BMBF-VNU-joint research project “Environmental and Water Protection Technologies of Coastal Zones in Vietnam” (EWATEC-COAST)

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Abstract

The project “EWATEC-COAST” (Technologies for environmental and water protection of coastal zones in Vietnam under climate change conditions) started in autumn, 2012. The project is funded by the German Federal Ministry of Education and Research (BMBF) as a part of the funding programme "CLIENT” and by the Vietnam National University of Ho-Chi-Minh City (VNU-HCMC). Study areas are the highly polluted inland water and estuary system of the Thi Vai river and the adjacent Can Gio mangrove forest. Both areas are located south-east of Ho-Chi-Minh City. In the past, various companies, which are mostly situated in industrial zones along the river, discharged wastewater without treatment into the river system. The Thi Vai river was therefore considered as ecologically dead. Most recently, the water quality of the river has been slightly improved because first control initiatives have been realized. A comprehensive strategy for the sustainable rehabilitation is still missing. EWATEC-COAST will significantly contribute to find ecologically and economically sound solutions for the rehabilitation of the affected water bodies, the fauna and the flora with focus on mangroves. Furthermore climate change impacts will be considered. Main task is the development and application of a model-based "management system" for sustainable water and environmental protection of the affected coastal zone. The system will serve for decision making. Components of the integrative system are meteorological data series for the past, present and future including climate change, and data on the quantity and quality of surface water and ground water systems, the mangrove ecosystem, aquatic organisms and coastal protection. Another

important task is the development and implementation of innovative water technology for the treatment of tannery wastewater. For this, a multi-stage pilot plant has been put in operation in an industrial zone located in the project region. The management system will be implemented at provincial and municipal authorities as well as research institutions and primarily serve as a planning framework. The project concept can be transferred to other regions of Vietnam and to other countries. First project results are very promising and confirm the suitability of the overall project strategy. Excellent perspectives for economic, scientific and technical exploitation of results are expected.

Key Words: EWATEC-COST, Vietnam, climate change, hydrologic modelling, hydrodynamic modelling, water quality modelling, Thi Vai river, Can Gio mangrove forest, coastal zone, environmental and water protection, tannery waste water.

1. Introduction

The country of Vietnam has more than 3000 km of coastline. Parts of the coast are frequently affected by devastating storm floods, often in combination with inland flood waters. The loss of lives, the economic losses and environmental damages are substantial. In addition to the threat caused by natural disasters, the environmental conditions have deteriorated significantly since the economic opening of the country in 1990 due to industrialization along many rivers and littorals. This critical situation is overlaid with the climate change and its consequences. For most of the coastal areas, these consequences with respect to the rise of the sea level and increasing extreme inland flood waters and low waters, respectively, have not been scientifically quantified. Moreover there is a lack of sustainable technologies in many areas – for example for the integrated management of surface and groundwater resources or for an efficient treatment of industrial wastewater. Water authorities and municipalities usually do not use well proved planning tools like management concepts or even model-based management systems for an integrated and sustainable water management. In the joint German-Vietnamese research project EWATEC-COAST (Technologies for environmental and water protection of coastal zones in Vietnam under climate change conditions), technologies and service tools for the sustainable improvement of an affected coastal zone located in southern Vietnam will be developed and provided. This project has been running since September 2012 and will last until about September 2015. The project is funded by the German Federal Ministry of Education and Research (BMBF) and the Vietnam National University of Ho-Chi-Minh City (VNU-HCMC). The research area of this project is the Thi Vai river landscape and the adjacent Can Gio Mangrove forest both being located about 2 hours south-east of HCMC. The German project partners are coordinated by the Leichtweiss Institute (LWI) for Hydraulics and Water Resources of the University of Braunschweig. The Vietnamese project coordinator is the Institute for Environment and Resources (IER) of the VNU-HCM.

The main objective of the project is (1) the development and application of a model-based "management system" for the sustainable protection of water, environment and human beings in coastal zones and (2) implementation of water technology with focus on industrial waste water man-

agement. The results of the water technology part will be accounted for by the management system. This planning instrument enables to identify and optimize combined measures for a sustainable improvement of the environmental and living conditions of the designated coastal zone. Anthropogenic influences as well as the natural climate variability and future climate change will be examined within the project. The project concept can be transferred to other concerned regions.

2. Project Area

The project area covers the Thi Vai river basin and the Can Gio mangrove forest in South Vietnam (Figure 1).

