case studies on soil and water conservation technologies and approaches gathered by WOCAT. It has produced CD-ROMs that contain much of the information from the Web site, including the database, questionnaires, published reports and general information. WOCAT-related articles and papers include Liniger and Schwilch, 2002; Liniger, van Lynden and Schwilch, 2002; Liniger *et al.,* 2002; and van Lynden, Liniger and Schwilch, 2002.

WOCAT is consolidating information by subject and area to make it more useful and accessible for planning exercises and in the field. It held its first regional training workshop in Kenya in 1995. Since then it has trained more than 400 experts in Africa, Asia and Europe to document and evaluate their knowledge. WOCAT questionnaires offer experts, technicians and extension workers a common framework and methodology for documenting and evaluating their experiences. Filling in the questionnaires encourages practitioners to analyse their achievements. The information gathered by WOCAT provides higher-level decision-makers such as planners and coordinating organizations with an overview of achievements, approaches and technologies.

The WOCAT tools and processes are being used by government departments, project staff, scientists and extension workers from across the world to help:

- monitor and evaluate individual technologies and approaches, and quantify costs and benefits;
- document, identify and transfer technologies and approaches from one area to another;
- identify key topics and gaps in the knowledge that need further research;
- evaluate the results of research trials, and assess the biophysical and socio-economic suitability of research-derived technologies and approaches; and
- disseminate information for use as an educational data resource.

The main rationale for WOCAT is that the information it gathers is put to good use. It aims to promote the increased use of its information for extension, research and educational purposes. The fundamental requirement for this is that WOCAT has a volume of good-quality up-to-date information that has been checked and entered into its database. The next need is to link national and regional WOCAT activities with ongoing and potential government-, donor- and NGO-supported projects and programmes at all levels. Thirdly, WOCAT needs to tap the skills and knowledge of people and organizations involved in soil conservation and watershed management and help them to obtain technical and financial support to carry out their work. Finally WOCAT needs to broaden the common perception of its role, from being a questionnaire-filling process to being a field appraisal tool that enables research and extension workers to determine the environmental impact and socio-economic costs and benefits of technologies and approaches. WOCAT's strengths and weaknesses are listed in Box 2.

BOX 2

WOCAT'S STRENGTHS AND WEAKNESSES

Strengths:

- works at the field, national and global levels;
- considers both socio-economic and ecological aspects;
- fills a gap (nationally and globally) for the documentation and exchange of information;
- sets global standards for methods, tools and outputs;
- brings practitioners, researchers and planners together;
- provides tools and a platform for collecting a standard set of comparable information.

Weaknesses:

- questionnaires are quite complicated and some practitioners have difficulties in responding fully;
- low quality of some data.

DATA QUALITY

One of WOCAT's main concerns is the quality of the data it collects. One problem is that it is often difficult to tell whether incompletely filled questionnaires show important gaps in the data or just reflect a respondent not bothering to reply. A study on the potential for improving the data (Douglas, 2003) suggested that WOCAT should focus less on the correct filling in of questionnaires and more on providing specialists with the skills to evaluate the impacts and cost-effectiveness of their own activities. However, collecting the available data through questionnaires is an intrinsic part of this evaluation process.

Improving the quality of data received demands that respondents are more critical about their own knowledge, and that they fill in questionnaires properly. Respondents need to:

- review their knowledge and experience of technologies and approaches critically and systematically;
- recognize and challenge their technical preconceptions and biases, which often lead to wrong assumptions about problems and the effectiveness of technologies or approaches;
- avoid assuming that a technology or approach being implemented automatically means that land degradation is being controlled; and
- have a proper understanding of how land degradation processes operate under specific local conditions.

While filling in questionnaires, respondents should take care to:

- complete them in close consultation with other experts;
- undertake field verification and discussions with land users;
- provide detailed descriptions specific to the technology being documented, rather than generalized descriptions that could apply to similar technologies;
- give adequate details of technical specifications that explain how a technology performs;
- differentiate between the characteristics of the wider area in which the users of a technology are operating and the conditions specific to sites where technologies have been adopted;
- provide detailed cost breakdowns, as omitting key cost elements will give a false impression by underestimating actual costs; and

- make use of secondary data from project documents and technical manuals to document and check technical specifications and costs and benefits of particular technologies and approaches.

