GIS-APPLICATION FOR INTEGRATED WATER RESOURCES MANAGEMENT ON THE EXAMPLE OF THE UPPER DONG NAI RIVER BASIN, VIETNAM

S. Schuster, H. Stolpe, F. Klingel, A. Borgmann

Ruhr-University of Bochum,
Faculty of Civil and Environmental Engineering,
Institute of Environmental Engineering and Ecology,
44780 Bochum, Germany, (E-mail: ecology@rub.de)

ABSTRACT

Implementing Integrated Water Resources Management (IWRM) is one of the most pressing issues of Vietnam's water sector. However, moving from rhetoric to practical implementation of IWRM is a challenging process requiring multiple and concerted efforts by key players throughout all sectors and administrative levels.

The Vietnamese-German Research Project IWRM-Vietnam aims at contributing to this process by developing methods to facilitate spatial planning and decision making in water resources management using the example of the Upper Dong Nai River Basin. These methods focus on organizing all available data relevant for water resources management in Geographical Information Systems (GIS). Modeling hydrology and social, economic and land use development allows the prediction of water demand and availability. Aggregation of data and their visualization in a Decision Support System (DSS) allows decision makers to assess the impact of different options. In this way, decisions about investments in water infrastructure, water allocation, and regulation of wastewater discharge, etc. can be based on actual data and science-based predictions of impacts.

The developed system is illustrated at the example of the estimation of pollution caused by wastewater discharge and its environmental impact at the scale of a river basin.

1 INTRODUCTION

1.1 IWRM in Vietnam and the need for decision support tools

Integrated Water Resources Management (IWRM) has been adopted as a guiding principle for the water sector in many countries worldwide during the last decade.

The Global Water Partnership defines Integrated Water Resources Management as a process which "promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000).

In practice IWRM is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. Another important principle for practical implementation of IWRM is that water should be managed in natural units such as river basins, rather than in administrative units.

Establishing IWRM is a big challenge for governments and institutions as it generally can only be realized in a long process of implementing numerous elements ranging from restructuring legal and institutional frameworks, investing in infrastructure, and involving stakeholders in decision making to capacity building and establishing efficient monitoring and information systems.

The Government of Vietnam has recognized that improving water resources management along the principles of IWRM will be crucial for Vietnam's achieving further economic development on a sustainable basis. Even though the Government of Vietnam has undertaken important steps towards implementing the principles of IWRM (Government of Vietnam, 2006), it is still far from being a reality in the day-to-day management of water resources in Vietnam: the institutional restructuring is on-going and open questions about future responsibilities persist on ministerial and lower administrative levels. Newly founded institutions for water resources management such as the provincial Departments of Natural Resources and Environment continue to suffer from lack of resources and qualified staff. The capacity of institutions on all levels to monitor, control and sanction water use, land use or water pollution remains weak (KBR Ltd., 2008).

1.2 The Research Project IWRM-Vietnam

The Research Project IWRM-Vietnam, funded by the German and Vietnamese Governments, addresses one important challenge for implementation of IWRM in Vietnam: environmental data are scattered throughout numerous administrative units with little or no exchange, which results in a lack of well funded information for decision makers on the state of water resources and the expected impact of proposed interventions (KBR Ltd., 2008).

