Development of a Water Resources Assessment and Audit Framework for Sri Lanka

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Abstract

The demand and use of water resources is permanently increasing, while the quality of water is dropping and the availability of water in the context of climate change is becoming uncertain. To meet these growing problems it is necessary to carefully assess the existing water stocks and future trends in a country. The accuracy of such an assessment highly depends on the quality of data and information used. In other words – we cannot manage what we do not measure. In most developing countries, the lack of readily accessible and quality controlled data is the major obstacle for scientifically-based assessments on water resources, water development planning and evaluating the status and trends of water resources. Sri Lanka too faces similar obstacles.

Recently IWMI initiated the development of a prototype system for managing national water resources data and information, which can be accessed online by various users and interested stakeholders. The data and information in the system is being organized in modules to provide user-friendly access. The 'overview' module includes information on topography, soil, land use, land cover, river network and settlement patterns. The 'water availability' module contains data on various components of the hydrological cycle, including rainfall, runoff, evaporation, ground- water, river basin characteristics, per capita water availability and trends, and water scarcity. The 'Demand and use' module focuses on the factors that affect demand, such as population growth, sectoral demand, irrigation requirements and withdrawals. The 'water quality' module provides information on salinity, water quality constituents and water-related diseases. The 'governance and management' module contains information on institutions, legislation and finances in the Sri Lankan water sector. The 'disaster and risk' module focuses on the characteristics of floods, land slides, tsunami etc. Finally, the 'climate change' module covers the impacts of climate change on rainfall, salinity and sea level rise to guide adaptation planning.

The system is designed with a view to facilitate assessments of water resources at various administrative (e.g., province, district) and hydrological (e.g., river basin) units. The map-based interface ensures quick access to available data and allows the date to be downloaded and

displayed. The system is currently a 'work in progress' and only an illustration of what can be achieved. It is envisaged that by cooperating with national agencies, the system will be enhanced into a unified platform for maintaining and sharing data by various participating agencies and will be used to conduct a systematic assessment of water resources in Sri Lanka. By developing a comprehensive and national water audit, Sri Lanka may provide as an example to other developing countries too.

Introduction

The demand and use of water resources is permanently increasing, while the quality and availability of water is declining. According to the Comprehensive Assessment (Molden 2007), about 2.8 billion people in the world live in areas facing water scarcity. By 2025, one-third of the population of the developing world will face severe water shortages (Keller et al. 2000). Climate change can affect the quantitative and qualitative status of water resources by altering hydrological cycles and systems which in turn, will increase temperature and shift precipitation patterns (EEA 2007). To meet these growing problems it is necessary to carefully assess the existing water stocks and future trends in a country. The accuracy of such an assessment is highly dependent on the quality of data and information used. In other words – we cannot manage what we do not measure. In most developing countries, the lack of readily accessible and quality- controlled data is the major obstacle to scientifically-based assessments of water resources, water development planning and evaluating the status and trends of water resources.

Most of the studies on water scarcity assessment rank Sri Lanka as a country with either little or no water scarcity or moderate water-scarcity conditions, but they do not consider the spatial and temporal variation of water availability in the country (Amarasinghe et al. 1999). Sri Lanka experiences high seasonal and spatial variations in rainfall due to the bi-monsoonal climatic pattern (northeast monsoon from October to March and southwest monsoon from April to September)—(Amarasinghe et al. 1999). Large tracks of the country are drought prone. Droughts occur in both semi-arid and humid zones – in different degrees (Imbulana et al. 2006).

At present in Sri Lanka, water resources data and information are hosted by multiple government agencies, and there is a need to integrate such data into a coherent water resources information system (Imbulana et al. 2006). Recently IWMI initiated the development of a prototype system for managing national water resources data and information, which can be accessed online by various users and interested stakeholders. The present paper describes different modules of the system.

Methodology

The heart of the system is the data base, which targets various user groups and provides useful information to assist in their management decisions. Information is retrieved from the platform, through web interface enabling subject-wise access. The system includes the following data and information types:

- Spatial data in GIS format (e.g., administrative boundaries, transportation, river basins, land use, etc.)
- Attribute data: data linked to some spatial unit (e.g., population, irrigation)
- Time series data (e.g., rainfall, runoff)
- Descriptive information (e.g., policy documents)

The data and information are categorized into several topics:

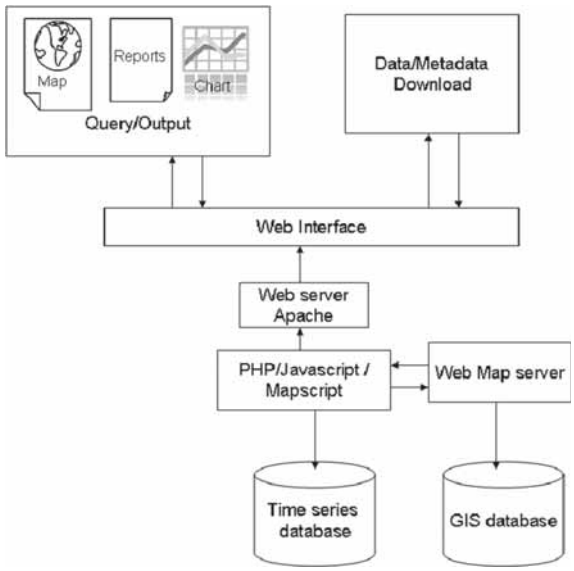
- Data and information that help users to understand the physical settings of the country
- Water availability, including current status and future trends
- Water demand and use
- Water quality
- Water governance, including institutional and legislative information
- Water-related disasters and risks
- Climate change impacts on water resources

Data from different agencies, stored in heterogeneous formats, are harmonized to enable comparison and presentation.