CONCLUSION

WOCAT is the first large-scale attempt to document soil conservation and watershed management activities in a standardized way. It enables the comparison, evaluation and mapping of technologies and approaches. The comprehensive questionnaires encourage users and contributors to take a more inclusive attitude towards their work. The main challenge is for the information collected to be widely used in the field and for planning purposes.

REFERENCES

Douglas, M.G. 2003. Improving WOCAT data quality – some observations and suggestions. In *Proceedings of the Eighth International Annual Workshop and Steering Meeting (WWSM8), 4-8 November 2003, Kathmandu, Nepal.* Bern, Centre for Development and Environment.

Liniger, H.P. & Schwilch, G. 2002. Better decision-making based on local knowledge – WOCAT method for sustainable soil and water management. *Mountain Research and Development Journal*, 22(1).

Liniger, H.P., van Lynden, G.W.J. & Schwilch, G. 2002. Documenting field knowledge for better land management decisions – experiences with WOCAT tools in local, national and global programs. *Proceedings of ISCO Conference 2002, Vol. I,* pp. 259–167. Beijing.

Liniger, H.P., Cahill, D., Thomas, D.B., van Lynden, G.W.J. & Schwilch, G. 2002. Categorisation of SWC technologies and approaches – a global need? *Proceedings of ISCO Conference 2002, Vol. III*, pp. 6–12. Beijing.

Van Lynden, G.W.J., Liniger, H.P. & Schwilch, G. 2002. The WOCAT map methodology, a standardised tool for mapping degradation and conservation. *Proceedings of ISCO Conference 2002, Vol. IV*, pp. 11–16. Beijing.

WOCAT. 2003a. *Questionnaire on SWC technologies. A framework for the evaluation of soil and water conservation (revised).* Bern, Centre for Development and Environment, Institute of Geography, University of Bern.

WOCAT. 2003b. *Questionnaire on SWC approaches. A framework for the evaluation of soil and water conservation (revised).* Bern, Centre for Development and Environment, Institute of Geography, University of Bern.

WOCAT. 2003c. *Questionnaire on the SWC map. A framework for the evaluation of soil and water conservation..* Bern, Centre for Development and Environment, Institute of Geography, University of Bern.

WOCAT. 2003d. *Proceedings of the Eighth International Workshop and Steering Meeting*; WOCAT October 2003, Kathmandu. Bern, Centre for Development and Environment.

CHAPTER 5

NEW TECHNOLOGIES FOR WATERSHED MANAGEMENT

Ashvin K. Gosain
Indian Institute of Technology, Delhi; Sandhya Rao, INRM Consultants, New Delhi

Ian R. Calder
Centre for Land and Water Resources Research, University of Newcastle,
Newcastle upon Tyne, United Kingdom

INTRODUCTION

A complex of factors determines the quality and availability of water supplies from watershed areas. The integrated watershed management approach goes a long way towards handling these complexities, and in many situations is accepted as the best approach to managing natural resource (Calder; 1998; 1999).

In India, policies have been developed and programmes run to address water problems in ways that promote equity and sustainability and alleviate poverty. Water resource management projects have ranged from major irrigation projects catering to millions of hectares of land, to small structures fulfilling the needs of one small community. Countrywide programmes have included the Drought-Prone Area Programme (DPAP), the Desert Development Programme (DDP) and the Integrated Watershed Development Programme (IWDP). Some of these programmes are still being implemented, but it is uncertain how far they have reached their objectives. Consistent evaluation has not been carried out and there has been no integrated framework for planning, monitoring and managing watershed management programmes. In addition, the integrated approach has often not been properly implemented.

