INTEGRATION OF REMOTE SENSING PRODUCTS IN REGIONAL INFORMATION SYSTEMS TO SUPPORT DECISION MAKING IN LAND AND WATER MANAGEMENT IN CENTRAL ASIA

Ruecker, G.[1,*], Wehrmann, T.[1], Schettler, I.[1], Conrad, C.[2], Landmann, T.[2], Klein, D.[2], Fritsch, S.[2], Schorcht, G.[2], Mund, J.P.[1], Kuenzer, C.[1], Keil, M. [1], Mehl, H.[1], Dech, S.[1,2]
[1]German Remote Sensing Data Center (DFD), German Aerospace Center (DLR)
Muenchner Strasse 20, 82234 Wessling, Germany, [*]Corresponding author´s email
gerd.ruecker@dlr.de
[2]Chair of Remote Sensing, Institute of Geography, Julius-Maximilians-University Wuerzburg,
Am Hubland, 97082 Wuerzburg, Germany

Irrigated croplands are key assets in Central Asian economies. However, agricultural decision makers in Central Asia have to deal with multiple challenges in order to achieve sustainable crop yields. These include e.g. designing appropriate water distribution plans, achieving sustainable land use and targeting optimized fertilizer applications. In order to meet these challenges, managers of water user organization (WUA), regional and, national decision makers need updated and spatial explicit information on the state of land and water resources. Among others, land parcel geometry and land use data, knowledge on the respective seasonal regional crop growth, supply and demand of water, and yield amounts are essential parameters for decision support. Many of these important information layers can be supplied by remote sensing products that are integrated in user-tailored regional information systems. This study describes experiences in the development of remote sensing products and regional information systems that are useful to support decision making in land and water management in Central Asian irrigation systems. The study is integrated in the German Central Asian Water (CAWa) initiative of the German Federal Foreign Office.

Building on the long-term ZEF/UNESCO Khorezm project in Uzbekistan, a hierarchical object-oriented land use classification approach based on high resolution SPOT 5, IRS-P6, and MODIS data was designed for annual updates of crop distribution and crop rotations. Based on this land use product, a variant of the SEBAL model was developed to derive seasonal actual evapotranspiration at 1 km MODIS scale. MODIS vegetation indices and fraction of absorbed photosynthetically active radiation were integrated in an agro-meteorological model for annual estimations of crop yields and in particular of the predominating crop cotton at 250 m resolution. Experimental satellites like Proba-1/CHRIS or ASTER and ground measurements allowed adequate validation and calibration of the models and estimation of further crop parameters such as leaf chlorophyll status for improving fertilizer application. The remotely sensed geoinformation served as inputs into regional water balances and performance indicators to measure sustainability, adequacy and productivity of irrigation water supply. GIS-analyses disclosed spatial and temporal patterns of water consumption and weaknesses of the irrigation and drainage network. These products are presently further developed using time-series data from recently launched satellite sensors such as RapidEye for crop yield forecasting and GIS-based irrigation scheduling models.

The developed products and further remote sensing products to be developed will be integrated in regional information systems that are tailored to the requirements of Central Asian decision makers. For this task, we build on experiences gained in the “water related information system for the Mekong Delta” (WISDOM) project – a German-Vietnamese bilateral initiative. There, a prototypical spatial data enabled application has been designed and implemented using free software components. The utilisation of easy-to-use web applications in combination with up-to-date earth observation data, hydraulic models and results from socioeconomic surveys supports administrational activities for the integrated water resource management in the Mekong Delta. Integrating validated remote sensing products on crucial land and water issues, user-specific regional information systems and local capacity development measures in these techniques is a powerful regional adjusted research and development approach. This approach will support decision makers with crucial management information for better and timely decision making in Central Asia.

1. Introduction

Improved knowledge on the spatial and temporal distribution of land surface parameters in Central Asian irrigation systems can help decision makers to adjust land and water use according to the actual and site-specific requirements within and between irrigation systems. Remote sensing has proven highly valuable for generating such knowledge by providing contiguous spatial coverage and repeated measurements throughout the annual crop growth cycle. Nevertheless, the site-specific development of remote sensing based products and the timely provision of derived information by regional information systems according to the needs of users at different spatial and institutional scales (e.g. managers of water user organization (WUA), regional and national decision makers) remains one of the major challenges. The objective of this paper is to describe experiences in the development of remote sensing products that are integrated in regional information systems to support decision making in land and water management in Central Asia. The study is integrated in the German Central Asian Water (CAWa) initiative of the German Federal Foreign Office (project number AA7050002). The CAWa project is coordinated by the German Aerospace Center (DLR) and the GeoResearch Center Potsdam (GFZ), while the Universities of Wuerzburg and Giessen are partners with remote sensing contributions among other participating institutions.

