STRIVER

STRIVER POLICY BRIEF

Strategy and methodology for improved IWRM
- An integrated interdisciplinary assessment in four twinning river basins

PB No. 7

Modelling water and nutrients balance in Tungabhadra river basin: scenario analysis and management recommendations.

The use of a management model can help in a better understanding of the water, sediment and nutrient balance in the river basin, allowing then to single out critical geographical or problematic areas where management policies must be carried out. Scenarios, developed through interaction with stakeholders, can be simulated to help in the decision taking process.

The STRIVER Policy Brief series translate the results from the EC FP6-funded STRIVER project into practical and useful information for policy makers and water managers

Modelling water and nutrients balance in Tungabhadra river basin: scenario analysis and management recommendations

Antonio Lo Porto, IRSA-CNR, Italy
Line J. Barkved, NIVA, Norway
Gosain K. Ashvin, IITD, India

A river basin model was applied in the Tungabhadra river basin to assess the present and future water, nutrients and sediment loads. Stakeholders were involved in all the phases of the modelling process including the development of the scenarios and discussion of the simulation outcomes. The results of the model simulations shed light over the three management actions. Climate change (10 year time horizon) will require that erosion control should be a prime objective in landscape management and planning. Ongoing policies on sewage treatment in urban and rural areas were documented to have a significant impact in reducing nutrient loads to the river system. The introduction of new techniques in rice cultivation was shown to play an important role in saving water resources. The study also showed that limitations in data availability especially water quality data, seriously hamper the pollution load modelling. More efforts for collection of environmental data and monitoring of water quality are therefore needed.

References

This STRIVER Policy Brief is based on the following research reports and scientific literature:

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Neitsch, S. L., Arnold, J. G., Kinry, J. R.,Williams, J. R., 2002. Soil and water assessment tool. Version 2000. Theoretical documentation. USDA-ARS, Temple, TX.

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Fact box

The use of simulation models allows

- ✓ to estimate nutrient and sediment loads and to quantify the effects on water quality of downstream river reaches and/or reservoirs;
- ✓ to identify pollution sources, study source apportionment and rank critical source areas;
- ✓ to asses suitable Best Management Practices and to rank them on the basis of expected efficiency.

Why physical models?

In the Tungabhadra river, serious conflicts originate from the available water resources which are not enough to sustain all the needs that exist in the region for drinking water, agriculture (irrigation), fishery and industrial production. Not only the quantity of the resource is limited compared to the needs, but also the quality, impaired by non-sustainable use and less sound management, prevent the available water resources to be suitable for selected uses.

The river basin is dominated by large agricultural and urban settlements. The main sources of pollution are agricultural runoff, untreated/partially treated wastewater from industries, urban sewage, and silt from mining activities, which have greatly degraded the water quality.

Several water works have been built in the last decades to increase water storage at catchment scale (dams, tanks) and to transfer water resources through canals to irrigated agriculture areas.

The complexity of landscape, climate and pollution sources (both point and diffuse sources) require modelling tools to be used to help understand the complex interactions between the various sources and environmental processes.

With the modelling tools, as in this case, it is possible to estimate nutrient and sediment loads and to quantify the effects on water quality of downstream river reaches and/or reservoirs, including the identification of pollution sources along with the required source apportionment that is needed to rank critical areas.

These tools -as a single model or as chained sequence of different models - can also be used in selecting suitable Best Management Practices, ranking of sources and expected efficiency in nutrient reduction magnitude and costs in addition to pollution impacts on various mitigation measures and scenarios.

Modelling approach and data availability problems in the Tungabhadra basin

As a first stage, a statistical assessment of water quality and quantity monitoring data were performed in order to identify pollution levels and events.

A detailed continuous semi-lumped model, SWAT, was then used to assess the spatial

Monitoring and Modelling

Measured data from monitoring campaigns play a fundamental role in allowing to understand the processes acting in a catchment. They are also a prerequisite for allowing models of any type (simulation, statistical, et cetera) to be used and draw reliable predictions from. Furthermore, in order for the model simulations to be trusted, a model need to be calibrated and validated through comparing the simulated time series against measured ones.

Thus monitoring campaigns must be planned well in advance and are worth the resources allocated to them.

In this framework, key parameters to be considered include weather, river flow, water quality, outlets and inlets, crop statistics. In particular the inclusion of ammonia, phosphorus (at least as total P) and sediment should be measured.

pattern of contribution within the catchment to runoff and pollutant transport generation and to generate and compare different environmental and management scenarios (Neitsch, S. L., et al., 2002). This choice of model was mainly based on the following facts:

- the model is comprehensive in simulating hydrology, crop growth, agricultural management, BMPs;
- it is free and open source;
- it is widely used in the world and a large and co-operative user community exists.

To be able to run the SWAT model, it was necessary to utilize several geo-referenced databases including information on geomorphology (DTM, hydrology, geologic features), landuse, weather (temperature, rainfall, wind, radiation), management practices, point sources in the area, surface and groundwater flow and water quality monitoring data.