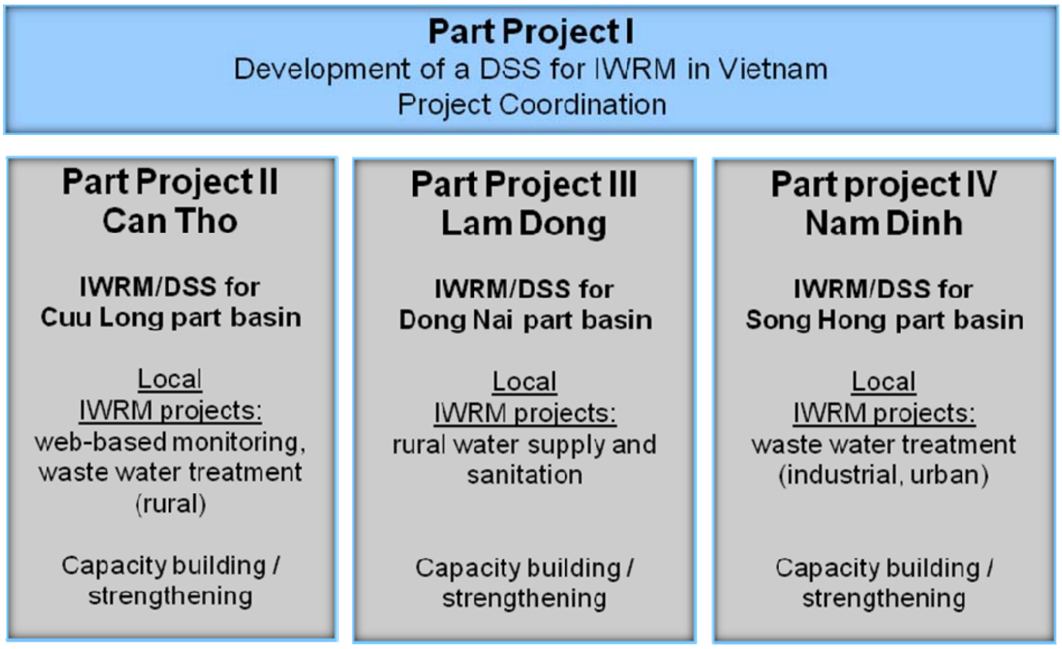

Figure 1: Project structure

The project addresses this issue by developing a Decision Support System (DSS) consisting of tools and methods for better use of available data on water resources for problem analysis, planning and decision making. The DSS is developed for three areas as examples: the Upper Dong Nai River Basin, and parts of the Mekong and Red River Deltas (Research Project IWRM-Vietnam).

There are four part projects within the project IWRM-Vietnam with responsible institutions and scientists as follows (Figure 1):

I. **University of Bochum, Prof. Dr. Stolpe, Dipl.- Ing. F. Klingel**: Coordination of the entire project, development of a Decision Support System for IWRM on the examples of the Provinces Nam Dinh and Lam Dong and Can Tho.

II. **University of Bonn, PD Dr. J. Clemens, Dipl.- Ing. K. Spoth**: The Research in Can Tho additionally focuses on the implementation of two different measures for IWRM: Anaerobic treatment of agricultural wastewater and optimized surface water monitoring.

III. **University of Bochum, Dipl.- Ing. F. Klingel**: The Research in Lam Dong additionally focuses on the development of an IWRM-concept for a local watershed in Hoa Bac and implements IWRM-measures such as the construction of a central water supply system.

IV. **University of Greifswald, PD Dr. Kasbohm**: The Research in Nam Dinh focuses additionally on local measures in connection with waste water discharge of a metalworking handicraft village and urban wast water.

The Project IWRM-Vietnam is working on different scales: From regional planning scale river basin and sub-basin scale (ca: 1:300.000) down to a local scale. Figure 2 shows the different scales and their relationship to the administrative levels in Vietnam. The part project I (Decision Support System for IWRM) is working on the level of river basin and Sub-basin. The Part projects II, III, IV are working below on the level of part regions of sub-basins or on local sites.