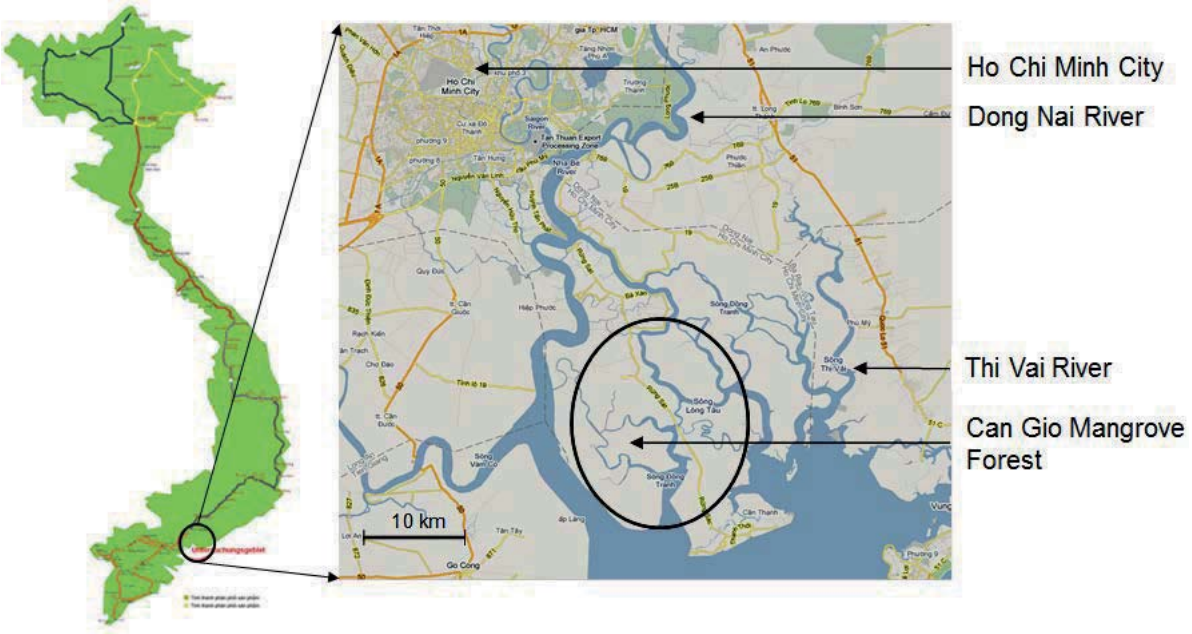

Figure 1. Project area "Thi Vai river" and "Can Gio mangrove forest ", modified map from Google 2011

The river has a length of 37 km from the Ba Ky weir to the sea mouth. The mean temperature of the Thi Vai catchment is about 28°C, the mean annual rainfall amounts to about 1800 mm. The area is affected by the tropical monsoon climate with a rainy season from May to November and a dry season from December to April. The whole river is strongly affected by tide. The Ba Ky weir has the task to prevent the salt intrusion into the upper part of the Thi Vai river. Towards downstream, the width of the

main river bed increases significantly up to 900 m. In addition to the main reach, several meandering subreaches exist. The river system is exposed to the strong tide. The daily tidal range is about 3 m. The strong tide effect hinders the transport of polluted inland river water into the sea. Until 2009, the Thi Vai basin was considered as a “hot spot” with regard to surface water pollution in Vietnam. The main reason was and still is the release of untreated industrial wastewater into the river system. From about 1994 to 2008, the large Vedan company released highly concentrated waste water into the main river Thanks to a partially improved control and punishment campaigns by local and superior authorities, the surface water quality of Thi Vai River has slightly improved in the recent years. A comprehensive strategy for a sustainable rehabilitation is still missing. Consequently, planning instruments and their implementation and application are essential for the region.

The Can Gio mangrove forest is located about 40 km south-east of Ho-Chi-Minh City and is a UNESCO biosphere reserve. It is about 760 km^2 in size and is adjacent to the Thi Vai river basin. The forest also serves as a protection barrier against storm floods which threaten Ho-Chi-Minh City. In recent years this nature reserve was ecologically damaged by erosion and sedimentation along the coastal zones, by aquacultures, inflowing untreated wastewater and oil spills. Parts of the soil had been chemically changed due to the reduced freshwater inflow from inland, saltwater intrusion from the sea and an increasing evaporation. Large parts of the trees and other resources in the Can Gio mangrove forest have therefore disappeared. Because of the expected rise of the sea level due to climate change and increasing pollution loads from the inland, a sustainable protection of this nature reserve is urgently needed.

3. Structure of the EWATEC-COAST project

The EWATEC-COST project is divided into 9 subprojects (SP) according to Figure 2. Components of the modelling-based subprojects are combined in SP 9 “development and application of a model-based management system for the sustainable protection of water, environment and human beings in coastal zones”. The SP 8 includes the installation, operation and optimization of a pilot plant for the treatment of wastewater from a tannery locat-

ed in an industrial zone at the Thi Vai river. Results of SP 8 will be considered in the management system.

