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The integrated project AquaTerra of the EU sixth framework lays foundations for better understanding of river–sediment–soil–groundwater systems

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Abstract

The integrated project "AquaTerra" with the full title "integrated modeling of the river–sediment–soil–groundwater system; advanced tools for the management of catchment areas and river basins in the context of global change" is among the first environmental projects within the sixth Framework Program of the European Union. Commencing in June 2004, it brought together a multidisciplinary team of 45 partner organizations from 12 EU countries, Romania, Switzerland, Serbia and Montenegro. AquaTerra is an ambitious project with the primary objective of laying the foundations for a better understanding of the behavior of environmental pollutants and their fluxes in the soil–sediment–water system with respect to climate and land use changes. The project performs research as well as modeling on river–sediment–soil–groundwater systems through quantification of deposition, sorption and turnover rates and the development of numerical models to reveal fluxes and trends in soil and sediment functioning. Scales ranging from the laboratory to river basins are addressed with the potential to provide improved river basin management, enhanced soil and groundwater monitoring as well as the early identification and forecasting of impacts on water quantity and quality. Study areas are the catchments of the Ebro, Meuse, Elbe and Danube Rivers and the Brévilles Spring. Here we outline the general structure of the project and the activities conducted within eleven existing sub-projects of AquaTerra.

Keywords: EU integrated project; Organic and inorganic pollution; Soil; Sediments; Groundwater; Surface water; Climate change; Land use change; River basin scale; Management tools; Transport-hydrological and climate modeling

1. Introduction

As one of the first environmental Integrated Projects within the sixth EU Framework Program, "AquaTerra" has been active since June 2004 and will continue until May 2009. The project has the full title "Integrated modeling of the river–sediment–soil–groundwater system; advanced tools for the management of catchment areas and river basins in the context of global change" and hosts a multidisciplinary team of 45 partner organizations in 12 EU countries as well as in Romania, Switzerland, Serbia and Montenegro. Scientific management of the project is carried out by the Center for Applied Geoscience at the University of Tübingen (ZAG), while the associated company, Attempto GmbH, ensures financial and administrative management.

The project is integrated across various disciplines that range from biogeochemistry, environmental engineering, computer modeling and chemistry to social sciences. The work involves researchers, but also practitioners and end-users such as policy-makers, river basin managers and regional and urban land planners. The principal task of AquaTerra is to provide the foundations for an improved understanding of the behavior of environmental pollutants. New field and laboratory as well as historical data are assembled and addressed for the catchments of the Ebro, Meuse, Elbe and Danube Rivers and the Brévilles Spring (Fig. 1).