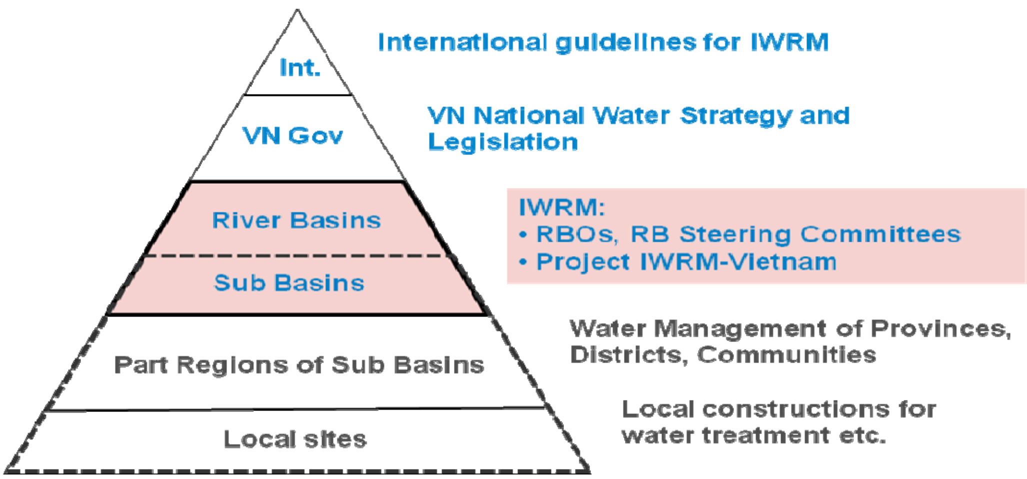

Figure 2: Administrative levels and corresponding levels of water resource management in Vietnam

The level of developing the DSS for IWRM is "River Basin" and "Sub-Basin" (parts of Cuu Long, Dong Nai, Song Hong). The objective of the DSS is to support decisions on the overall planning level.

1.3 Objectives

The Research Project IWRM-Vietnam is divided into the following work packages. Underlined are the results of the work package:

1. Methods for investigation and evaluation of the actual situation: water resources, water use / land use, socio-economic situation: database, GIS-maps

2. Methods of prognosis of future development: quality and quantity of water resources, land use, population growth etc.: scenario definition, estimation, calculation, modeling

3. Methods for identification and evaluation of water related problems, deficits and conflicts: multicriterial spatial evaluation, sub basin reports, problem ranking

4. Definition of targets, identification of instruments and possible measures for IWRM: cooperation with the steering committees of the river basins

5. Methods for compiling measure proposals for the improvement of IWRM, cost estimate: sub basin reports

6. Rounding up the procedures developed under 1 – 5 as a Planning and Decision Support System (DSS for IWRM)

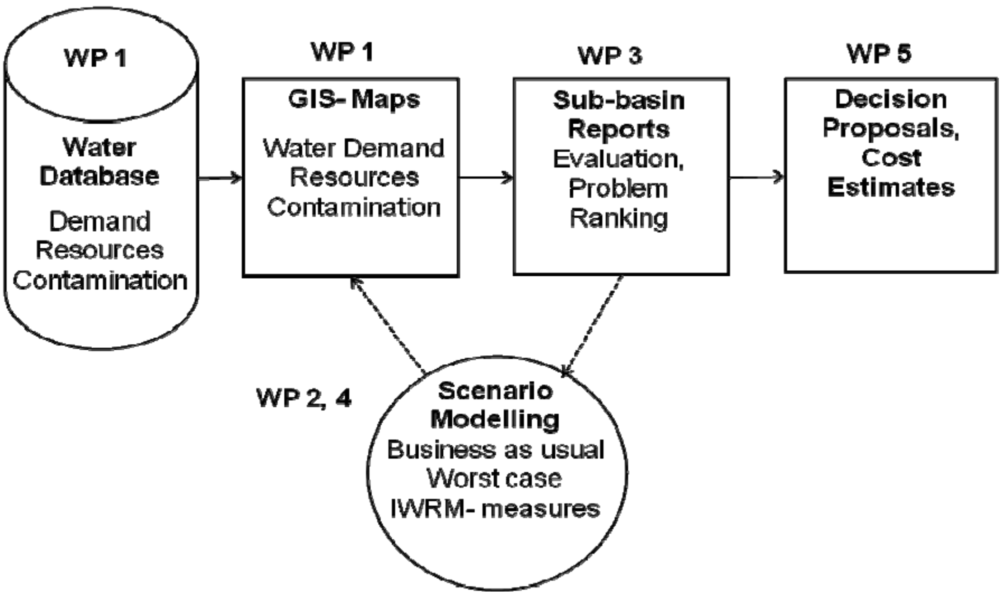

Figure 3: Work packages (WP) of the Project IWRM-Vietnam (WP 6 is the complete procedure)