2. Generic concept: Integrating remote sensing, information system and capacity building

Agricultural decision makers in Central Asia have to deal with multiple challenges in order to achieve sustainable crop yields. These include e.g. designing appropriate water distribution plans, achieving sustainable land use and targeting optimized fertilizer applications. In order to meet these challenges, local, regional, and national decision makers need updated and spatial explicit information on the state of land and water resources. Among others, land parcel geometry and land use data, knowledge on the respective seasonal regional crop growth, supply and demand of water, and yield amounts are essential parameters for decision support. Building on the long-term ZEF/UNESCO Khorezm project in Uzbekistan, data from satellite sensors ranging from high spatial to medium spatial resolution (SPOT 5 to MODIS) are used to generate a land use and land cover classification. Based on this reference, more complex products are developed such as crop-specific evapotranspiration, yield, and leaf nitrogen using time-series of satellite data. These and further necessary remote sensing parameters are input into spatial analyses to calculate the performance of the system and to simulate alternative land and water distribution. In order to make these remote sensing products and further data easily and operationally accessible to decision makers, regional information systems can provide the necessary platform. An example of a prototype of such an information system has been generated within the WISDOM project for water related decisions in Vietnam. This system is structured into four main components ranging from data management, data collection (integrating the remote sensing and other parameters) over modelling, analysis and visualization of views for different policy makers. The development of the remote sensing products and the regional information systems are accompanied by customised trainings and tailor made course programs on most recent geoinformation technologies and earth observation methods to clients and project partners in Central Asia to support the implementation and sustainability of the whole system solution. The generic concept is shown in figure 1.