The Government of India adopted integrated watershed management in its National Water Policy, 2002 (MoWR, 2002) as a key strategy to conserve natural resources. The policy calls for involving local users in planning and managing natural resources at the watershed level. However, the mechanisms to achieve this have been inadequate, and new tools need to be developed to handle the complexities of integrated watershed management. It is important that the information they produce is accessible in order to help planners arrive at appropriate decisions.

This paper shows how Geographic Information System (GIS)-based modelling of information on water, land, forests and other variables can be used in local planning to prioritize watersheds and site structures. It presents a technique for prioritizing watersheds scientifically. It also discusses the authors' efforts to account for socio-economic factors in watershed management.

INTEGRATED WATERSHED MANAGEMENT

Integrated watershed management planning should facilitate all stakeholders within a watershed to identify local natural resource issues and then to develop and implement watershed plans that promote environmentally, socially and economically sustainable development.

Integrated watershed management began in India in the 1970s. Since then there have been many changes in how it has been implemented. Until 1995, watershed development projects were coordinated within multi-sectoral programmes. A 1999 review by the Ministry of Rural Development (MoRD) and the Ministry of Agriculture (MoA) led to the 2001 introduction of common operational guidelines, objectives, strategies and expenditure norms for watershed development programmes in India. These encourage the involvement of NGOs, semi-governmental institutions, private enterprises, universities and training institutes. However, concerns are being raised that watershed development programmes are still based around the misconception that water is an infinite resource, with the collection and extraction of ever more groundwater to meet human needs (KAWAD, 2001).

Integrated watershed management does not merely involve running an inventory of different activities. It is also necessary to evaluate the impacts of proposed actions. Watersheds are the smallest units for evaluating human-induced impacts on natural resources. Therefore, although the administrative unit of panchayat village clusters remains as the implementation unit for watershed management programmes, impacts need to be assessed at the watershed level.

The main shortcomings of watershed management in India are that it often:

- does not pay enough attention to watershed hydrological boundaries;
- ignores the connectivity of watersheds and treats each one as a stand-alone unit, irrespective of downstream relations;
- ignores the hydrological characteristics of watersheds when deciding on interventions;
- ignores environmental sustainability aspects; and
- fails to monitor and evaluate impact properly.

These shortcomings are due to a number of factors, including the lack of a unified framework to account for the influence of all the elements that influence an area’s hydrology. In India, a watershed is considered as the smallest unit of a drainage basin. It is essential to develop a hydrological framework to track the interconnectivity of these units. The impacts of actions at the watershed level will be experienced within the containing drainage basin. A framework is needed to assess these impacts. Such a framework needs to be well-maintained and updated to serve the needs of planning agencies and line departments. This is best done using computer modelling.

The second major problem encountered in watershed management programmes is that much of the information needed for integrated planning and management is not available at the watershed scale. This especially applies to the quantities of surface water and groundwater. It is not financially viable to measure directly local water availability and its variability over time. Hydrological simulation modelling is a very effective tool that helps to estimate water quantities in watersheds. The present study demonstrates the application of one such model that simulates the quantity of water and sediment erosion in a watershed.

SWAT HYDROLOGICAL MODEL

The Soil and Water Assessment Tool (SWAT) was developed by the United States Department of Agriculture (USDA) Agricultural Research Service (Arnold *et al.*, 1990) to simulate the land phase of the hydrologic cycle in daily time steps. It can also simulate the detachment of sediments from watersheds and model their transport through drainage systems. The SWAT model simulates the passage of water and sediments from individual watersheds through river systems. It can factor in the effects of off- and onstream tanks, reservoirs, check dams and different agricultural practices. Its major advantage is that unlike conventional simulation models, it needs little calibration and so can be used on ungauged watersheds.

The model can show water availability under different demand and use levels, with both domestic and agricultural use factored in. It can show the situation for existing and anticipated water uses and indicate under what circumstances water shortages will occur. It completely accounts for the quantities of water that: 1) are supplied to the land by precipitation; 2) enter streams as surface runoff; 3) are used and returned to the atmosphere by natural vegetation, agricultural crops and evaporation; and 4) percolate through the root zone to recharge groundwater.