2 GIS-BASED METHODOLOGY FOR DATA EVALUATION AND AGGREGATION

This paper focuses on the GIS-Maps for water demand, water resources and contamination, corresponding to the work package 1 of the research project (Figure 3). The project develops a GIS-map system:

- **Water use / water demand:** amount of used water / water demand

- **Water resources:** sustainable yield (surface water, ground water), infiltration, runoff vulnerability of ground water and surface water and waste water discharge vulnerability of rivers

- **Contamination potential, contamination:** waste water discharge potential of point sources, contamination potential of point- and non-point source

The maps will be aggregated in the following way:

- Water use / water demand versus water resources: **deficit, surplus of water resources**

- Vulnerability of water resources versus contamination potential: **contamination risk of water resources**

This way enables to identify problem areas (WP 3) and measure proposals (WP4) and cost estimates (WP 5). The results will be compiled as “sub-basin-reports”.

This paper shows examples of the methodology for assessing wastewater discharge and its impact, developed using the example of the Upper Dong Nai River Basin.

The objectives of the methodology are to allow for better management of water resources, to facilitate interpretation and assessment of the data and to allow for combined management and assessment with other data relevant for water resources management.

The most important feature of the methodology is to process the data in a way which allows rapid understanding by professionals and decision makers of the general situation and the main problems. Another important factor is that the method has to be replicable to other localities throughout Vietnam. Both criteria require a considerable amount of generalization. On the other hand, transparency of the data processing is crucial to avoid misinterpretation of generalized conclusions.

2.1 Use of GIS

To fulfill the above mentioned criteria a GIS is very comfortable in use. Digital maps and their underlying data base are well suited for water resources planning. The application of a GIS and a subsequent geo-relational database allows data capture, processing, analysis, and visualization in support of decision making.

To build up the water resources planning tool the GIS Software ArcGIS 9.2 by ESRI have been selected.

In the WP 1 (Figure 3) all necessary data and operations of data processing and analysis with the tools provided by ArcGIS 9.2 are managed in a data base. The data of the data base constitute the basis for maps describing the current state and the scenario modeling in WP 2 and 4.

The GIS layer concept coincides with the reasonable data capture by storing each theme in its own layer. That allows that all results of the modeling are also thematically stored in the data base. The functions of merge, union etc. are used to combine and aggregate the data of water resources, land use and socio economy in the WP 3. In doing so, special question concerning f. e. the contamination risk versus the vulnerability of surface water, can be easily answered.

With special developed classification rules the results of the aggregation processes are transformed into new maps. By overlaying and blending several thematic maps hot spots in water resources can be recognized on the map.

Another useful function of ArcGIS is used to prepare reports according to the water resources for each sub-basin. In the report spatial- and non-spatial data of the data base are used to describe the situation of the water resources, concerning the water demand, water use, contamination risk, future development and measurable future situations as well as cost estimation to avoid negative development or to improve the situation. These reports will help decision makers to find easy information on the sub-basin.

For the decision makers, who are not familiar with the ArcGIS software, a user friendly user interface is developed. Maps and information in form of tables or diagrams can be created by pushing one button. In this way, the decision maker can assess a situation or scenario according to his requirements without any GIS knowledge.