Within the present project phase, the management system will reach the following working level:

- Analysis of the past up to the current state.
- Prediction of the effects of future climate changes and other factors on water and environment “without measures”.

The system will be transferred to the Vietnamese users, in particular to the Departments of Natural Resources and Environment (DONRE) of the concerned provinces, to municipalities and other institutions. The project partners will support the local users to develop planning variants “with measures” including environmental technologies against water pollution and adaptation measures to meet the climate change. It is foreseen that the management system will be extended in a future project phase to cover all relevant planning variants “with measures”.

It is emphasized that the development of the management system is accompanied by a supervisory group consisting of the future users - mainly DONRE personnel – and national and international advisors.

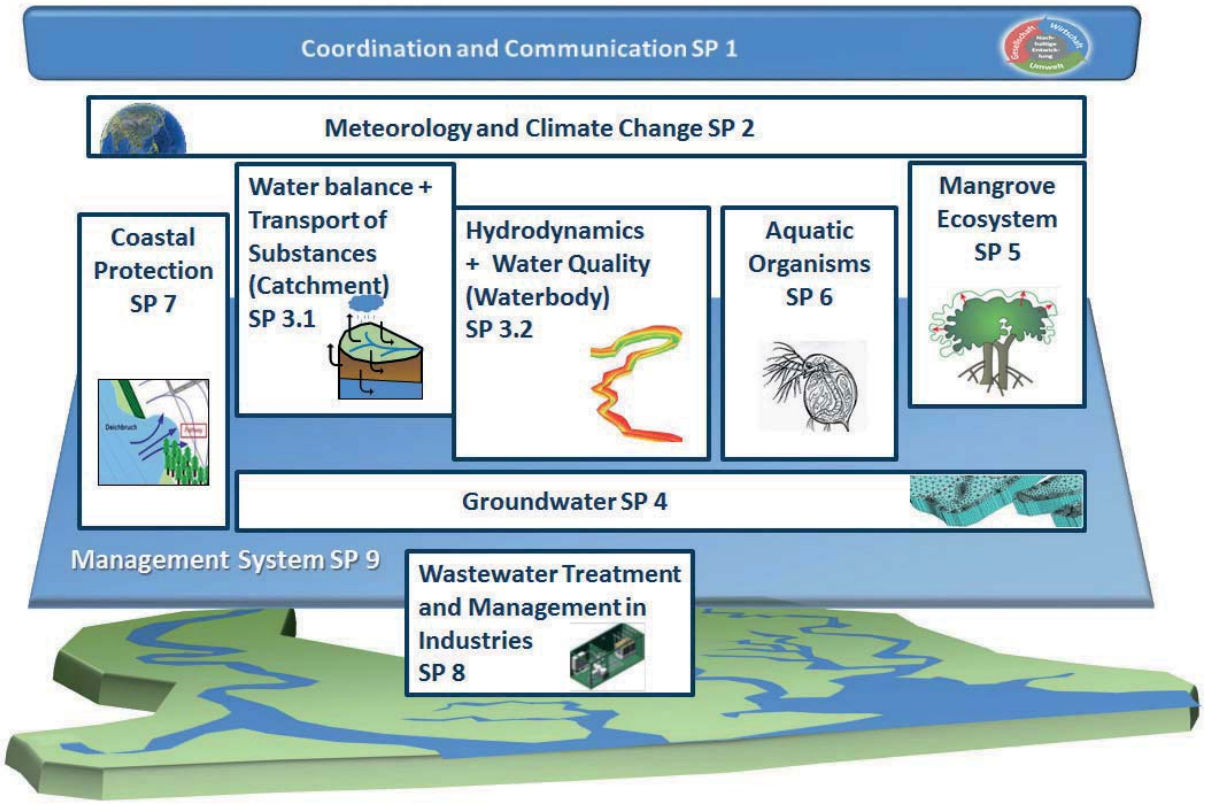

Figure 2. Structure of the joint research project EWATEC-COAST with a total of 9 subprojects

4. Subprojects

Subproject 1 has the task of professional and administrative coordination for the whole project. It is important to pay special attention to the successful content-related and methodological cross-linkage of the subprojects and cooperation between the Vietnamese and the German partners. Within the project, an EWATEC-COAST contact group (ECCG) was established. The group consists of members of the Vietnamese and German project coordinators who ensure that questions, problems or exchanges between the responsible scientists in the different subprojects can be continuously communicated. The ECCG is thus able to convey between the partners, to support existing contacts, as well as to build new contacts between German and Vietnamese partners. In addition, the ECCG cooperates with the stakeholders and the interested Vietnamese public such as Ministry of Natural Resources and Environment (MONRE), provincial Departments of Natural Resources and Environment (DONRE) and with the supervisory group mentioned in chapter 3 with the aim of developing an implementation plan of the project results.