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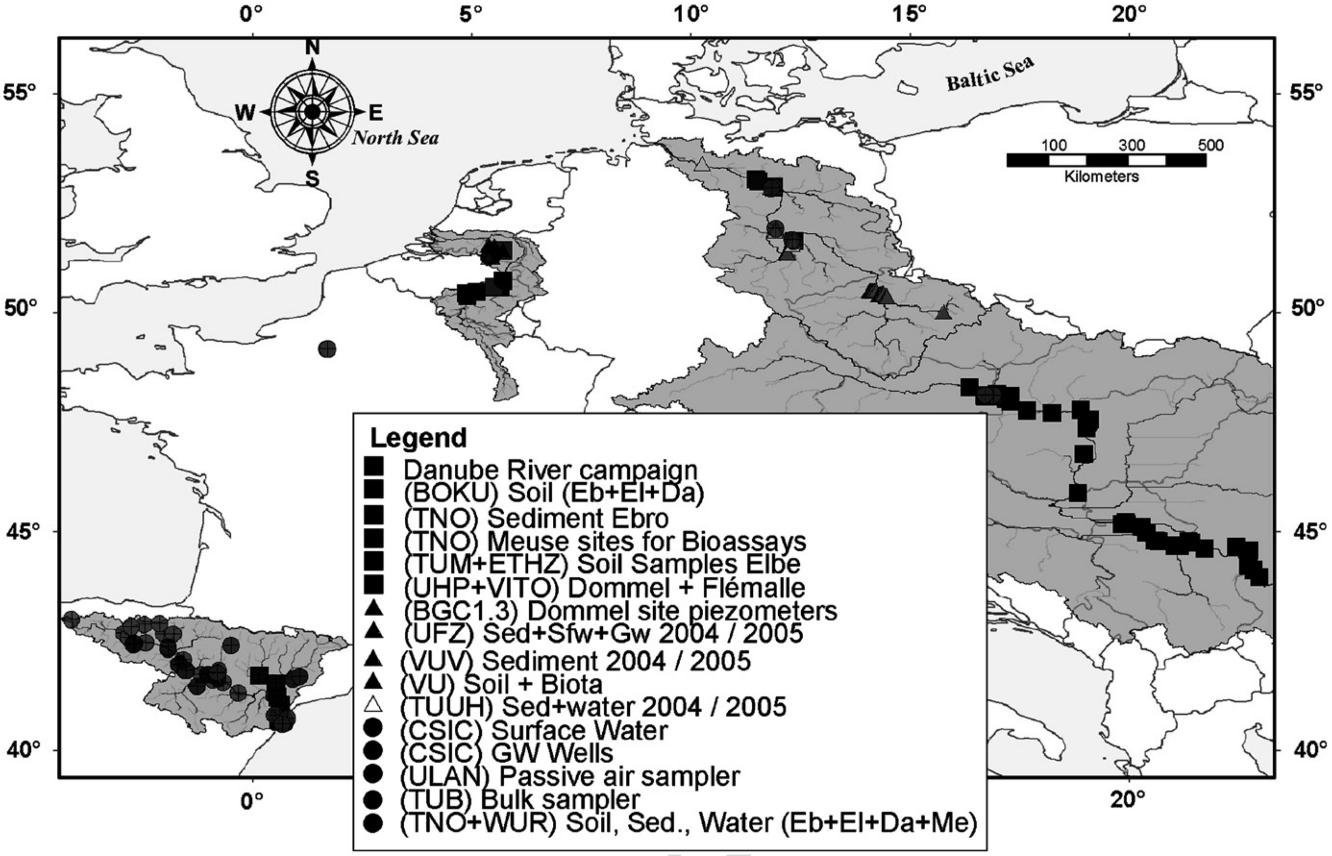

Fig. 1. The four AquaTerra river basins (Ebro, Danube, Elbe and Meuse) and the French catchment Brévilles. More than 1700 samples were collected in the first project year. BOKU = University of Natural Resources and Applied Life Sciences, TNO = Netherlands Organization for Applied Scientific Research, TUM = Technische Universität München, ETHZ = Eidgenoessische Technische Hochschule Zürich, UHP = Université Henri Poincaré Nancy, VITO = Flemish Institute for Technological Research, BGC = BIOEGEOCHEM, VUV = Masaryk Water Research Institute Prague, UFZ = Umweltforschungszentrum Halle-Leipzig, VU = Vrije Universiteit Amsterdam, TUHH = Technische Universität Hamburg-Harburg, CSIC = Consejo Superior de Investigaciones Cientificas, ULAN = Lancaster University, TUB = Eberhard-Karls-Universität Tübingen, WUR = Wageningen University. Map was created by David Kuntz.

Based on these biogeochemical, climatological and material flux data, new simulation models are being developed to improve our understanding of trends and pollutant transport with respect to soil functioning and the water cycle. These models integrate key biogeochemical and hydrological processes from the laboratory bench- to the river basin scale. Further conceptual integrated models are developed to characterize and assess the direct (physico-bio-chemical) and indirect (socio-economic) impacts of global change. They will provide science-based decision support systems for river basin management.

AquaTerra is divided into 11 sub-projects that each have several work packages. Sub-projects and work packages provide information and logistical support to each other (Fig. 2). The sub-projects are called BASIN for field work logistics and contact with stakeholders, BIOGEOCHEM for biogeochemical and sorption investigations, FLUX for flux determinations, TREND for spatial and temporal trend analysis, MONITOR for development of new analytical techniques in the field and laboratory, HYDRO for consideration of climate scenarios and COMPUTE for hydrological and transport modeling. Further sub-projects with focus on social sciences are INTEGRATOR to establish links to stakeholders such as water agencies and river basin managers and EUPOL to detect gaps between science and European environmental policy development. An additional sub-project, KNOWMAN, has the role of knowledge transfer and dissemination, while the sub-project PROMAN has the role of administrative and scientific management of the project.

A large amount of information about new results and recent project advances from the 11 sub-projects is available on the AquaTerra Website (http://www.eu-aquaterra.de/).