Macro-watersheds (catchment areas) are made up of a number of micro-watersheds. The use of a number of discrete watersheds in a simulation is particularly beneficial when different areas of the macro-watershed are dominated by different land uses or soils that have differing impacts on the hydrological response. In the SWAT model, the input information for each watershed is grouped with respect to weather; unique areas of land cover, soil and management practices. These are called hydrologic response units (HRUs).

Model outputs include all the water balance components of surface runoff, evaporation, lateral flow, recharge, percolation and sediment yield for each watershed. These are available at daily, monthly and annual time steps.

These technologies have been integrated and promoted through the UNDP-sponsored project GIS-Based Technologies for Local Level Development Planning, implemented by the Government of India's Department of Science and Technology. The techniques presented in the following case study were worked out by the authors during the course of this project (Gosain and Sandhya, 2001; Sandhya and Gosain, 2001)

CASE STUDY OF DODDAHALLA WATERSHED

A demonstration case study of the SWAT model was set up on the Doddahalla watershed in northern Karnataka. The aim was to show how the model can help to identify the micro-watersheds within a macro-watershed that are most in need of interventions, according to their hydrological, demographic and socio-economic status (CEE, 2001). This work was carried out in collaboration with the Centre for Environment Education, Bangalore, which was the lead organization handling the project on Prioritization of Micro-Watersheds for Better Management in Bijapur district of Karnataka under the World Bank's Water and Sanitation Programme.

The Doddahalla watershed in Bijapur district, northern Karnataka covers about 61 000 ha. It is in a chronically drought-prone area with a large agrarian population that depends on rainfed agriculture. The upstream part of the macro-watershed – covering about 31 000 ha – was considered as the area under treatment in the case study, while the 30 000 ha downstream area was the subject for the case study's detailed impact analysis. The downstream area covers the 30 villages of Indi and Bijapur taluks (subdivisions of districts).

Gathering basic information

First, hydrological modelling was used to generate information on runoff and sediment yield. This and socio-economic parameters were used to prioritize the area's micro-watersheds.

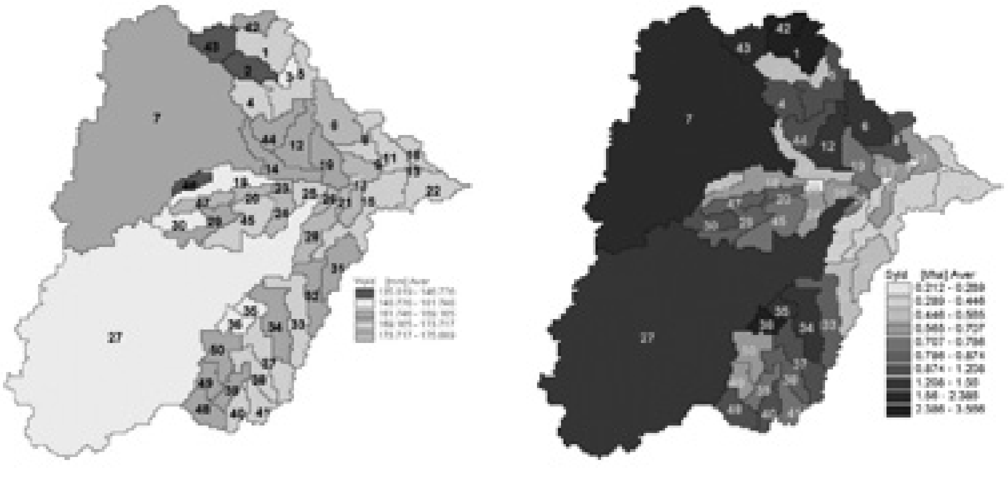
GIS technologies were used as a pre-processor to the SWAT model in order to create spatial data and organize the other data on land use, soil and weather. The model gave the flow availability and sediment yield at drainage points of each micro-watershed. GIS overlay analysis was then used to prioritize micro-watersheds according to the MoRD's guidelines. This involved generating a digital elevation model (DEM) to delineate micro-watersheds automatically. This was then overlain with the land use and soil layers to derive HRUs – areas with uniform land use and soil characteristics.