System Architecture

The system is developed with an open source technology to minimize the cost of implementation and replication. The architecture of the system is shown in Figure 1. The user interface is coded with PHP/Java script to provide web-based access for queries, outputs and data download. Apache web server version 2.2 (http://httpd.apache.org/) is used for hosting the system. Minnesota web map server (http://mapserver.org/) is used with PHP map script (http://www.maptools.org/php_mapscript/) to develop the mapping interface. The attribute and time series data are stored in an open source PostGRESQL database.

Figure 1. System diagram.



System Modules

The system currently contains seven information modules mentioned in the 'Methodology' section .The detailed descriptions of each module are given below.

Overview

The overview module contains base data to provide an overall picture of the geo-physical conditions of the country. It includes the following data sets:

Administrative Boundaries: Many of the statistical and census data are aggregated by different administrative levels. There are four levels of administrative boundaries in Sri Lanka namely: Provinces, Districts, DS Divisions and GN Divisions. The present system includes administrative boundaries up to DS divisions (Figure 2).

Topography: The system contains 90 m SRTM digital elevation model to represent the topography of the country (Figure 3).

Soil, Land Cover and Agro-ecological Zones: Agro-ecological zones are land resource mapping units, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use (FAO-AEZ website). Sri Lanka is divided mainly into two major agro-ecological zones, namely the dry zone and the wet zone (Figure 4). A transitional intermediate zone was recognized in 1956-1961 during the study conducted by the Canada-Ceylon Colombo Plan Survey (Somasekaram et al. 1997). The soil map mainly shows the great soil groups. The maps on land expanse show the major areas of land cover including forests, paddy, tea, rubber and coconut cultivation areas.

Figure 2. Administrative boundaries.