3 APPLCIATION EXAMPLE: ESTIMATING WASTEWATER DISCHARGE IN THE UPPER DONG NAI RIVER BASIN

In following the developed methodology will be illustrated at the example of the estimation of wastewater discharge in the Upper Dong Nai River Basin

3.1 Project area

The Upper Dong Nai River Basin has been selected as pilot area for the development of the DSS. It is defined as the basin of Dong Nai River upstream of the inlet of Tri An Lake. The basin is located in the Central Highlands with an altitude ranging from 50 m up to 2,400 m. The surface area is around 14,790 km^2 and includes the provinces of Lam Dong, Dak Nong, Binh Phuoc, Binh Thuan and Dong Nai.

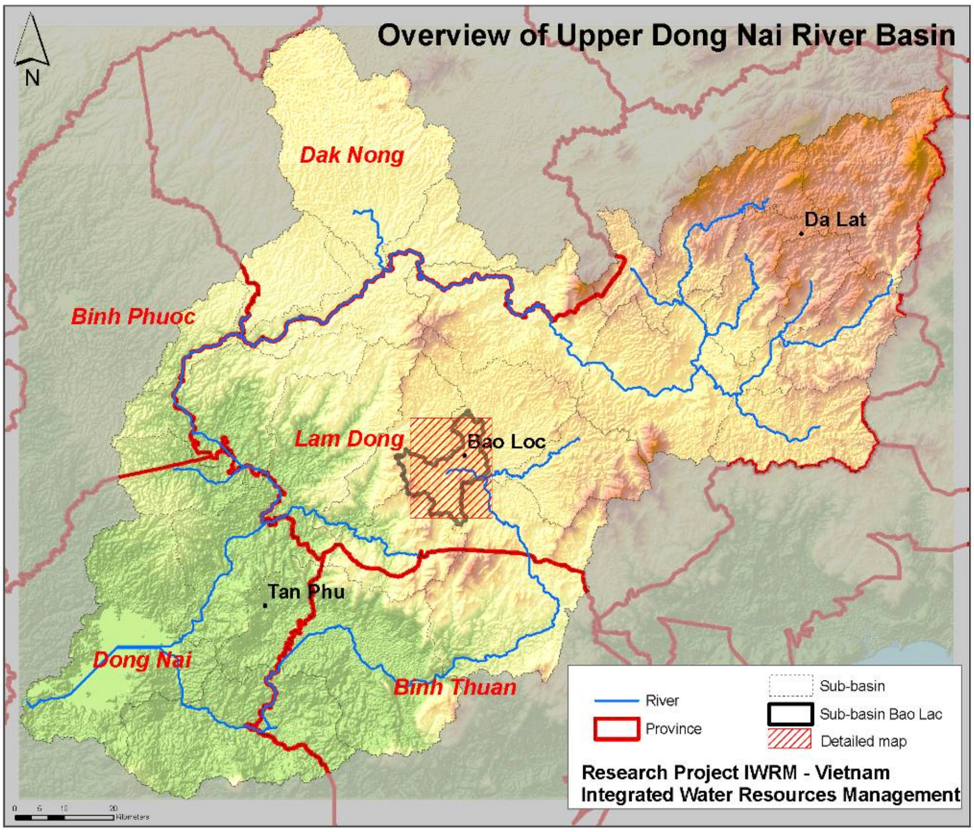

Figure 4: Overview map of the Upper Dong Nai River Basin

Apart from the heavily industrialized Dong Nai Province, the basin is dominated by agriculture and has a relatively low population density. The available water resources are generally sufficient to meet the demand for irrigation of mainly industrial crops such as coffee, tea and rubber as well as for other uses. The River Basin is characterized by numerous reservoirs for hydropower and irrigation. The current boom in hydropower development leads to an additional number of reservoirs currently under construction or being projected. The main threats to water resources in the basin include increasing exploitation for irrigation and hydropower development, changes in the area's hydrology due to construction of reservoirs, deforestation, heavy use of fertilizers and pesticides, as well as discharge of untreated industrial and domestic wastewater. The main urban centers in the river basin are Da Lat and Bao Loc in Lam Dong Province. The main industries in the river basin mainly relate to food processing and textiles such as silk production.