Subproject 2 "meteorology and climate change" is linked to all subprojects in the management system (Figure 3). Weather and climate information (including precipitation, temperature, evaporation, air humidity, wind, radiation, sunshine duration) had been created as meteorological data series for the current situation (past to present) and for the future (approx. 2040-2070) by using state-of-the-arts methods. Meteorological data being available from the region and from international databases had been collected in cooperation with Vietnamese climate researchers. Using this data, the climate and its variability and extreme events were analyzed. In the next step, a statistic-dynamic downscaling based on the COSMO Climate Local Model (CLM) for the Thi Vai basin and the mangrove area has been conducted. The obtained long-term data series are being further refined with the help of a probabilistic regionalization. The results are used as an input for the water budget and water quality modelling in SP 3, groundwater modelling in SP 4, analysis of sea level in SP 7 and investigations of the mangrove ecosystem in SP 5. Particular emphasis is given on an appropriate spatial and temporal resolution of the climate data, as well as on quantitative and qualitative precision regarding the spatial projection. Hence, a relevant research focus is the quantification of uncertainty of scenario data by taking into account the different meteorological regional models and various greenhouse gas scenarios. The meteorological data sets will finally be provided to SP 9. Furthermore SP 2 includes air pollutant modelling for the research area. The assessment of air quality with increasing air pollution as a result of the population and industrial growth provides the basis for the devlopment of technologies to improve environmental and living conditions in the coastal region.

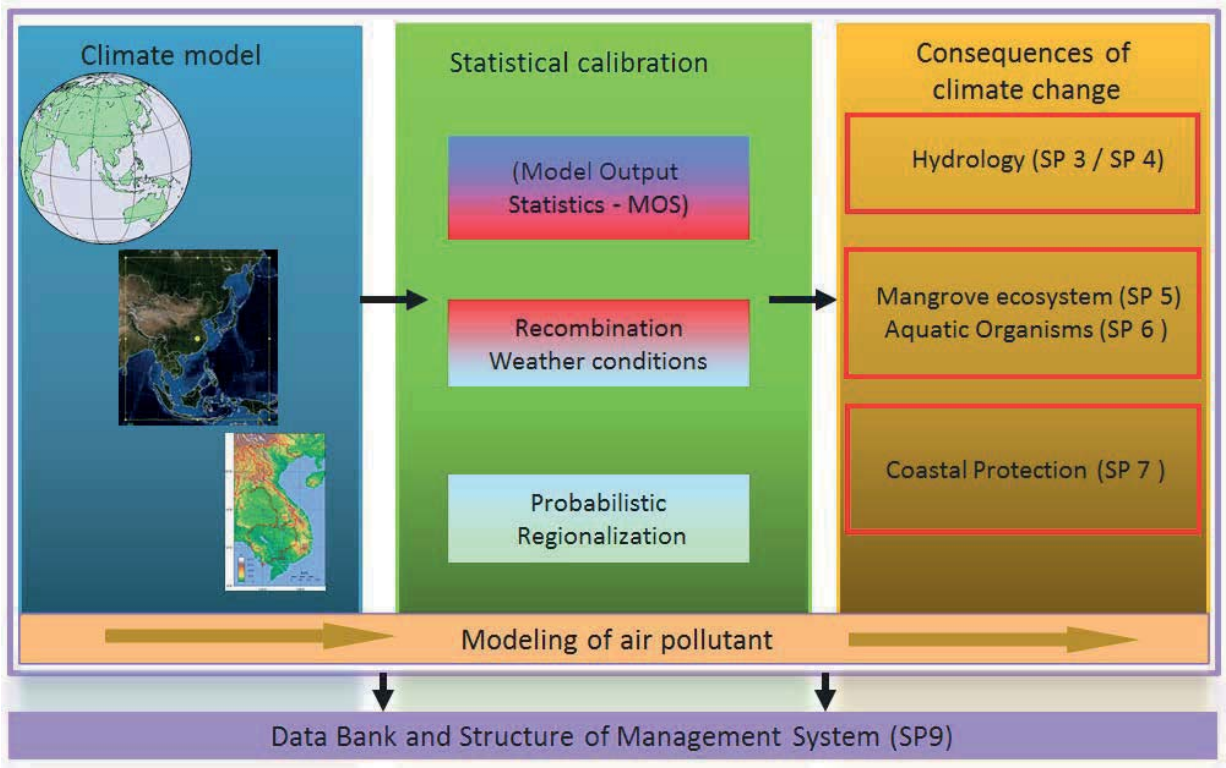

Figure 3. Working scheme of SP 2 "Meteorology and climate change"