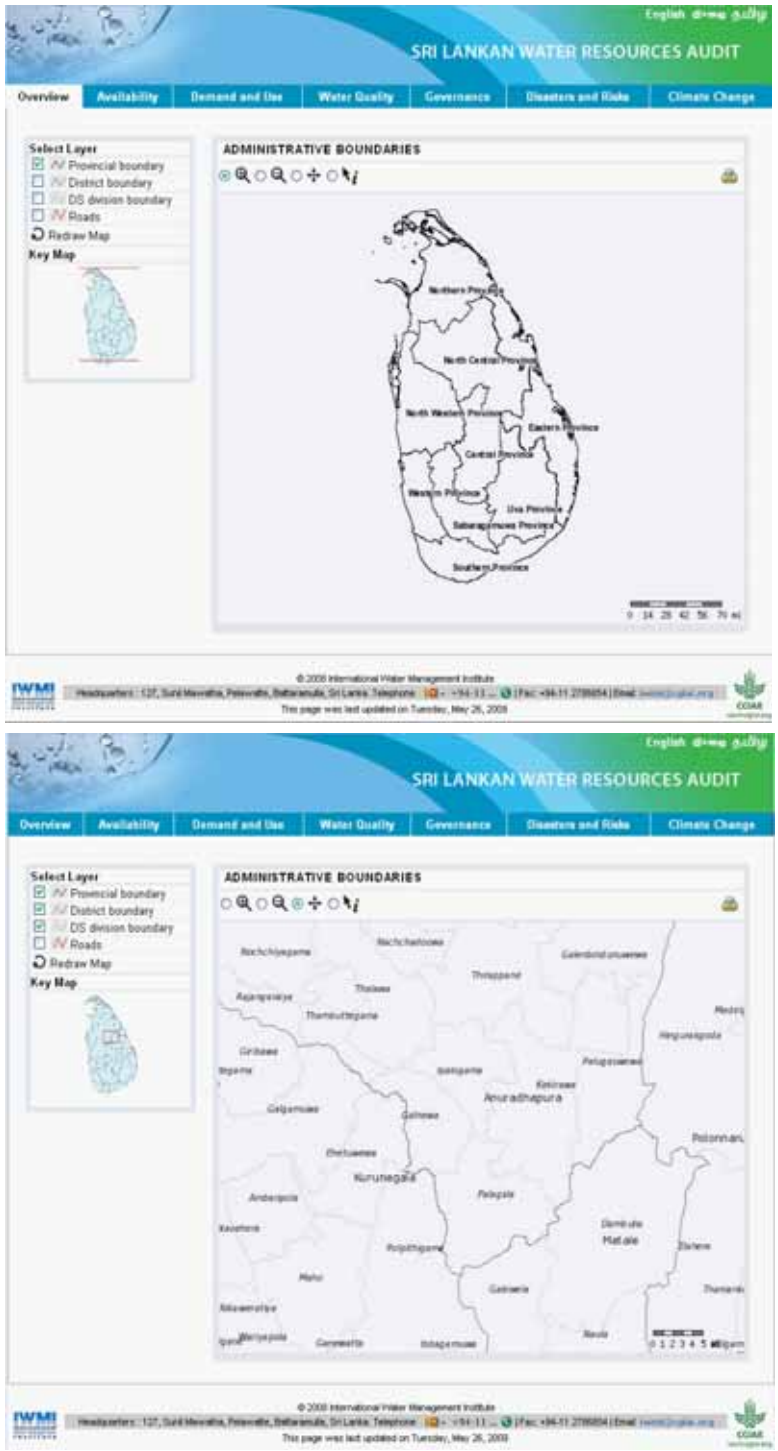


Figure 3. Topography.

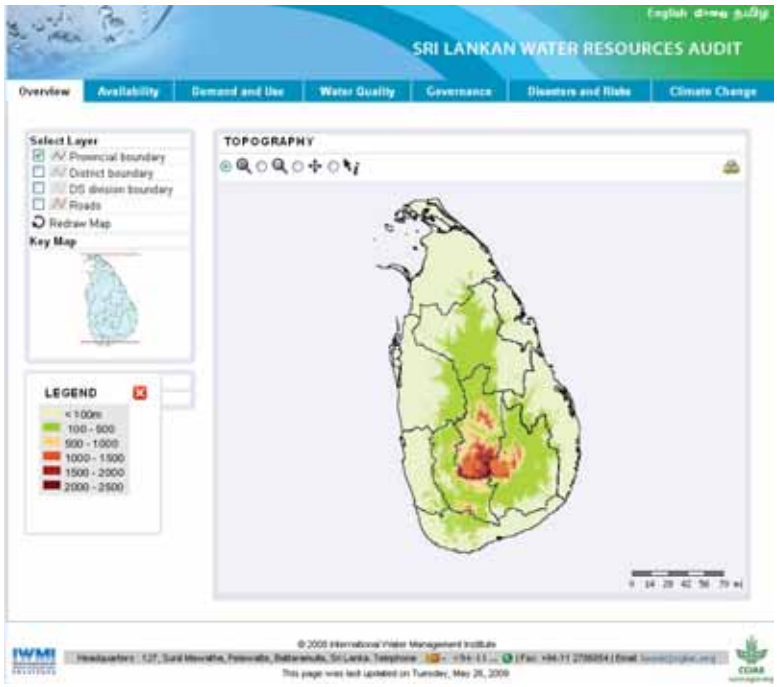
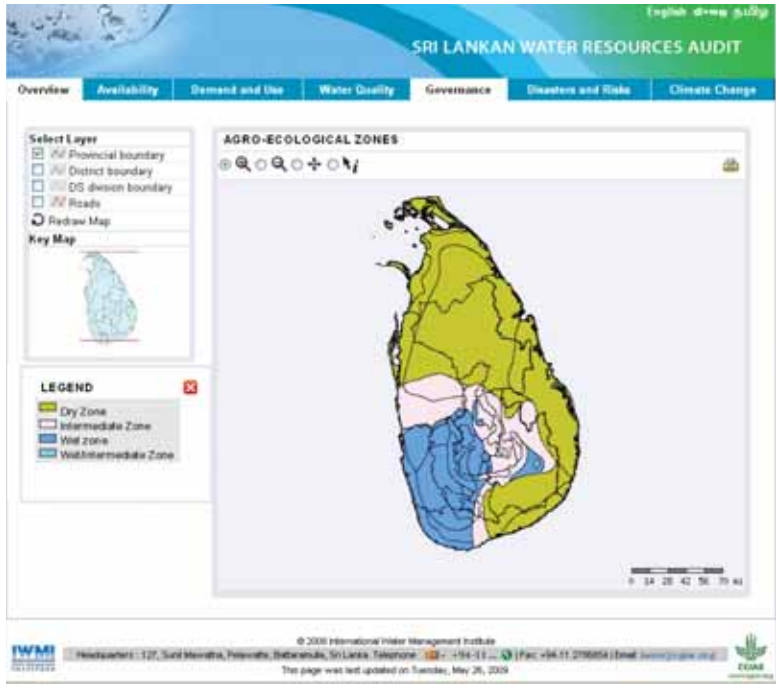


Figure 4. Agro-ecological zones of Sri Lanka.