Very often data availability constitutes a problem when using such complex and data demanding models; nevertheless some alternatives exist when detailed data are not available. In particular, adequate soil type maps were missing, together with information on agricultural practices (actual crops, fertilizers and pesticide use).

Uncertainties and Assumptions

- Detailed info on land use and soil type was not available
- Detailed data on the agricultural land use in the form of actual cropping pattern were missing
- Sewage contributions were calculated from literature data
- Point sources water use was assumed to be not consumptive
- Assumption of no changes in land use in the modelling of future climate scenario

In the Tungabhadra modeling exercise, it was possible to resort to several "global coverage" data sources, i.e.:

- DTM from the NASA SRTM experiment ,
- Land use/ land cover from the Global Land Cover Facility (Hansen, M. C., et al., 1999)
- Soil map based on FAO Global soils (FAO, 1995).

Some data were only available at district level (i.e. actual crops, urban and rural settlements): in this case some statistical calculations were used to distribute this information within the delineated subbasins.

Moreover, it was only possible to calibrate and validate the water flow. The water quality time series were incomplete, especially concerning the temporal resolution. Furthermore measurements on phosphorus and sediments were completely missing.

Highlights from the baseline simulation

The model output gave valuable information on especially the following issues (see Fig.1.):

- Gross accumulated water availability in the catchment;
- Source areas for surface runoff, erosion and nitrate surface losses (which are the highest in the south-west and north part of the basin; Fig. 2).
- Nitrogen source apportionment in the catchment (diffuse sources account for around 90% of total N).

It was also possible to document that the Tungabhadra dam, drains the most sediment loaded subbasin in the river basin, thus explaining the huge siltation rate recorded for the dam (22% volume lost due to siltation).

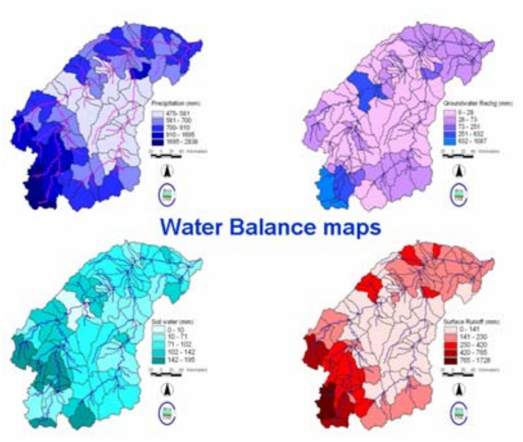

Fig. 1 Water Balance maps; SWAT output

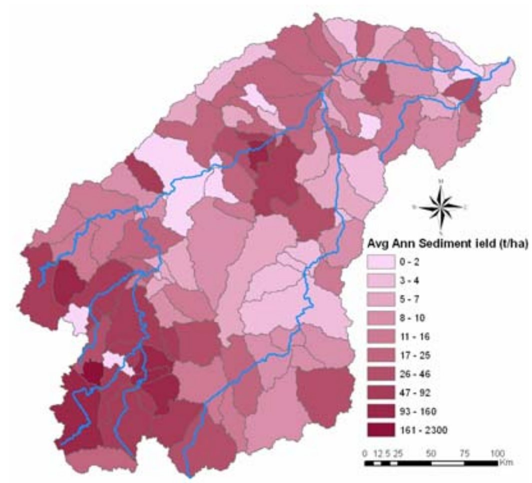

Fig. 2 Spatial distribution of Average Sediment Yield

Stakeholder participation all along the model process

The stakeholders were involved in all the major stages in the entire process (Fig.3):

1. during the "scoping" phase in which key problem areas are searched and ranked
2. in evaluating model outputs in baseline conditions and in developing and agreeing on the "conceptual model" built on the basis of the simulations
3. in developing alternative, feasible, acceptable and consensus-based scenarios to be evaluated using the models.

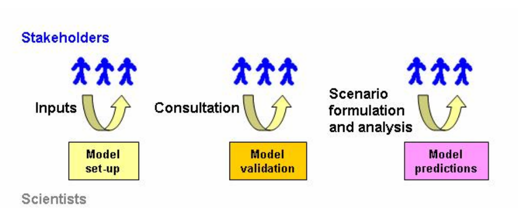

Fig. 3. Interactions of stakeholders and scientists at the different stages of the modelling process.

Stakeholder-developed scenarios

During the stakeholder meetings, the participants were divided into break-out groups, each discussing the likely and acceptable future changes. Scenario topics particularly addressed were (i) water demand for different uses, (ii) land use and cropping pattern, (iii) agronomic practices, (iv) treatment of effluents and urban sewage, (v) sanitation practices in the rural areas, (vi) trend in urbanisation.