2. The detailed structure of AquaTerra

The sub-project BASIN investigates selected areas of the river basins and catchments named above (Fig. 1). A work package has been defined for each of the five case-study areas to summarize specific research demands, coordinate research activities and to provide existing data as well as

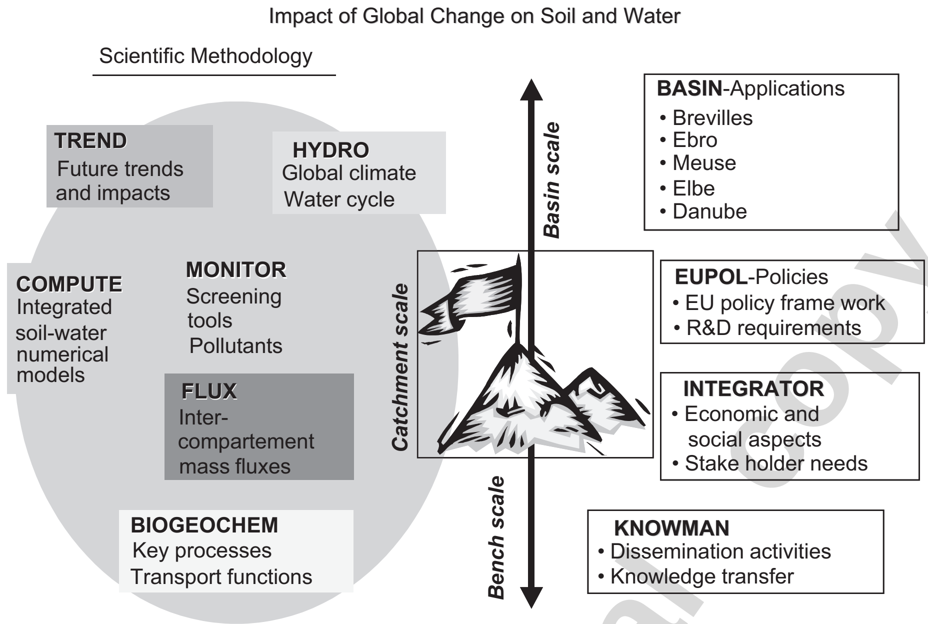

Fig. 2. The 10 sub-projects of AquaTerra working on different levels and scales. The sub project PROMAN is not shown here as it has administrative character.

links to stakeholders. BASIN provides field research logistics and data to the other sub-projects and connects the scientific research of all AquaTerra partners to selected case studies. BASIN has the two main objectives of (a) investigating soil–groundwater–river processes and (b) examining fluvial bottom sediments as well as flood-plain–sediment–river interactions. Water, soil and sediment quality are given special consideration in view of possible changes in drying–wetting cycles that may influence their filtration, buffering and transformation functions.

Building on this, BIOGEOCHEM quantifies filtration, turnover and transport functions mainly in the vadose zone to yield better understanding of the fate of pollutants in soils and sediments. Processes investigated include the enhanced transport of solid matter and pollutants in subsurface and surface waters, the interaction of pollutants between solids and water (sorption, partitioning, desorption), biodegradation and the influence of changing redox-conditions and their impacts on water and soil quality. The work also considers inorganic and organic pollutants, which are influenced by environmental properties such as persistence, bioactivity and flux as well as dispersion behavior.

In collaboration with the above, the sub-project FLUX studies the transport of inorganic and organic solids and solutes to evaluate the effects of changes in land use. Particular focus lies on the transition of pollutants across boundaries of environmental compartments (Fig. 3). The sub-project aims at quantifying the fluxes from precipitation, sub-surface and river flow and incorporates the sources and sinks of contaminants within soils and sediments. Studied processes include atmospheric deposition and re-volatilisation of persistent organic pollutants such as pesticides, PCBs and PAHs, with input/output mass balances (F1 in Fig. 3). Investigations also include mass balances and the determination of solute discharges from groundwater into the river system and vice versa (F2 in Fig. 3). FLUX further aims to establish basin-scale fluxes of dissolved species and chemicals bound to solid matter (F3 in Fig. 3). This includes determinations of input and output budgets through geochemical signatures of several natural and anthropogenic end-members (e.g. rock weathering, agricultural and urban sources). Another issue is to determine how suspended matter originates from different parts of basins through geochemical signatures. Furthermore, this work includes extensive comparative analyses of river particulate fluxes at the basin scale by conventional and newly designed geo-acoustic methods. Investigation of sediments and soils also relies on collaboration with BIOGEOCHEM to elaborate details of sinks through biodegradation and sorption as well as closer investigation of particulate and colloid-facilitated transport.