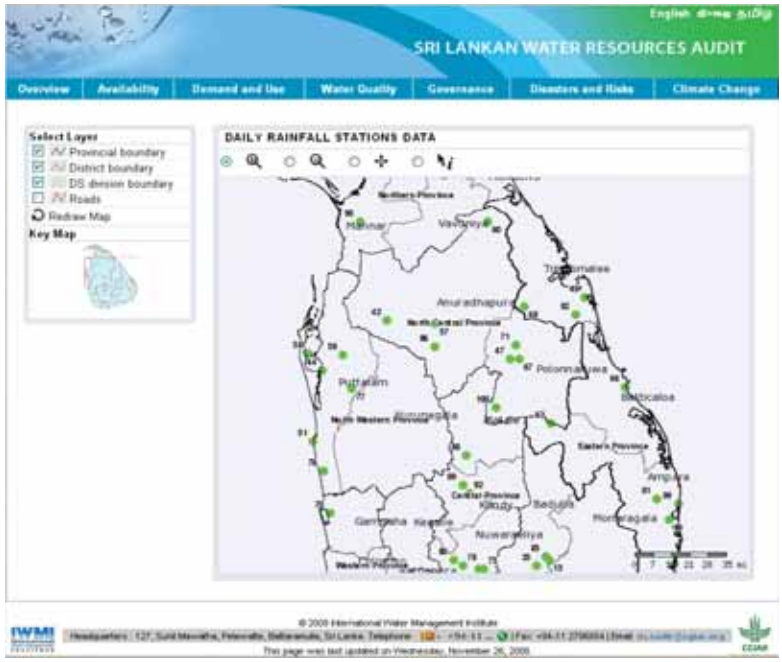
Water Availability

The 'water availability' module contains data on various components of the hydrological cycle, including rainfall, runoff, evaporation, groundwater, river basin characteristics, per capita water availability and trends, and water scarcity.

Time Series Data

The system provides a map-based interface to display rainfall, runoff and evaporation station locations and retrieve daily and monthly station data (Figure 5). The data are displayed in tables and charts with an option for downloading in text or XML format.

Figure 5. Location of rainfall station and data.