The qualitative scenarios (in a 10-year perspective) were then translated into the following quantitative agreed scenarios:

- Climate change: Hadrm3 model, A2 and B2 emission scenarios; 2070-2090[1]
- Sewage treatment: 80% septic tanks in rural areas; 50 % treatment in urban areas
- Change in irrigation: sprinkler system for 80% areca nuts
- "System for Rice Intensification" (SRI[2]): 40% shift upstream of the TB dam and 10% downstream

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1 **Hadrm3** is a Regional Climate Model (RCM) and has been developed by the Hadley Centre for Climate Prediction. A2 and B2 are two different emission scenarios.

2 **System of Rise Intensification** is a method of increasing rice yield developed in recent years based on keeping soils moist but not saturated and transplanting young rice seedling in a wider way than traditional cropping method,

These were then used as input to the SWAT modelling.

Results from the scenario analysis

After the model was calibrated and validated in the baseline simulation ($R^2>0.90$ NS=0.44), it enabled us to apply the scenarios after having parameterized them (that is converting concepts into numbers used by the model).
However uncertainties present in the baseline simulation are reflected into scenarios output: the scenario on irrigation changes is not commented here because of uncertainties embedded in the cropping pattern and practices.
Some of the results can be summarized as in the following Tab.1.

	Baseline	**A2**	**diff %**
Precip mm	829	928	12
ET mm	469	539	15
Surf.runoff mm	177	219	24
Water Yld mm	334	365	9
Sediment load t/ha	12.4	28.9	132
water inflow reserv mm	261	444	70
water outflow reserv mm	141	177	26
sed.inflow reserv t/ha	0.6	1.9	253
sed.outflow reserv t/ha	0.02	0.02	27

Tab. 1 Summary results of the A2 climate change scenario

The climate scenario impact results indicate the following:

- a doubling in the sediment load;
- the sediment inflow into the TB dam is expected to increase three times while the sediment outflow will remain more or less stable. This will lead to a great increase of the siltation rate and a reduced life-time of the dam;
- a lower groundwater recharge rate is expected (Fig.4).

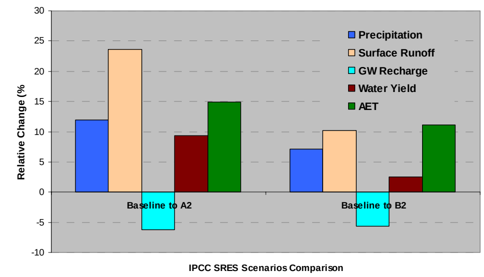

Fig.4 Change in water balance components from baseline to A2 and B2

The other simulated scenarios lead to the following conclusions.

- the simulated spread of SRI leads to an expected 6% saving of the river basin water yield, accompanied by an overall increase of around 20% of rice yield;
- the simulated sewage treatment scenario showed that a 50% reduction from sewage discharge can be expected in both N and P contribution to the overall river pollution.

Even if the model was calibrated only for the hydrology, scenarios simulations are considered reliable since:

- climate change simulation are based on hydrology except for erosion;
- calculated actual erosion rate is in agreement with measured siltation rate in the Tungabhadra dam (since monitored sediment transport is missing);
- water saving due to SRI diffusion scenario is based on changes in irrigation and then mostly on hydrology;
- sewage treatment scenario is obtained on simple point source load calculations.

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allowing higher yields, less seeds requirement and less water for irrigation.

Management implications

- It is necessary to put larger efforts in planning effective monitoring activities: more frequent water quality sampling, a larger selection of parameters to be measured, namely phosphorus, ammonia and suspended solids.
- The actual high level of erosion and increase in simulated trend in the future due to climate change suggest that erosion control should gain a high priority in next future landscape management policy.
- Investment in improved sewage treatment in urban and rural areas will significantly reduce the nutrient load to the river and can dramatically decrease the level of pathogens in surface water.
- Active policies must be undertaken with a deeper effort to help the diffusion of new techniques in rice cropping (SRI) that roved to play a relevant role in saving water resources.

Fig.4 The Tungabhadra Dam. Public domain. Courtesy of Wikipedia users (http://www.wikipedia.com).

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The STRIVER Policy and Technical Brief series translate the results from the project into practical and useful information for policy makers and water managers.

The Briefs are also available online: www.striver.no

About STRIVER

STRIVER- Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins is a three year EC funded project 2006-2009 under the 6th framework programme (FP6) coordinated jointly by Bioforsk and NIVA. The point of departure for STRIVER is the lack of clear methodologies and problems in operationalisation of Integrated Water Resource Management (IWRM) as pointed out by both the scientific and management communities.13 partners from 9 countries participate as contractual partners in addition to an external advisory board.

Title of project:
Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins (STRIVER)

Instrument: SUSTDEV-2005-3.II.3.6: Twinning European/third countries river basins.
Contract number: 037141
Start date of project: July 2006 Duration: 36 months

Project funded by the European Commission within the Sixth Framework Programme (2002-2006)

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Frontpage photo: Tungabhadra River at Hampi. Compliments of HoboTraveler.com (http://www.hobotraveler.com)

Editors: Per Stålnacke and Udaya Sekhar Nagothu (Bioforsk)

Launch date: 17 November 2008