The sub-project TREND addresses improved understanding of temporal and spatial variabilities of soil and water quality by extrapolating historical data into the future. It focuses on the long-term behavior and biological impact of contaminants and investigates their fate due to anthropogenic changes and natural perturbations of the soil–groundwater–sediment–river system. Changes in ecological soil functions are mapped by using a chronosequence approach that accounts for soil formation processes and land use impacts (Fig. 4). TREND also provides spatial subdivisions of groundwater systems in selected basins and establishes links between historical environmental changes

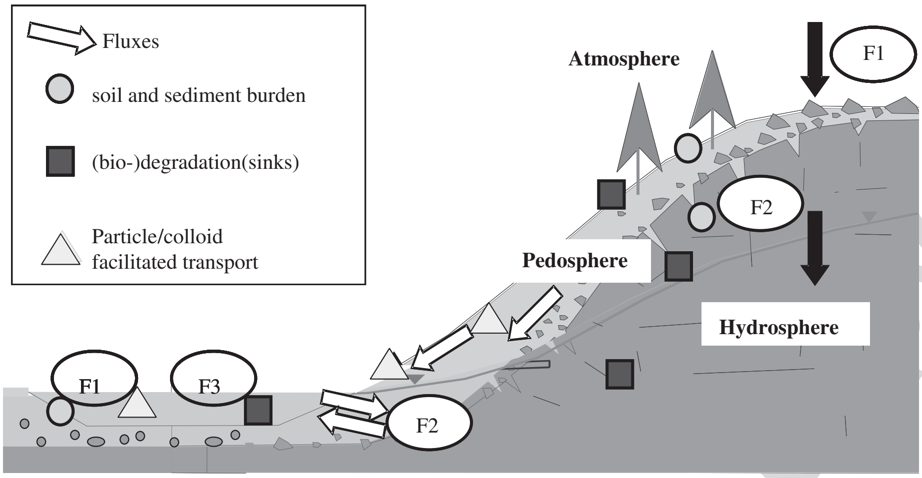

Fig. 3. Potential fluxes through the atmosphere, soil, sediment, groundwater and river system showing different forms of transport and sinks. Investigations include atmospheric deposition and re-volatilization of persistent organic pollutants (F1), the determination of solute discharges from groundwater into the river system and vice versa and the establishment of mass balances in the infiltration/seepage area from groundwater to surface water and vice versa (F2). Further aims of this sub-project are to establish basin scale fluxes of dissolved species and of chemicals bound to solid matter (F3).

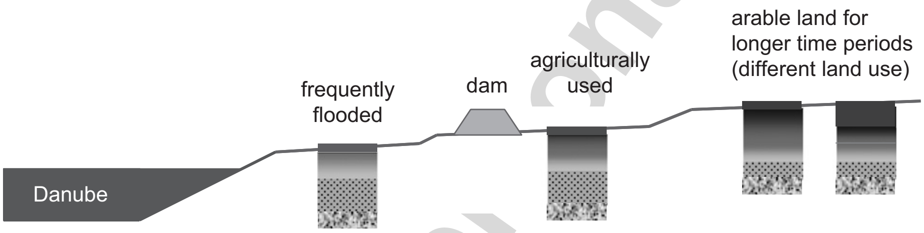

Fig. 4. Chronosequence of soils in the Danube floodplain following changes in the soil functions due to soil formation and land use.

and groundwater chemistry. This yields a better understanding of the functioning of ecosystems and their temporal evolution as a result of environmental change. A further aim is to develop data-records based on artificial neural networks (ANN) for trend analysis in river basins.

In support of the other sub-projects, MONITOR develops and validates new analytical techniques for fast screening and innovative monitoring. This includes the development of time-integrated passive sampling techniques and the integral screening of magnetic proxies to map environmental impacts in top-soils. The sub-project also investigates selected EU priority substances and emerging contaminants, including persistent organic pollutants (POPs) such as pesticides, pharmaceuticals and flame retardants. To date, emerging contaminants are poorly characterised on regulatory lists and therefore there is an acute need for unified analytical methods and protocols. MONITOR works to close these gaps through the validation and harmonization of existing and new protocols. This will also improve the understanding of storage and turnover of these compounds in the environment.