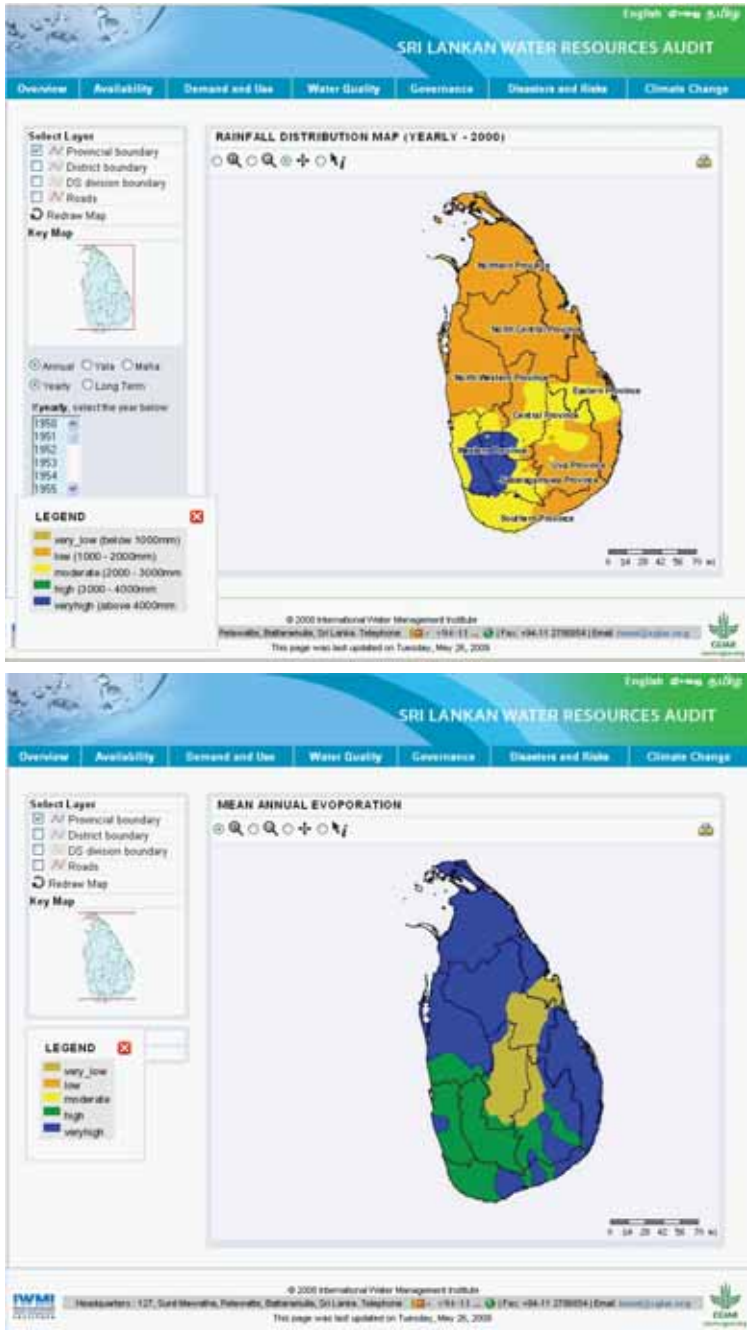


Location ID	Station Name	Latitude	Longitude	Daily	Value
60	Padawiya	8.830	80.77	05 Jan 2003	24.80
60	Padawiya	8.830	80.77	06 Jan 2003	41.50
60	Padawiya	8.830	80.77	07 Jan 2003	2.10
60	Padawiya	8.830	80.77	08 Jan 2003	19.00
60	Padawiya	8.830	80.77	05 Feb 2003	2.90
60	Padawiya	8.830	80.77	06 Feb 2003	0.60
60	Padawiya	8.830	80.77	16 Mar 2003	4.40
60	Padawiya	8.830	80.77	26 Nov 2003	137.40
60	Padawiya	8.830	80.77	27 Nov 2003	209.20
60	Padawiya	8.830	80.77	28 Nov 2003	16.70
60	Padawiya	8.830	80.77	02 Dec 2003	20.00
60	Padawiya	8.830	80.77	03 Dec 2003	5.00

Time Series Grid

Interpolated time series data are useful to visualize the spatial distribution of hydro meteorological variables. The system includes annual and seasonal rainfall distribution for 1950 – 2005 (Figure 6). Similar data could also be generated for other variables.

Figure 6. Distribution of mean annual rainfall, 2000, distribution of mean annual evaporation.



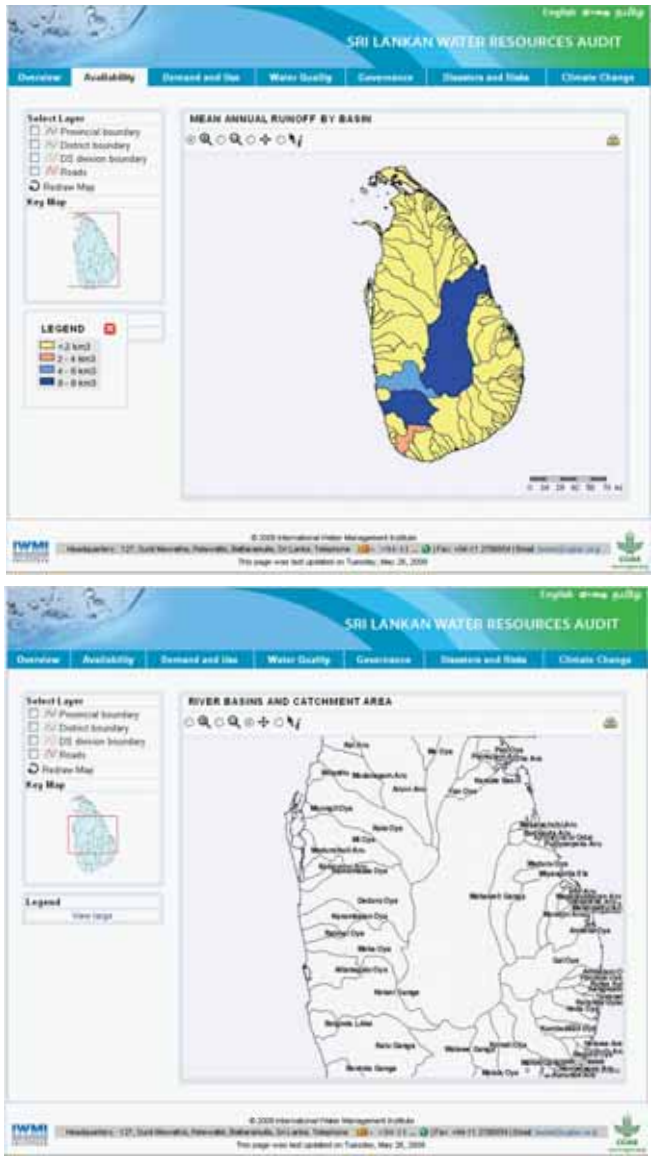
Long-term Averages of Hydro-meteorological Variables

These provide an overall picture of variation in hydro-meteorological variables across the country. The system includes the distribution of annual and seasonal long-term mean rainfall and evaporation.

Summary of Statistics

This is a summary of hydro-meteorological variables in terms of their administrative and hydrological units, which data is useful for planning at those levels. The system includes rainfall and runoff data summarized according to districts and basins (Figure 7).