3.2 Approach

As stated above, the lack of reliable and freely available data is a major challenge for water resources management in Vietnam. A decision support tool cannot therefore be based entirely on accurate information. A considerable amount of simplification and generalization is required to produce information for decision making based on the inadequate data that is available.

The approach chosen is to produce generic assessments for smaller units of the river basin. A set of sub-basins has been identified and will serve as the basic unit for the assessment procedure. The objective is to produce a report for each sub-basin stating its main features and the state of its water resources, socio-economic situation and land use. The use of coherent indicators for the whole set of sub-basin reports allows comparison of the water resources situation throughout the river basin and visual representation of the various indicators using standardized maps. The coupling with different models also allows rapid assessment of the impact of different proposed interventions for each sub-basin.

While the approach strives to include all information on water resources, this paper deals with the elements of the approach that focus on information about wastewater discharge. In the following, a detailed description of the process of wastewater data collection, processing, assessment and visualization is given.

3.3 Sources of data on wastewater emitters

In a first step, information on wastewater emitters was collected. In order to develop the methodology it was not required to have access to complete and up-to-date data records. However it was important to collect data representative of the whole variety of wastewater emitters as to both size and type and which allow a consistent and realistic overview to be obtained of the situation in the project area.

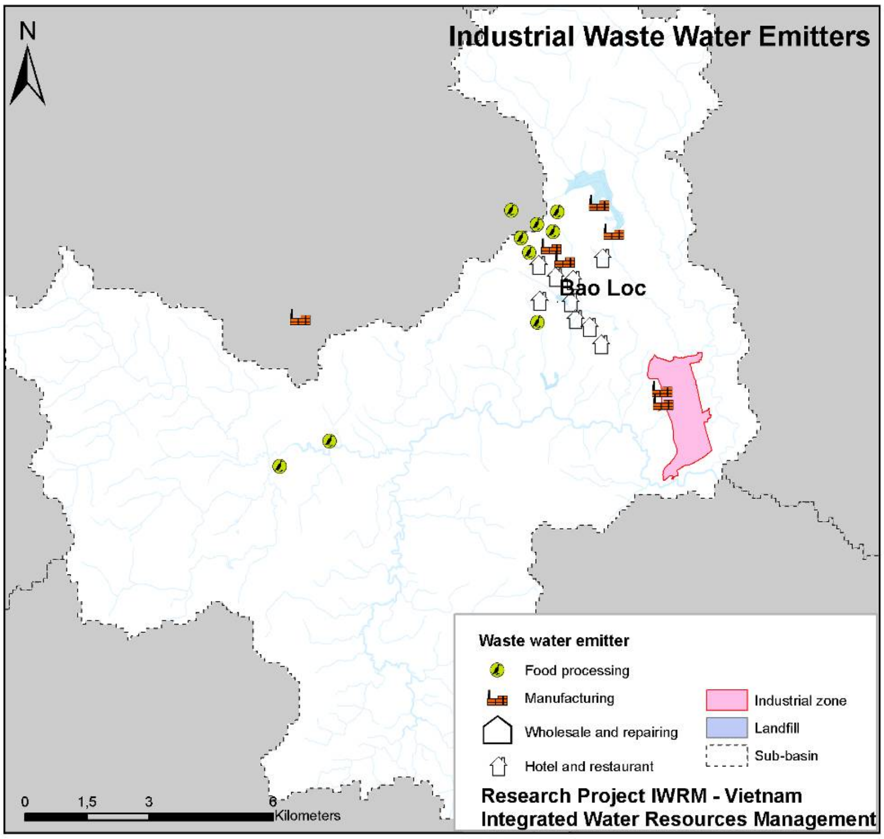

Figure 5: Data on industrial wastewater emitters integrated in a Geographical Information System

3.4 Structuring, processing and assessment of data on industrial wastewater discharge

The data collected on industrial wastewater sources were structured into tables and integrated into a Geographical Information System (GIS).