The sub-project HYDRO provides data to allow evaluation of the impacts of climate change on the water cycle. This includes water quality and quantity as well as soil functions. It will bring together innovative methods in generating climate and rainfall scenarios to drive integrated surface–subsurface models developed by other sub-projects. Such a synergy has not previously been realised and will provide a much needed understanding of the role of precipitation variability in the key biogeochemical processes in soils and sediments (through FLUX and BIOGEOCHEM), their influence on water quality and quantity (through COMPUTE) and changes in these relationships under perturbations of climate and land-use (TREND). The sub-project will also provide a detailed water budget for the Brévilles catchment and observed climatic variables such as precipitation, temperature, humidity, potential evapotranspiration and wind speed for the four river basins. These will be used within the sub-projects FLUX, BASIN and COMPUTE. HYDRO also focuses on the spatial and temporal downscaling of climatic variables from global climate model outputs to the catchment scale. Here state-of-the-art climate model projections will be combined with new and emerging downscaling methods to provide future climate scenarios to the other sub-projects. For example, by combining dynamic downscaling approaches with stochastic rainfall modelling, daily rainfall series of more than 1000 years duration can be generated and applied within COMPUTE to drive integrated and up-scaled river basin models.

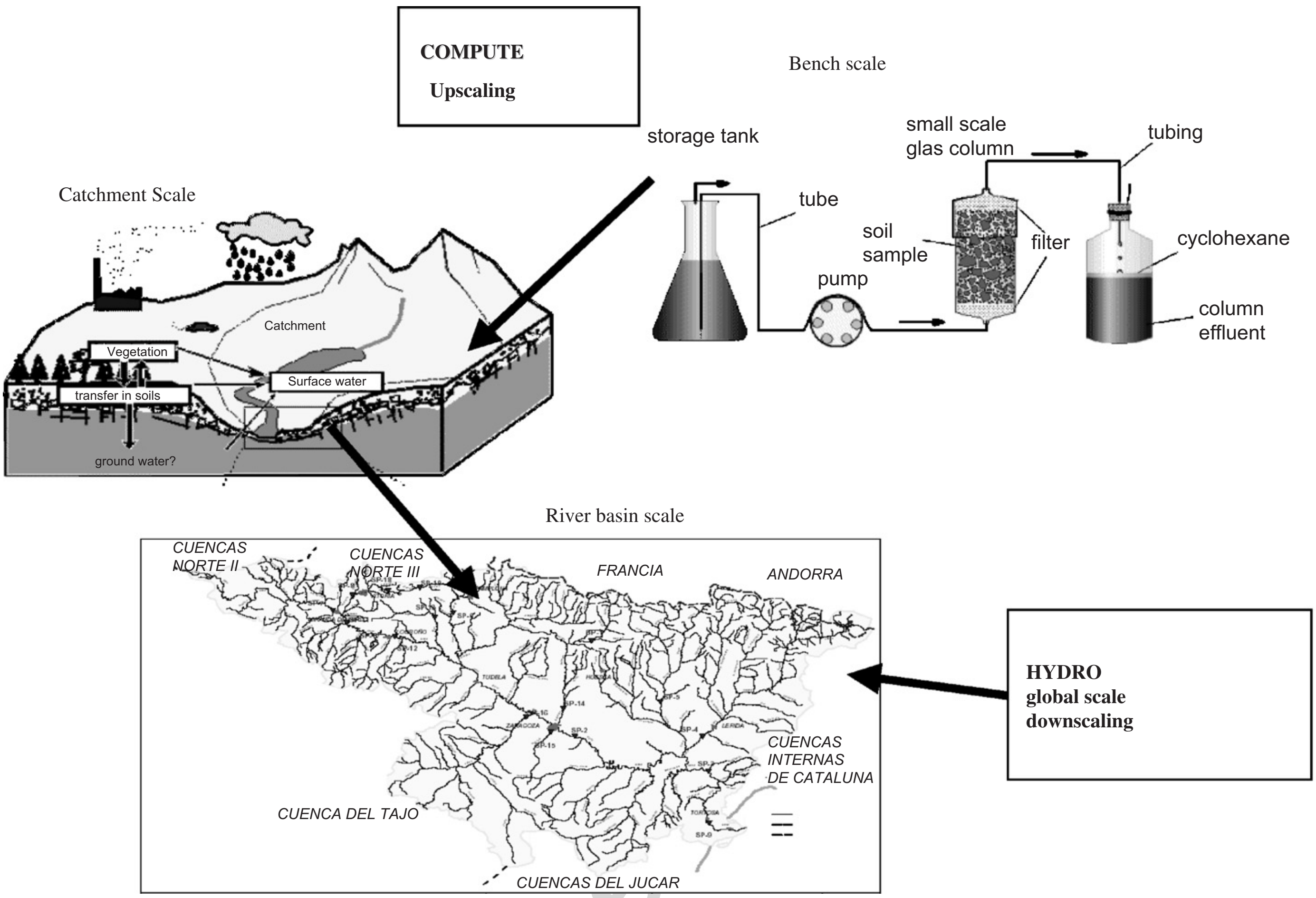

Fig. 5. Merging of scales including the up-scaling from laboratory bench experiments to the river basin scale by COMPUTE and downscaling from the global climate models by HYDRO.

COMPUTE uses historical data and new outputs from the above sub-projects to develop modeling approaches at various scales. For example, effects of land use changes on water quantity and quality at various scales (from the laboratory bench to catchments) will be investigated (Fig. 5). The understanding of relevant physical, biological and chemical processes gained at the bench-scale will be applied to larger scale models through systematic up-scaling processes. This retains the essence of the phenomena under investigation while neglecting less important details that are difficult to characterize at the basin scale. The most relevant novelties that COMPUTE adds to AquaTerra include coupling of large-scale hydrologic modeling with innovative methodologies for generating climatic scenarios and development of simplified biogeochemical models through interactions with other sub-projects. Another integral part of COMPUTE will be the development of up-to-date software tools and user instructions to provide a modern modeling framework for river basin management in Europe and elsewhere.