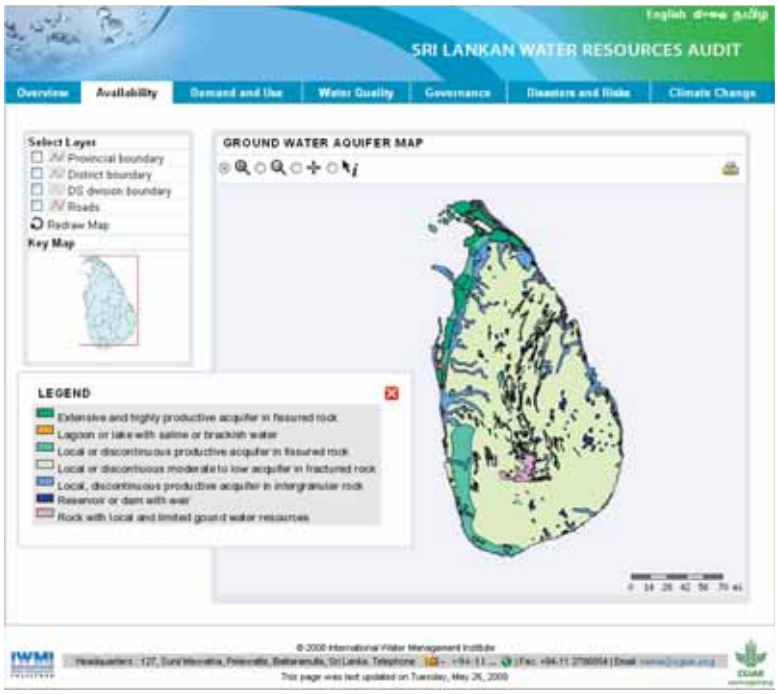
Figure 7. Annual total runoff for basins.



Groundwater

There is no baseline groundwater quantity or quality monitoring system in Sri Lanka (Imbulana et al. 2006). A groundwater aquifer map is included to better depict the groundwater condition (Figure 8).

Figure 8. Groundwater aquifer map.



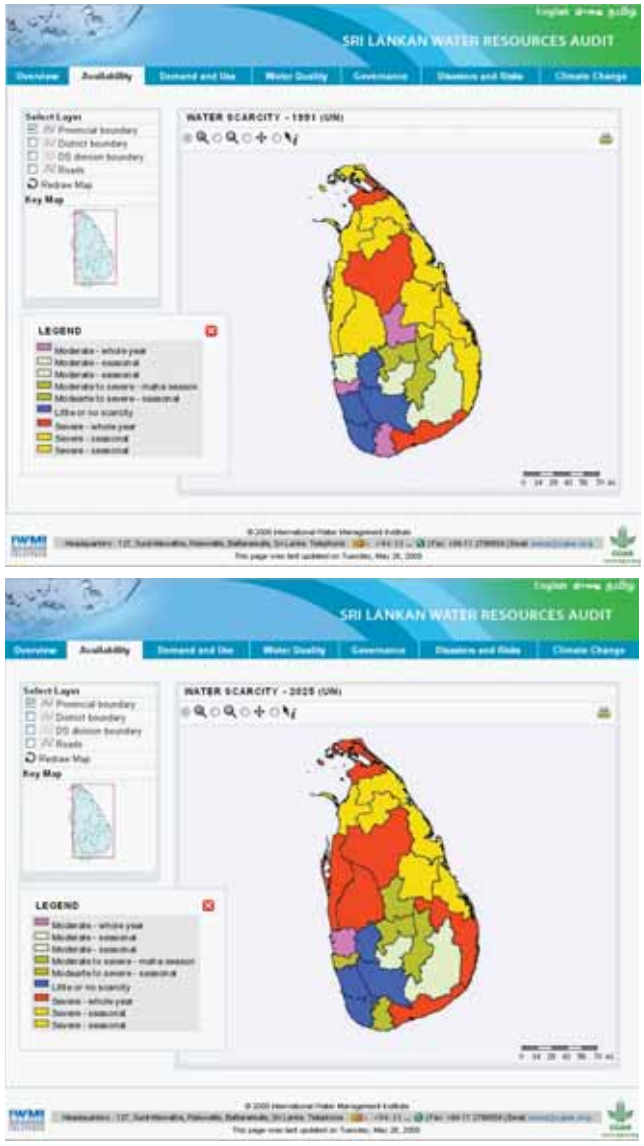
Per Capita Water Resources

The system includes an analysis of district-wise per capita water resources and water scarcity maps (Figure 9). These are helpful to identify resource-scarce areas.

Storage Capacity

Given that about 34 % of the net inflow of water in Sri Lanka is drained to the Indian Ocean, there appears to be some scope for further water resources development (Bastiaansen et al. 2003). Because of the sporadic spatial and temporal distribution of precipitation, the only way water supply can be controlled to match demand is through storage. (Keller et al. 2000). A map is included in the system to show the storage capacities of different districts.

Figure 9. Water scarcity map.