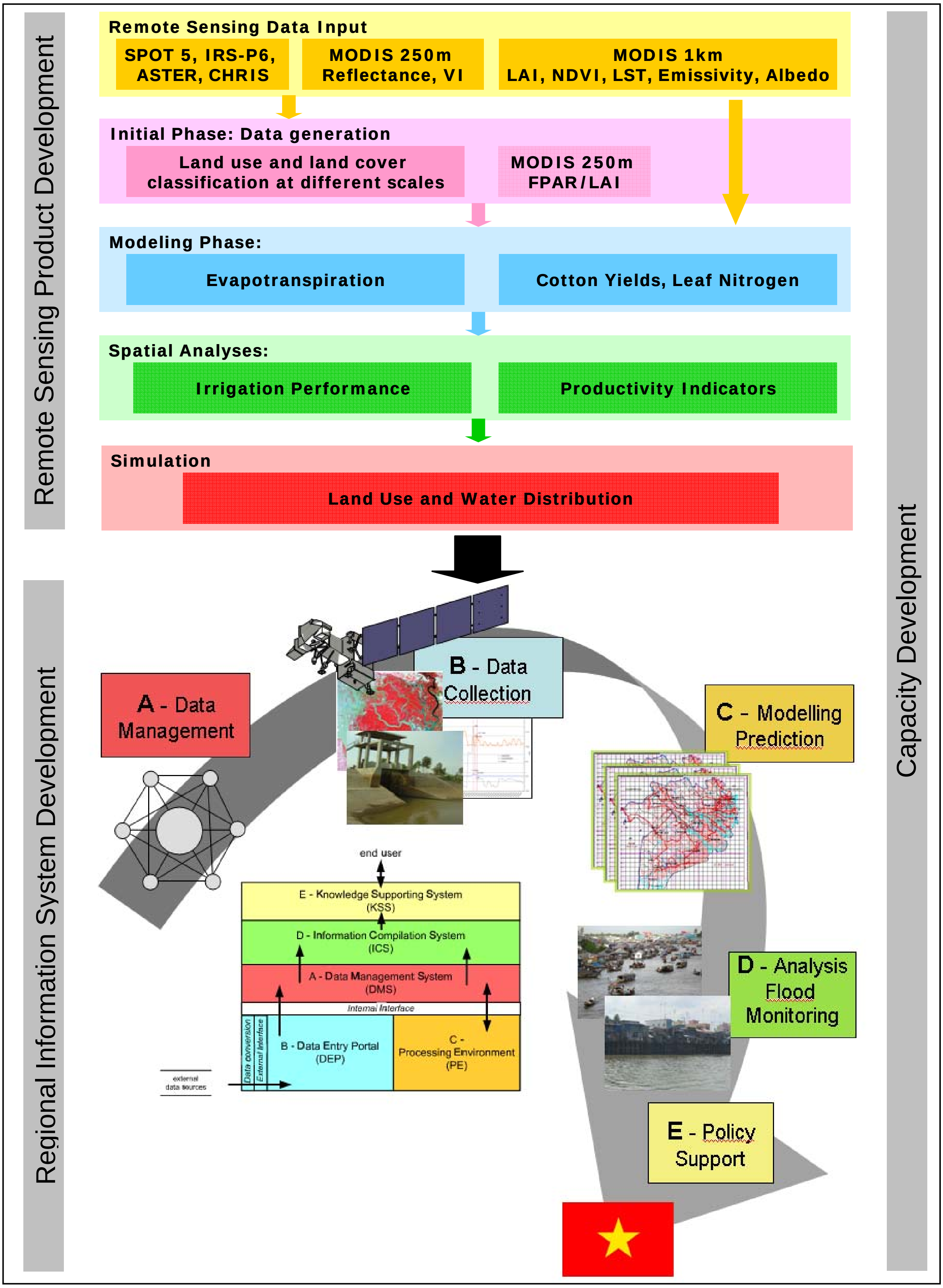

Figure 1: Generic concept on a system solution combining the development of remote sensing products their integration into regional information systems and capacity building.

3. Regional land and water parameters derived from satellite images

Based on the conceptual framework different land and water parameters were derived from remote sensing data for the Khorezm region at the Amu Darya River in Uzbekistan. Following a hierarchical classification approach land use was derived based on MODIS data. Seasonal actual evapotranspiration was estimated using different MODIS and meteorological time series data in the SEBAL approach (Conrad, et al., 2008). Based on a regionally adjusted Monteith approach crop yields of cotton were estimated by time-series of different MODIS data, meteorological and crop specific inputs (Shi, et al., 2007). Hyperspectral time series data of the ESA space-borne sensor CHRIS on board of the Proba-1 platform were used to estimate leaf chlorophyll of cotton as an indicator for leaf nitrogen (Ruecker, et al., 2009). Some of these parameters were combined with other information to calculate water balances and performance indicators. Figure 2 shows examples of these parameters.