In the above framework INTEGRATOR aims to merge results from the natural sciences with the economic and social sciences by integrating new knowledge and stakeholder needs. This will be achieved by developing approaches and conceptual tools for decision- and policy-makers with a focus on local stakeholders. Decision support systems incorporate scientific results of AquaTerra, thus providing a first scientific basis for decision-making. For instance the participatory scenario process was identified in the first project phase as the most relevant for river basin management. It comprises the pre-, actual and post-scenario phases. This approach lists the following goals for the management of scenarios: (1) creating consensus, (2) anticipating possible future policy questions, (3) becoming sensitized to current and future developments such as economic growth, (4) comparing different policy options with respect to costs and impacts, (5) creating a baseline for negotiations and (6) developing future visions. INTEGRATOR has the main goal to develop and analyze impacts of various economic and environmental change scenarios on the groundwater–soil–sediment–river system. The key driving forces are identified using a drivers–pressures–states–impacts–response (DPSIR) approach. In this approach factors of influence are ranked according to importance and uncertainty, using relevant indicators (Table 1).

In close connection to this, EUPOL defines knowledge gaps for future EU policies that deal with climate change,

Table 1
Preliminary example of possible indicators for INTEGRATOR

Category of driving forces	Examples of factors/indicators influencing soil–water system
Socio-economic	Population growth, spatial distribution of population (population density, population migration), income, lifestyle, water price, Gross Domestic Product per activity sector, etc.
Agriculture/forestry	Agricultural area, agricultural production and productivity, extent of the irrigated area, irrigation water efficiency, forest surface, etc.
Industry/energy	Level and structure of the industry, industrial change, industrial water use, indicators on technological innovation (e.g., related to water pollution), etc.
Urban/domestic	Development plan, growth of urban land use, number of households, domestic water use, etc.
Environment	Climate change (temperature, precipitation, etc.), soil characteristics, topography, change in biodiversity, etc.
Policies	Policies related to soil-water system (water, land use, agricultural, industry, other) including subsidies, taxes, etc.

soil and water quality, land use and pollution. On the one hand, it investigates the missing scientific background needed for such policies and on the other hand identifies information that AquaTerra can provide. In order to elucidate details, meetings with stakeholders have already taken place and further ones are planned. Furthermore, interviews with policy-makers at the European level have also been performed. Combined with contributions to European events such as the Vita Soil Conference or the Common Forum on Contaminated Sites Management, key pressures on the river–sediment–soil–water system have been identified. They include the diffuse pollution of water, insufficient wastewater treatment, and inefficient water use in agriculture. Preliminary responses that may be necessary were assessed together with existing information gaps.