Subproject 3 "surface water" is the core subproject for the water management system, since it includes the modelling of water resources with a focus on surface water quantity and quality (Figure 4). The SP 3 is thus closely related to all subprojects of the management system. The main objective of SP 3 is the development and application of a linked model system for long-term-continuum simulation. In this system, a model for the hydrological water balance and transport of substances (point and non-point sources) from the catchment into the river for the whole catchment area of the Thi Vai river has been developed. For this the model PANTA RHEI programmed by the Leichtweiss Institute, University of Braunschweig (see Riedel et al., 2011) was selected. This ecohydrological model or hydrological water quality model will be coupled with a hydrodynamic water quality model (DELFT3D, see Deltares, 2014) for the main river.

In addition to the meteorological data being available from SP 2, SP 3 requires series of hydrometric data and water quality data for calibration. These data were not available at the beginning of the project. Consequently, a monitoring program was performed. It consists of the installa-

tion and operation of 7 hydrometric stations – 3 at relevant tributaries, 4 along the main river - since early 2013 for a continuous measurement of the water level. With the help of ADCP technique, rating curves had been elaborated to transform the water level into discharge – a challenging task because of the strong tide and because of the increasing width of the main river bed towards the river mouth. For the water quality, water samples were taken at all stations in short time intervals and analyzed in a project laboratory which was installed in the industrial zone close to the pilot plant. The water quality measurement will end at the end of June 2014, and the water level measurement will last until the end of March 2015.

In the meantime, the models had been built up. The models are being individually calibrated with the measured data. After that, the models will be coupled in cooperation with SP 9 to form the management system. Process equations will be adjusted to the specific circumstances of the river. For the real situation (past to present) and future scenarios (2040-2070), meteorological time series will be provided by SP 2, and time series of the sea water level by SP 7. The wastewater pollutants load from point sources was collected from the provincial DONREs in cooperation with the Vietnamese partner institute IER. As a result, the impact of anthropogenic influences and climate change will be quantified for the variant "without measures”. The data, the model system and the results will be integrated in the management system (SP 9). After implementation of the management system at various users, the project partners will help the local users to set up first scenarios respectively planning variants “with measures”. Extension of the management system to deal with the latter variants is envisaged in a consecutive project phase.

Concurrently, SP 3 serves as an interface to SP 8 "water technology". Cleaning effects achieved with the pilot plant in of SP 8 will be integrated in the model chain of SP 3 at all existing sites of tannery factories. But also effects of (future) treatment facilities for other types of wastewater, e.g. from firms producing tapioca starch, will be considered. For the latter, results from the completed German-Vietnamese research project TAPIOCA (Meon et al., 2013; Le Huyen et al., 2012) will be used.