The data collected on industrial wastewater emitters includes the following information:

- Name and address of company
- Type of industry and industrial branch according to NACE classifcation
- Size of industry (yearly amount of wastewater discharged, yearly production)
- Information on wastewater treatment (removal rate or approved discharge load)
- Geographical coordinates
- Sub-basin in which the industry is located and name of the nearest river
- Total yearly wastewater load (kg BOD/year)

Emitters from industry and services were classified according to different industrial branches using the UN nomenclature for the classification of economic activities from 2007 (United Nations Statistics Division). Data of satisfactory quality on the size of industries could not be obtained during the present research. However in later real scale application of the methodology, this information is crucial for the assessment of wastewater loads. To allow exemplary evaluation and testing of the methodology, industry sizes were estimated based on available information.

Typical values for wastewater type and strength were then attributed to the emitters. Food processing and textile production are the predominant industries in the project areas. These industries typically produce wastewater with high organic loads that can be assessed using the indicator of the biological oxygen demand (BOD). Typical values for BOD loads produced in different industries were deduced from catalogues developed in a similar project in Germany (Stolpe et al., 2006).

Information on the extent of wastewater treatment is also very important in order to assess the actual load discharged into the environment. Currently only very few industries and only one urban area in the river basin, Da Lat, have wastewater treatment facilities.

Total wastewater loads discharged per year by the various emitters are then calculated based on the amount of production per year, the typical wastewater loads per product, and the removal rate due to wastewater treatment.

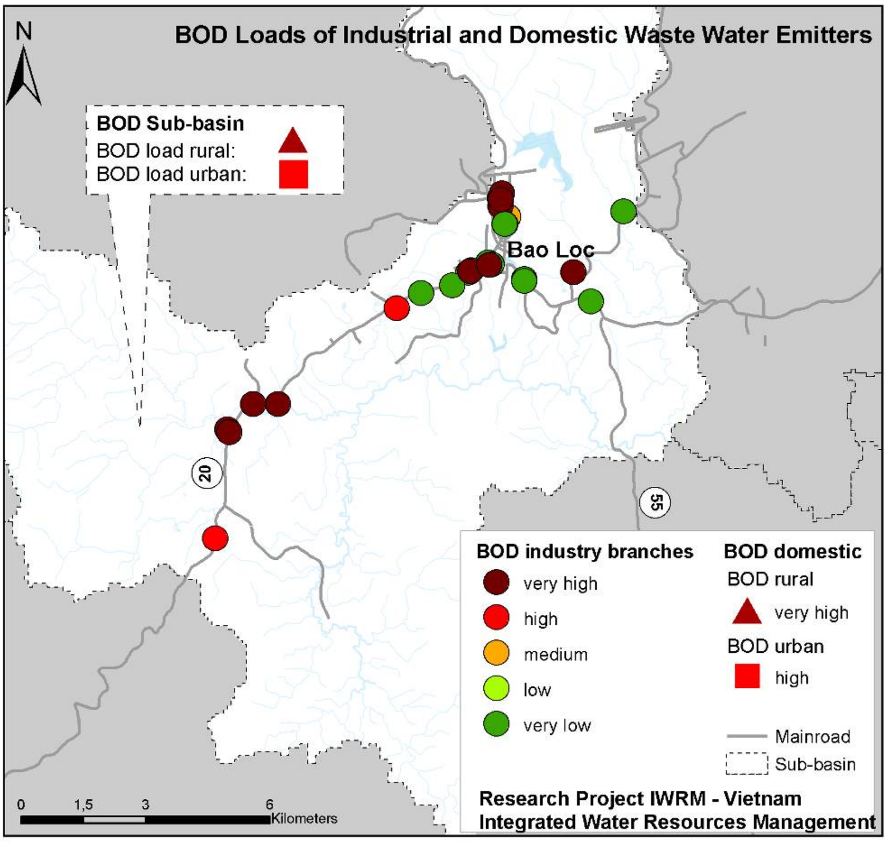

Figure 6: BOD loads of industrial and domestic wastewater emitters

The result used for the final assessment of industrial wastewater discharge is the figure for total yearly BOD load. This parameter is visualized for each emitter, allowing rapid visual assessment of the density of wastewater discharge (see Figure). The BOD indicator is appropriate for assessing the organic wastewater load from industries and households. As in the investigation area almost all industries produce mainly wastewater with high organic loads, the BOD indicator is ideal for comparing wastewater loads discharged by the various emitters.