The sub-project KNOWMAN disseminates project results to scientific and stakeholder communities through workshops, seminars, publishing activities and the AquaTerra Internet pages. It maintains links with all the other sub-projects, the steering committee, and peer review panel members of AquaTerra who assess results obtained from the different sub-projects in order to provide a network for evaluating and disseminating the project results. For instance, the first workshop on experimental and monitoring techniques took place in Tübingen (Germany) on September 26–27, 2005 and further courses on analytical techniques as well as modeling techniques and software demonstration are planned (cf. http://www.attempto-projects.de/aquaterra/31.0.html).

Finally, the sub-project PROMAN covers the overall management of the project. The activities are supported by the AquaTerra Website, which is accessible to the public and to the consortium.

3. Work undertaken so far

Integrated work among the various partners has so far led to the collection of more than 1700 samples across Europe (Fig. 1). Further additional activities are listed here with the acronyms of the responsible sub-projects in brackets:

- A sampling campaign on the Danube in August 2004 with collection of sediments, water fish and benthic organisms from 30 stations in six different countries along an 1150 km-stretch of the river (BASIN).
- The collection and analysis of sediment, water and suspended sediment samples on the Dommel, a tributary of the Meuse (BASIN, FLUX).
- The screening of available spatial and temporal datasets for the selected five catchments with identification of sampling points and review of available climate data from former projects (BASIN, HYDRO).
- The collection of 124 sediment and water samples in the Ebro Basin for microbiological investigation of organic contaminant degradations (BIOGEOCHEM).
- The installation of passive samplers in the Danube, Elbe, Ebro and Brévilles basins to measure fluxes of persistent organic pollutants such as polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) (BIOGEOCHEM, FLUX).
- The collection of nearly 400 soil samples in the Danube, Ebro and Elbe basins to assess the retention properties of solutes in soils from different time periods that influenced soils by various land uses and climates (TREND).
- Magnetic susceptibility screening to map magnetic anomalies as a proxy for sources of environmental pollution (MONITOR).
- A review of climate model data for future scenarios for impact studies including review of existing downscaling methods for climate change scenarios and the development of new scaling methods (HYDRO).
- The development of a participatory approach for building scenarios of environmental and economic change. Such actions involve stakeholders from the river basin management community and aim to prevent negative environmental impacts (INTEGRATOR).
- Interviews and brainstorming meetings with decision makers at European, national, regional and local levels. Meetings considered soil, water and land use sectors including agriculture, urban areas and industry. The aim was to identify key pressures and gaps in legislation and the technical tools that are necessary for river basin management (INTEGRATOR, EUPOL).

Additional project activities have included various specialist meetings, the publication of internal reports and national as well as international peer-reviewed manuscripts (Eljarrat et al., 2004; Kolditz and Bauer, 2004; Seuntjens et al., 2004; Zanotti et al., 2004; Beinhorn et al., 2005; Botter et al., 2005; Chen et al., 2005; Eljarrat et al., 2005; Hermand and Holland, 2005; Kalbacher et al., 2005; Kolditz et al., 2005; Meyer and Hermand, 2005; Barth et al., 2006; Brouyère, 2006; Eljarrat and Barcelo, 2006; Lacorte et al., 2006; Lair et al., 2006; Meyer et al., 2006; Ratola et al., 2006; Rinaldo et al., 2006a, b; Roulier et al., 2006). This is complemented by a series of press releases and public newspaper, radio and TV appearances. The AquaTerra consortium also had a special session at the ConSoil conference in Bordeaux (3–7 October 2005).

4. Conclusions

The above descriptions have shown that AquaTerra is an ambitious project for several reasons. First it is a logistical challenge to unite a large group of researchers, stakeholders and policy makers across a wide range of disciplines and geographical regions across Europe. This challenge is met by a management team that divides administrative and scientific tasks. Modern means of communication including an Internet platform for exchange of results and data but also ample scientific meetings among the various groups are indispensable tools for such management. Furthermore, the structure of AquaTerra with its division into sub-projects and subdivided work packages spreads responsibilities to individual researchers who are at the same time specialists in their field. This allows better links between science and management as well as to the European Commission.

The other challenge is to unite a large variety of specialists with different expertize in one project and to develop a common sense of direction. This goal has been set from the very beginning of the project by the fundamental objective to provide the foundations for an improved understanding of the behavior of environmental pollutants.

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