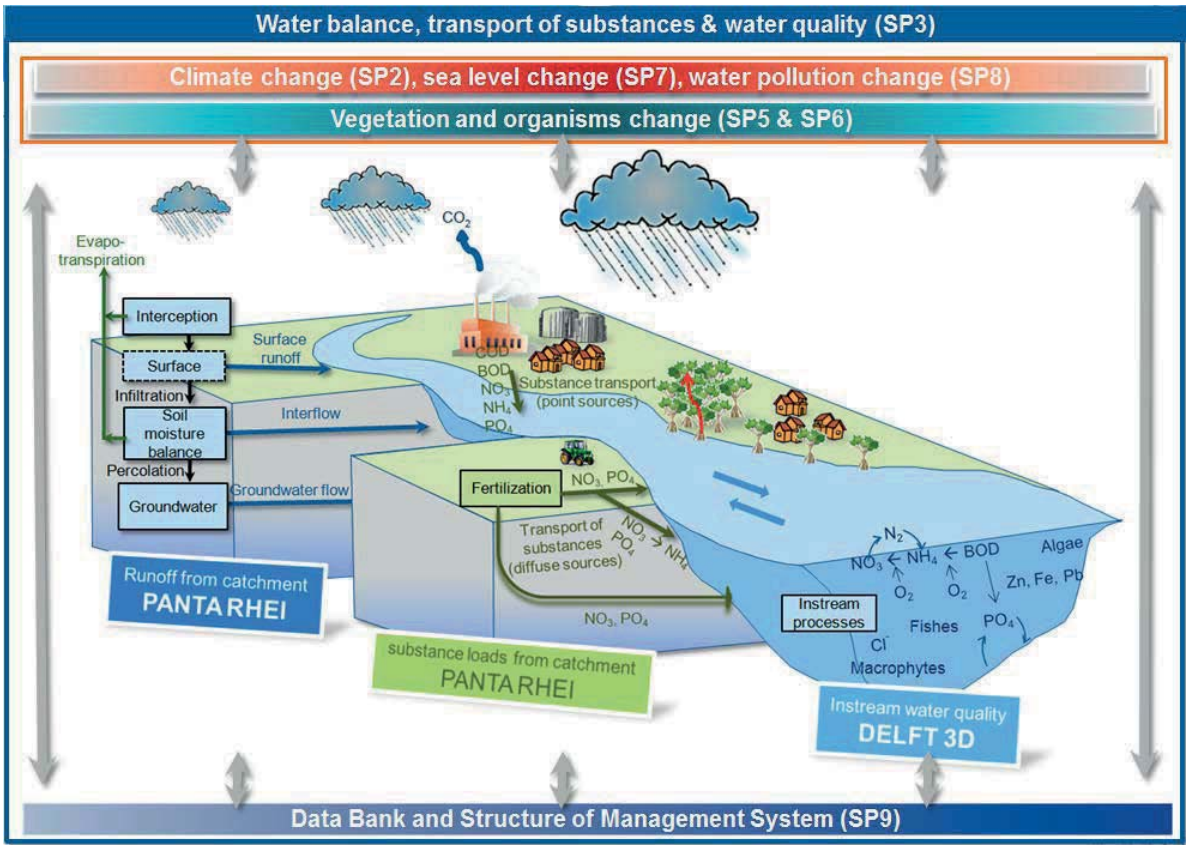

Figure 4. Working scheme of SP 3 "surface water"

Subproject 4 "ground water" is mainly linked with SP 3. The main objective is the development and the application of a regional groundwater model for relevant parts of the Thi Vai river basin. Due to the heavily pollution of surface water in the research area, groundwater is intensively used for domestic water supply, irrigation and for industrial water supply. The overexploitation of water, the salt intrusion in conjunction with changing climatic conditions requires a sustainable groundwater management as part of an integrated water resources management. The working scheme of SP4 is displayed in Figure 5.

Because of the weak data situation, own groundwater observation stations were established and are being operated together with the Vietnamese partners. In parallel the hydrogeological model FEFLOW (DHI-WASY, 2014) was set up. First results will be showed during the conference. The simulation for the current situation and the future situation is carried for the same periods as in the SP 3.

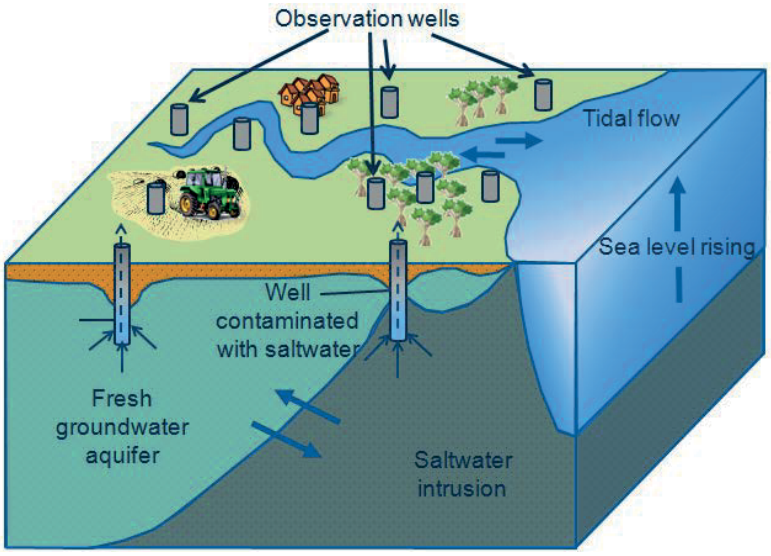

Figure 5. Working scheme of SP 4 "ground water"

In **subproject 5** "mangrove ecosystem", mangrove trees and forests are investigated with focus on their functioning as natural wetlands for the cleaning of polluted river water in the estuary system. Aim is to develop a model for the propagation and the degradation of pollutants by phytoremediation within a river basin (Figure 6). For this purpose, the processes describing the absorption of substances by roots, their distribution and degradation were already implemented in a local (point) mangrove model which represents a single mangrove tree. On the basis of the local model a simplified reactor model is being developed. The reactor model is characterized by the composition of the mangrove ecosystem, stocking density, soil properties, salinity and the hydrological regime. The next step is the upscaling from the reactor scale to a larger landscape scale (mangrove catchment) which includes simplified mass transport in the river system. In addition, the option of coupling the landscape model with the complex water quality model of SP 3 will be examined.