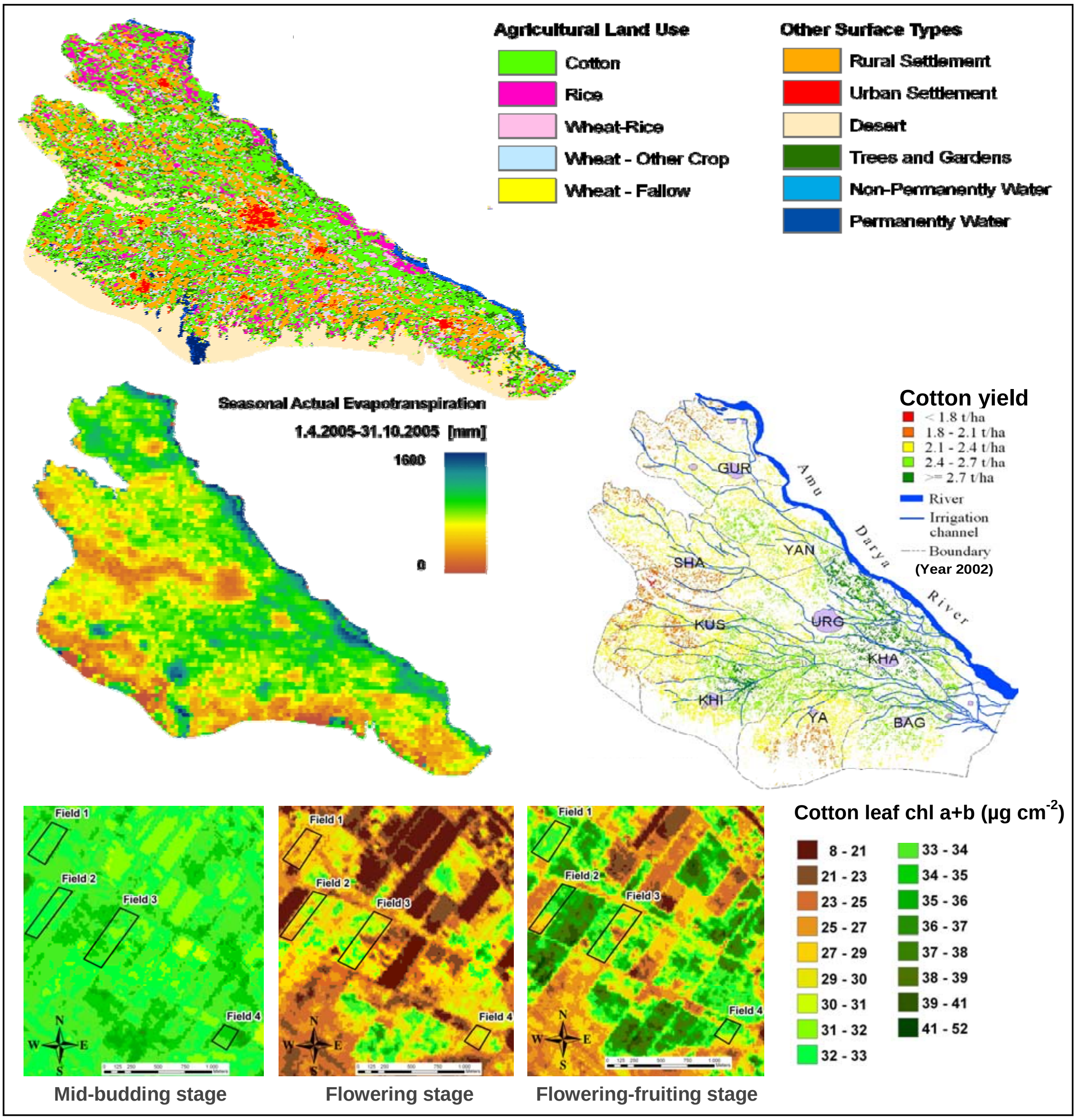

Figure 2: Examples of remote sensing parameters from the Khorezm region, Uzbekistan.

4. Regional information systems to support decision making in land and water management

The information system (IS) of the WISDOM-project in Vietnam is a key example that will be built on for the development of the CAWa IS: The aim of the WISDOM project is to design and implement an IS for the Mekong Delta in Vietnam. This Delta is characterized by a strong population increase, changing climatic conditions and regulatory measures at the upper reaches of the Mekong. These severe changes lead to extreme and more frequent events such as floods or droughts. Drinking water availability is increasingly limited and soils show signs of salinization or acidification. Concerning biodiversity, species and complete habitats diminish. In order to counteract these problems, detailed information on hydrologic, hydraulic, ecologic, and sociologic factors is inquired by decision makers for integrated management of land and water resources. For implementation of this integrated management the cooperation of international institutes as well as national, regional, and local authorities needs to be strengthened.

The IS should combine interdisciplinary information that is relevant for different decision makers´ information requests at various spatial scales. Technically, the IS is based on a standardized modular software and hardware architecture. It comprises of a data entry portal, automatic data ingestion, standardized spatial data infrastructures, a processing environment, and visualization, query, and analysis module. Key aspects are the derivation and integration of spatial data to support planning and management. The necessary data are derived as products from e.g. remote sensing products, ground based sensor data or statistics. Besides the provision of single information products via the IS, products are further used as input into a hydrologic model to generate integrated information products at higher levels, e.g. water balances and what-if-scenarios, thus supporting the work flows of use cases such as generating maps or reports at a standardized and regular basis. The project is planned for three phases and started in 2007, including project initiation, information system design and implementation. Within the current WISDOM project phase several aspects have been approved for the conception and design of the proposed CAWa IS. The following key lessons could be identified:

- Integrate all partners in system analysis: The advantages of an integrative information system with all its underlying data and functions cannot be overseen at the beginning of the project. Misunderstandings due to ambiguous concepts from different science domains require a common consent to ensure an interdisciplinary application.
- Define project-wide data standards: Shortly after project start a data standard was defined for data exchange within the project. The WISDOM data standard includes common data formats, projections, and additional metadata information according to ISO standard. This standard supports operational data integration into the data management system.
- Use open standards and open source technology: Existing open standards and corresponding formats and interfaces support the idea of modular system architecture. Powerful open source technologies can be used to adapt ideas and focus on project internal requirements.
- Develop prototypes: From the beginning it was difficult to define the right software requirements including both functional and non-functional requirements. The implementation of prototypes improves communication between the project partners and the stake holders to define, which IS functionalities and general conditions are required.
- Use demonstrator modules as showcase and discussion platform: The data and corresponding IS functions which are integrated in an implemented prototypical application permit stakeholders, users, data producers, and IT developers to discuss common goals in a practical way and to improve acceptance of the IS towards decision and policy makers.