The entire watershed area was divided into 50 micro-watersheds containing 175 HRUs. The upstream part of the watershed, although it is a contiguous part of the overall hydrological area, was not subdivided into micro-watersheds, but incorporated as a single unit. The daily rainfall and temperature data (1969 to 1990) for Bijapur station was then incorporated.

The water availability (mm/year) and sediment yield (tonnes/ha) are shown in Figure 1 for each micro-watershed, with the darker-coloured areas having the highest water and sediment yields.

FIGURE 1

Water availability and sediment yield map (20-year average: 1969–1990)



Watershed prioritization

The watershed prioritization model uses the guidelines developed by the National Watershed Development Project for Rainfed Areas (NWDPRA). NWDPRA was initiated in 1990–1991 to improve agricultural production in rainfed areas and restore ecological balance. It is a centrally funded programme that operates through state-level departments of agriculture or watershed development. NWDPRA's guidelines combine physical and socio-economic criteria to prioritize watersheds for management interventions. The following are the criteria used, in order of importance:

- highly eroded areas with much land degradation;
- a water scarcity problem;
- less than 750 mm rainfall per year;
- a net cultivated area of no more than 20 percent of the total area;
- an irrigated area not exceeding the state average or 30 percent of total land area; and
- no areas of long-duration or water-intensive crops.

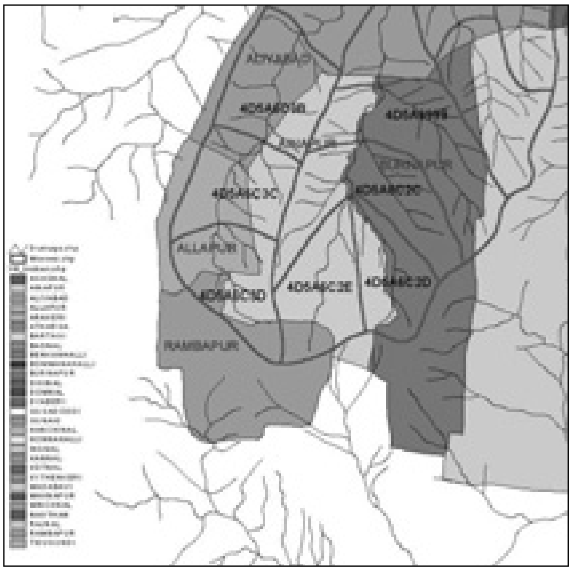
The guidelines also recommend that priority is given to villages and watersheds that have more economically poor people and people with small landholdings. As budgets are allocated to administrative units (villages in this case), another criterion is to choose watersheds whose boundaries mostly coincide with village boundaries.

For the model, each element of these physical and socio-economic prioritization criteria was made into a GIS layer, taking the micro-watershed or village as the mapping unit. Overlay analysis was performed by taking up two layers at a time in the sequence of priority, as indicated in the list above. For physical criteria, the highest priority level was given to headwater watersheds and watersheds that had the most degraded land and minimum water availability. The hydrological modelling (Figure 1) showed that seven watersheds met these criteria.

The next step was to identify which of these watersheds cover a larger part of the involved villages. This was done by using GIS to overlay the seven selected watersheds on to the village boundaries. Four of them (4D5A6C2B, 4D5A6C2C, 4D5A6C2D and 4D5A6C2E) –areas mostly inside the green circle – were found to cover a large proportion of the two villages of Ainapur (63 percent of the area) and Burnapur (50 percent). Information was then gathered on these two villages' socio-economic characteristics, including the number of people below the poverty line, the scheduled caste and tribe population and the size of landholdings. The four watersheds all had similar levels of socio-economic development. These four contiguous watersheds were thus identified for priority treatment. Figure 2 depicts these watersheds and the village boundaries.