For the calibration of the local scale model, local field measurements regarding the degradation are being carried out together with the Vietnamese partners. Totally, 6 plot stations on the forest site and located along the Thi Vai river and 6 other plot stations located inside the Can Gio mangrove forest were selected. Vegetation and soil samples of these 12 stations were taken and analyzed in Germany. In addition, a greenhouse was

constructed in July 2013 in collaboration with the IER. The purpose of the greenhouse is to test the capacity of mangrove trees in taking up contaminants. The first samples were harvested in November 2013 and analyzed by the IER. The landscape model should be able to predict the pollution in the Thi Vai River in dependency of the remediation potential of mangrove forests. The results are required for the development and quantification of protection technologies which can be quantified within the management system.

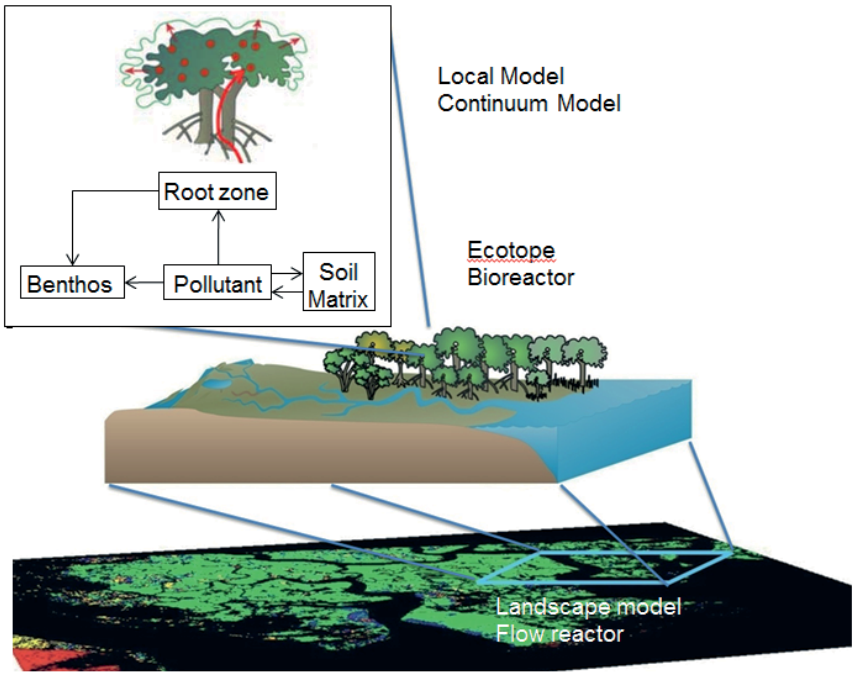

Figure 6. Working scheme of SP 5 "mangrove ecosystem"

In **subproject 6** "aquatic organisms" long time information (one to several decades) about water quality and water balance are derived by analysis of aquatic organisms (Figure 7). This information supplements the data inventory of water quality data. It can be compared with the new data from the monitoring program and the results of model simulations of SP 3. Within SP 6, sediment samples from the mangrove forests and the Thi Vai river estuary were taken. Physical parameters, nutrient contents and heavy metal were measured at the laboratory of IER. Species of aquatic organisms had been analyzed. On the basis of fossil species associations from continuously deposited sediments and the geochemical sig-

nature of the sediments, the development of the mangrove and estuarine ecosystem for the past decades is planned to be reconstructed.