Both, the profound experiences and the developed technologies of the IS in the WISDOM project are key assets in the design and the development of the IS in the CAWa project. Furthermore, components of other IS will be investigated towards suitability for the CAWa IS.

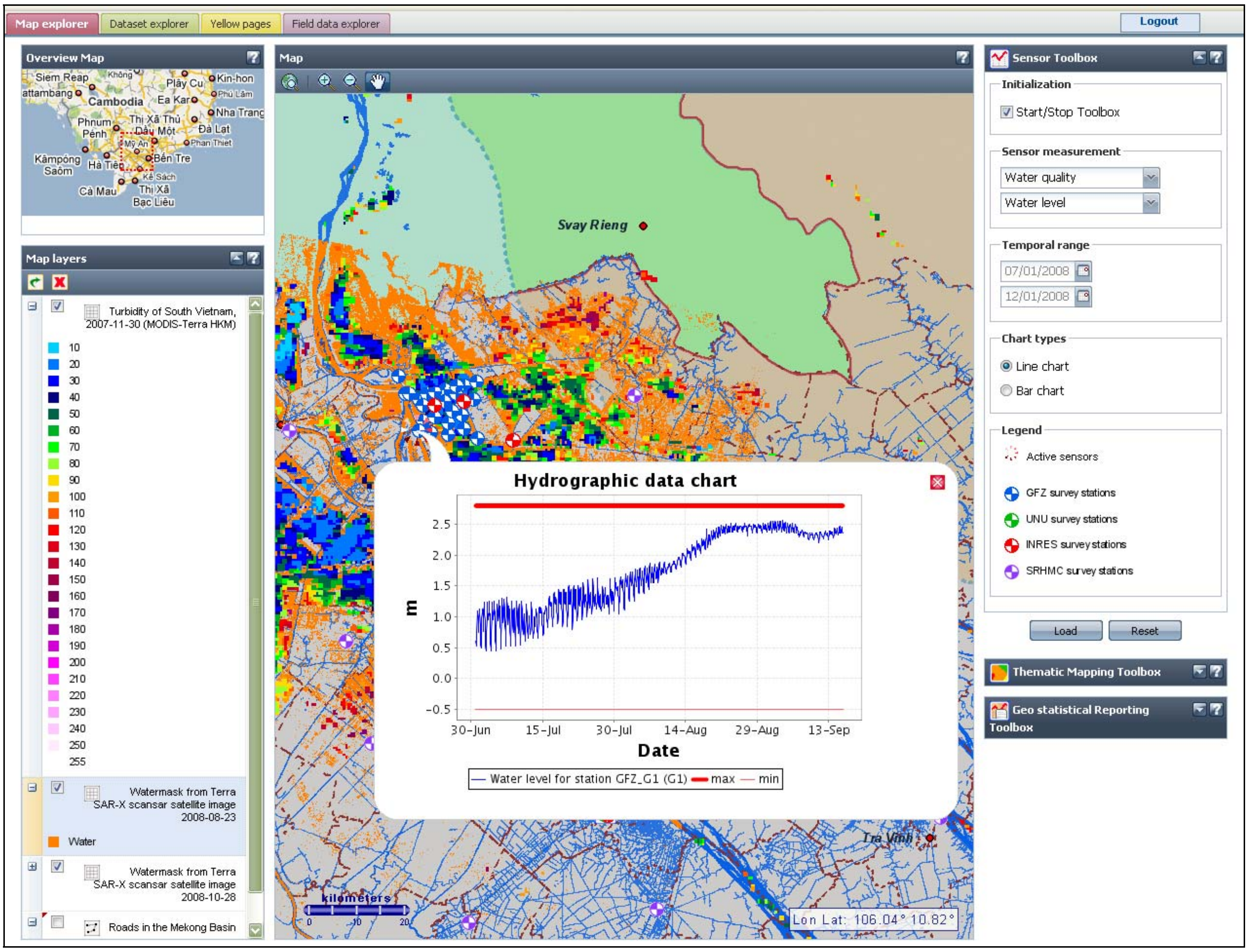

Figure 3: A typical web based graphical user interface serves as front-end of the information system for different users requesting information for certain topics.

5. Conclusions

Integrating validated remote sensing products, in-situ data and models on crucial land and water issues, user-specific regional information systems and local capacity development measures is a powerful research and development system approach. This system approach will support decision makers with spatial explicit management information for better decision making in Central Asia.

6. References

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