FIGURE 2

Watershed and village boundaries



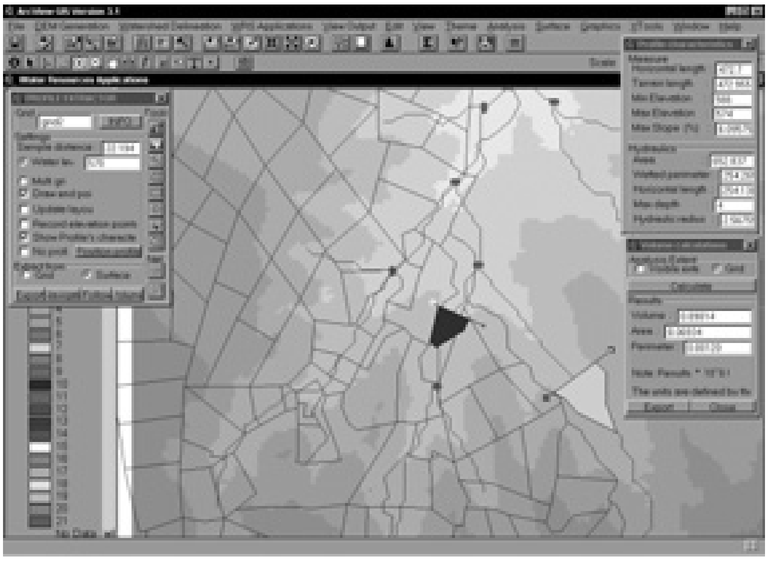
Strategies for watershed development

The next step was to generate detailed information on the four watersheds in order to help to decide which management interventions were needed. A survey was carried out to obtain detailed terrain information in order to generate a reasonably accurate digital elevation model (DEM). This was crucial to enable the latest GIS technologies to be used to show hydrological processes, including the availability of water for harvesting. This model was used to generate a map of the local drainage indicating the best sites for placing water harvesting structures, such as dams, ponds and contour bunds.

A demonstration facility was then made using ArcView software (Spatial Analyst extension) to help select the best sites for these structures. Profiles drawn on the digital elevation model give the hydraulic characteristics of the terrain, such as surface area and volume of impounded water behind a planned barrier. They show the area that would be inundated by water when superimposed on the plot or village maps. This rapidly provides the first level of feasible sites for locating structures, which can then be field tested to see their practical potential.

Figure 3 shows two alternative sites with different design parameters and resultant computations. Site 1 produced a storage volume of 0.8 ha million and a spread area of 3.02 ha for a crest height of 2.0 m, whereas site 2 produced a volume of 9.0 ha million and a spread area of 6.93 ha for a crest height of 4.0 m. This shows that site 2 is the best location for the dam as it will hold more than ten times the volume of water while inundating just over twice the area. Sites that give a comparable volume with less spread are preferred, as a larger spread leads to more evaporation and seepage loss.

FIGURE 3
Locating sites for water harvesting structures



This case study shows how computer software can compute information to help local planning for integrated watershed management. This tool has the advantage of making the factors behind decision-making more understandable to stakeholders and allows for more local participation.

DFID PROJECT ON FORESTRY AND LOW FLOWS

The project on Forestry and Low Flows, Spatial Modelling and Open GIS Dissemination of the Science Perception – India (DFID, 2002) was started in August 2002 and is due to run to March 2005. It is being funded under the United Kingdome Department for International Development (DFID) Forestry Research Programme.
The project is looking at the general perceptions of science of the interaction of water with landmasses. It aims to improve local understanding of natural resource management, improve scientific knowledge and promote improved watershed management. The goal is to help to direct development resources towards those projects that most improve the livelihoods of poor people. The project is working in pilot watersheds in Madhya Pradesh and Himachal Pradesh.

It is scientifically establishing the links between forests and low water flows. Many watershed development programmes promote large-scale afforestation in the belief that this will improve water resources, increase groundwater recharge and increase low water flows – a relation that is largely unsubstantiated.