3.5 Structuring, processing and assessment of data on domestic wastewater discharge

Data on domestic wastewater were deduced from publicly available information on population figures from statistical yearbooks. The data differentiates between rural and urban populations, where urban is defined as settlements with nonagricultural labor higher than 65%, a minimum population of 4,000, and an average population density of 2,000 people/km^2 or more (2001).

The figures for urban and rural population per district were then transformed into urban population per sub-basin, using data on land use to take into account the actual location of settlements.

Loads of domestic wastewater produced by the rural and urban populations in each sub-basin could be calculated using typical figures for drinking water consumption and concentration of urban wastewater. The BOD load based on population equivalent was calculated using a medium BOD value of 200 mg/l for domestic water in Vietnam (Government of Vietnam and Ministry of Natural Resources and Environment, 2006). In rural areas a wastewater amount of 60 l/p/d (Dinh Viet Duong, 2006) and in urban areas of 90 l/p/d (Lam Dong Provincial Peoples Committee, 2003) was used. Actual coverage with drinking water supply was also taken into account.

The domestic wastewater load was then visualized in the GIS in the same way as the data on industrial wastewater load, allowing for combined assessment.

For the final assessment the industrial branches were classified in five groups based on their BOD load The BOD loads produced by the urban and rural populations in all the settlements of a sub-basin were then combined. The load of BOD for domestic wastewater was also classified in the same five groups. In the next step the BOD loads of industrial branches and settlements were combined to obtain a BOD index. Each sub-basin received a BOD index, making it possible to compare the sub-basins.

3.6 Implementation

The methodology is ready for implementation for practical application. However, certain adaptations are recommended:

Firstly, the data input has to be coupled to data sources that are easily available to the institution and that are constantly updated. A good data source for the practical application would be, for example, the register of wastewater discharge approvals at the provincial Departments of Natural Resources and Environment. Databases of water supply companies and industrial zone administrations are also potential sources.

Furthermore, the catalogues of typical wastewater loads per industry have to be refined to more accurately reflect Vietnamese conditions. However, as long as reliable values for Vietnam are not available, the application of values from other countries is admissible as a step towards realistic comparison of the impact of different industries.

4 CONCLUSION AND OUTLOOK

A GIS based Decision Support System for Integrated Water Resources Management has been developed. The method allows management of spatial and non-spatial data related to water resources, land use and socio-economy. Analysis of current status of water resources has been conducted using GIS tools to recognize deficit and problem areas as well as areas with a good ecologic status. The integration of modeling results allows making predictions for the very close future as well as the developments in the next 10 to 20 years. Proposed measures for water resources management can be evaluated and their impacts easily assessed and visualized in maps. Tools for cost estimation for proposed measures complement the methodology.

The application example of the estimation of wastewater discharge in the Upper Dong Nai illustrates how the spatial assessment of the wastewater load discharged in a river basin from both domestic and industrial sources can be conducted with help of the GIS. The methodology is part of a larger set of tools for the cross-sectoral evaluation of all kinds of water resource related information. Data about wastewater discharge can be assessed in combination with data about the vulnerability of water resources and many other types of information in order to create summary assessments to support decisions on management interventions. The proposed methodology has therefore a great potential to contribute to the implementation of Integrated Water Resources Management in Vietnam, as it addresses one of the greatest challenges: providing decision support information in a situation with only little available data.

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