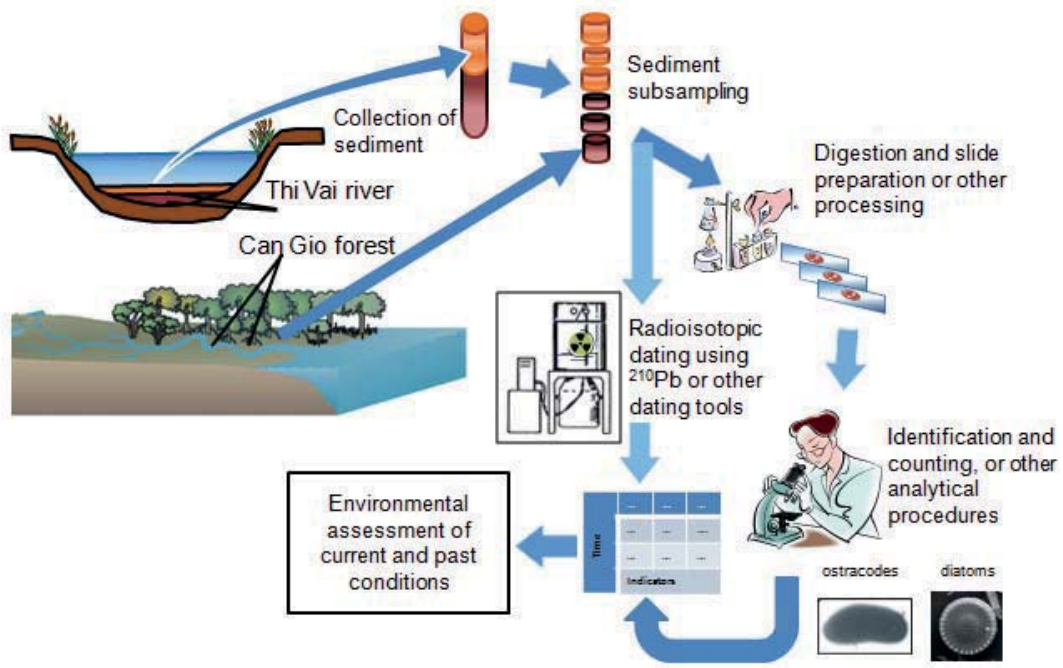

Figure 7. Working scheme of SP 6 "aquatic organisms"

The focus of subproject 7 "coastal protection" is on hydrological system and risk analysis of the coastal subarea stretching along the project region. Climatic and anthropogenic changes in the study area will be taken into account (Figure 8). The systems analysis is essential to develop a sustainable coastal protection strategy. Like in the other subprojects, existing data series of the corresponding sea water level were firstly collected and evaluated. These data are used as boundary conditions for the models of SP 3, 4 and 5. Based on time series analysis of these data, statistical analysis of the mean sea level (MSL) and of extreme discharge values observed in the Dong Nai river basin had been derived. These values were then transferred to the Thi Vai river basin. Both analyses are statistically superimposed for the purpose of identifying seaside and inland extreme situations and creating forecasts. The results are incorporated as boundary conditions in the hydrodynamic calculations of extreme flood inundations (landfall of tropical cyclones) in the coastal zone by means of DELFT 3D. For future extreme events in the coastal and estuary flood zones, the expected annual risk of loss of life and the annual economic risk costs will be estimated. For this purpose specific damage val-

ues are required and will be set up together with Vietnamese partners in the region. Quantitative risk indices such as the annual hazard and potential for damage for the period "past to present" and period "future without measures" will be determined. These parameters are used for a first development of technical and natural protection technologies. This work is strongly supported by Vietnamese partners at the VNU-HCMC. The integrative analysis of overlapping inland and sea-side extreme events, but also the modelling of the protective effect of existing mangrove forests to the reduction of the spread of storm surges in the coastal zone is a scientific challenge.

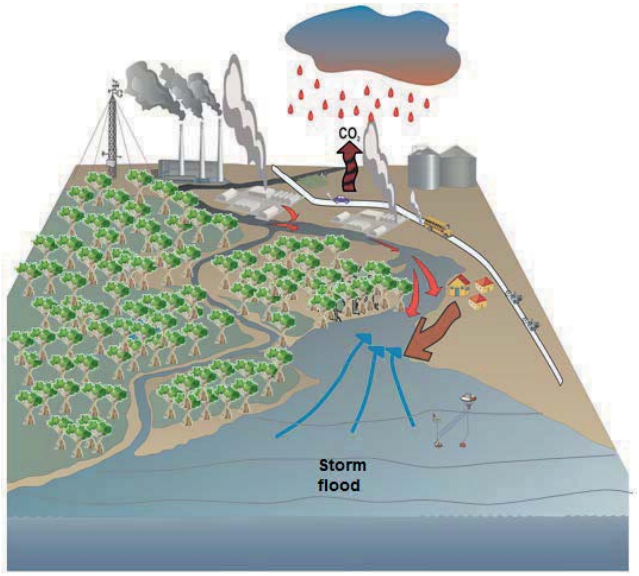

Figure 8. Working scheme of SP 7 "coastal protection"

Subproject 8 "industrial water management" refers to industrial waste water treatment and process water optimization. In this subproject, a pilot plant for leather wastewater treatment using German process engineering was developed. The pilot plant is now being further adapted to the on-site conditions and optimized during the project. A membrane bioreactor was built in Germany and shipped to Vietnam. It arrived in Vietnam in April 2013. Existing parts of the pilot plant from the former TAPIOKA project (Huyen Le et al., 2012) – in particular the anaerobic reactor (type EGSB) and a microflotation equipment - were removed from the old pilot plant location in the Tay Ninh province to the selected leather factory. This factory is located in an industrial zone located at the upper