The project is examining this relationship by setting up a hydrological model for different land uses in order to assess and demonstrate what impacts changes in land use, particularly forestry and irrigated agriculture, have on water availability. This should provide a decision support system. Water conservation structures such as check dams, percolation tanks and trenches retain storm flows and allow water to be used locally. However, when catchments or macro-watersheds reach a stage where water resources are fully used and, on an annual basis, there is little or no flow out of the macro-catchment, further investments in water conservation structures and other measures such as bunding become less cost-effective, as water that is being captured upstream is captured at the expense of other potential users downstream. The GIS-linked hydrological model that the project is developing will indicate the water quantity impacts of different kinds of decision-making relating to land use and water conservation for both watershed and downstream areas.

The project is also investigating the historical development of water policies at the state and national levels in India, and aims to assess public and donor perceptions of these policies' impacts. The project will combine this knowledge with the results of biophysical modelling of the pilot watersheds in order to recommend better water policies that take a more sustainable approach to catchment management. This will help to ensure improved water supplies, especially for the economically poor (Gosain and Calder, 2003).

The dissemination of these findings and the availability of land-use change simulations over the Internet will enable those responsible for land-use management to see the probable impact of alternative strategies. It is also proposed that the outputs of this exercise be disseminated over the Internet. This would allow local communities to see the local and basin-wide water resource implications of decisions that are made at the local level. This is practical in the light of rapidly increasing access to the Internet in India's villages, and will make it easier to carry out whole-catchment cost-benefit analysis of forests in relation to erosion, sedimentation and flooding.

CONCLUSIONS

The ability to identify micro-watersheds that will most benefit from treatment is very important for watershed planning. The first step is to generate estimates of water and sediment yield at the micro-watershed level – information that is often unavailable. The study is developing applications for identifying the interactions between administrative and watershed boundaries, and for placing water harvesting structures. Besides helping to site structures, these spatial tools help to estimate related parameters such as water spread area and available water storage capacity. This helps to make watershed management interventions more science-based. Efforts are also being made by project partners to strengthen watershed management in the pilot watersheds by promoting policy change and using cost-effective GIS tools.

REFERENCES

Arnold, J.G., Williams, J.R., Nicks, A.D. & Sammons, N.B. 1990. *SWRRB – A basin scale simulation model for soil and water resources management.* College Station, Texas, Texas A&M Press.

Calder, I.R. 1998. *Review outline of water resource and land use issues.* SWIM Paper No. 3. Colombo, Sri Lanka, International Irrigation Management Institute.

Calder, I.R. 1999. *The blue revolution, land use and integrated water resources management.* London, Earthscan.

CEE. 2001. *Prioritization of micro watersheds for better management in Bijapur district of Karnataka.* Bangalore, Centre for Environment Education (CEE).

DFID. 2002. *Project on Forestry and Low Flows, Spatial Modelling and Open GIS Dissemination of the Science Perception – India* (R8171). New Delhi, UK Department for International Development (DFID).

Gosain, A.K. & Calder, I.R. 2003. Inter-relating resource management issues. In *Proceedings of the KAWAD Conference on Watershed Development and Sustainable Livelihoods: Past Lessons and Future Strategies.* 16–17 January 2003, Bangalore. Delhi.

Gosain, A.K. & Sandhya Rao. 2001. SDSS for land and water management. In *Proceedings of GIS Technologies for Sustainable Development at Local Level.* New Delhi, Government of India, Department of Science and Technology.

KAWAD. 2001. *A fine balance: Managing Karnataka's scarce water resources.* Bangalore, Karnataka Watershed Development Society (KAWAD).

MoWR. 2002. National Water Policy. New Delhi: Government of India, Ministry of Water Resources wrmin.nic.in/policy/nwp2002.pdf.

Sandhya Rao & Gosain, A.K. 2001. The district almanac characterisation tool. In *Proceedings of GIS Technologies for Sustainable Development at Local Level.* New Delhi, Government of India, Department of Science and Technology.