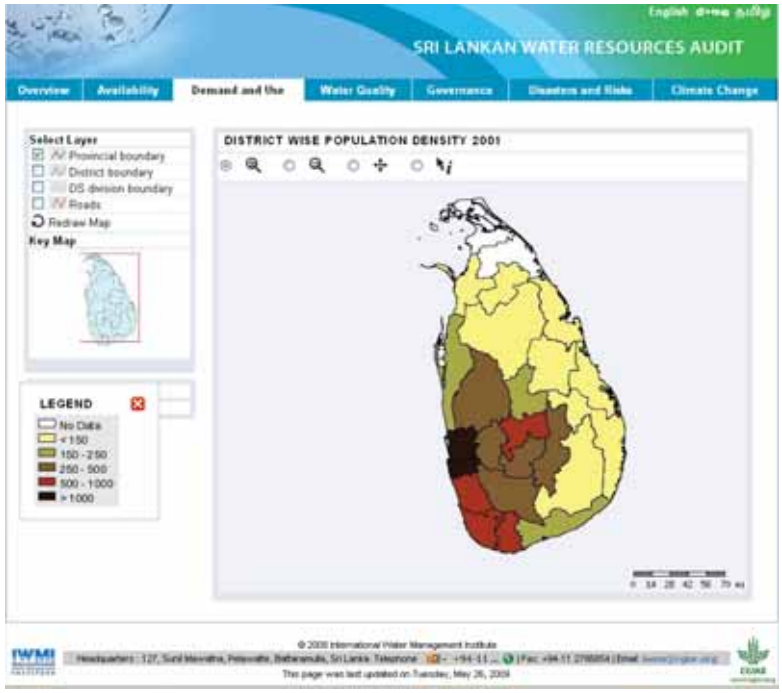


Water Demand and Use

The major driving forces behind the increase in water demand are population growth, urbanization, industrialization, increases in food demand and consumption patterns. The system at present includes several indicators of water use including the below mentioned.

Demography: Understanding population growth and spatial distribution is important when estimating current requirements and when forecasting future needs for water resources. Water use also varies according to different livelihood practices. Analysing changes in livelihoods, including consumption patterns in different areas, is also important in order to understand the potential demand that may arise from such changes. Demographic data are mainly collected and aggregated according to administrative boundaries. The current system includes district-wise data on population density and water consumption (Figure 10).

Figure 10. Population density 2001.

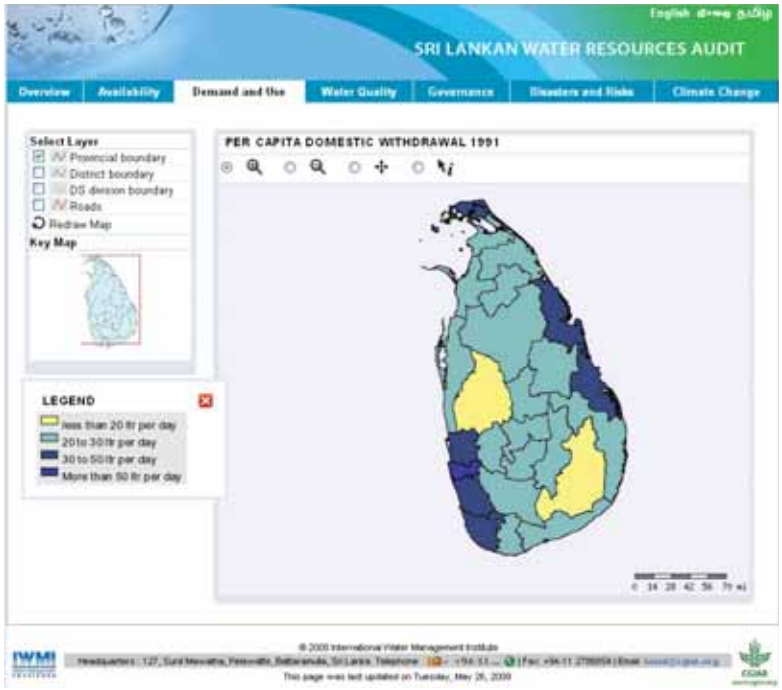


Water Withdrawal: Water withdrawal data is important to understand the exploitation of available water resources in different areas, which in turn can be used to identify areas of scarcity. The system also includes data on a sector basis of per capita withdrawal and the percentage of seasonal withdrawal from available water resources (Figure 11).

Water Quality

Water pollution is a major public health concern in Sri Lanka. There is a limited availability of water quality information in Sri Lanka. The Central Environmental Authority (CEA) undertakes water quality assessments in specific areas to address local needs and regulate local

Figure 11. Per capita domestic water withdrawal 1991.



development projects (Imbulana et al. 2006). The system is designed to incorporate data for monitoring water quality, and data on salinity and water-related diseases. None of the data mentioned in this module is currently included in this model.

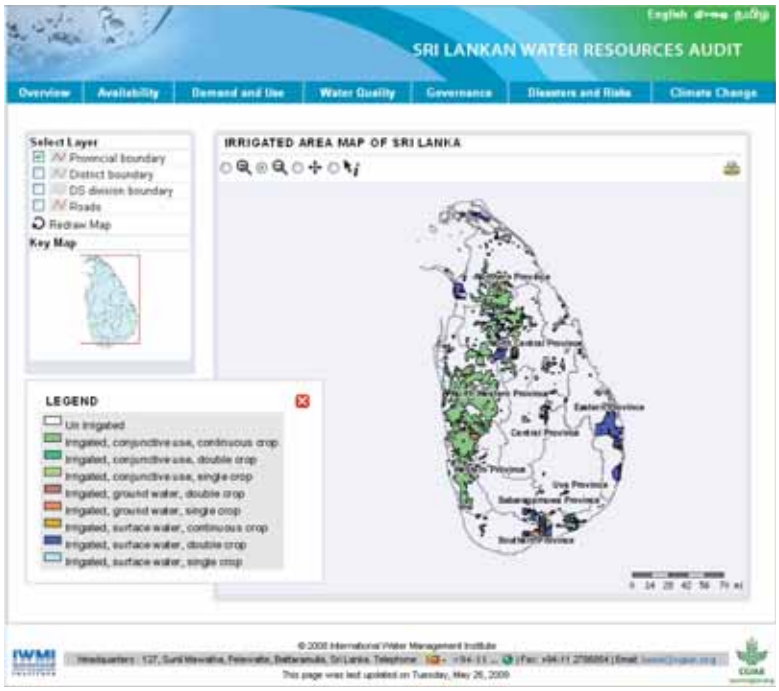
Governance

Governance includes implementing better planning and management in order to improve the availability of water resources and measures such as increasing efficiency in usage of water to cater future demand. Data and information in this module at present includes: irrigation and drainage development, institutions, legislation and finance.

Irrigation and Drainage Development

Irrigation activities in Sri Lanka date back 2,500 years (FAO 2008). The Mahaweli Development Program is the largest multipurpose national development program (Somasekaram et al. 1997). Besides this, there are 535 major irrigation schemes in the country. The system includes maps of irrigation schemes and the Mahaweli system. A map of the irrigated area, generated from satellite remote sensing, is also included (Figure 12).

Figure 12. Irrigated area map.



Institutions

There are about 30 government institutions contributing to water resources development in Sri Lanka (Imbulana et al. 2006). Coordination among these agencies is important to pursue good governance in water management. The system is aimed at obtaining information on these agencies, including contacts of key people, roles and niches of institutions etc. Therefore, the proposed data and information sharing strategy will address and remedy, at least to some extent, the major challenge of overlaps and contradictions in some development programs adopted by institutions to manage water resources.

Legislation

There are over 43 Acts of Parliament concerning the water sector. These laws have been enacted over time to meet specific needs (FAO 2008). A compilation of these laws to provide one-stop access would be useful to identify overlaps, gaps and conflicts. The system aims to include all the water-related laws in the country in the on-line database. Creating a common point of access to existing studies that analyze the laws and institutional jurisdictions regarding this area would be useful in this respect. Another useful feature may be to provide a list of the various provisions dealing with specific topics, e.g., groundwater, farmer organizations and their functions, etc.

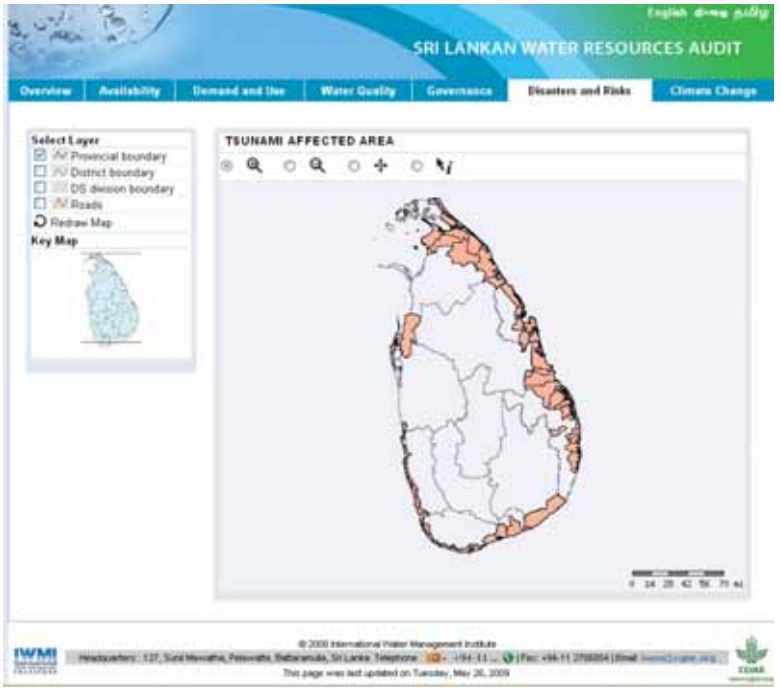
Finances

Investment in water resources has varied from 8 % a decade ago, to around 2 % of total capital investment of the country (Imbulana et al. 2006). Information on tariff structures for the domestic water supply, funding of irrigation development and financing irrigation water resources management will be captured in this section of the on-line 'water audit'.

Disaster and Risks

Major water-related disasters in Sri Lanka include floods, droughts, landslides and tsunamis (Figure 13). Cyclonic storms and gale-force winds are also frequent with monsoon activity or as a result of severe weather changes in the Bay of Bengal (Imbulana et al. 2006). Fifty-eight percent of the country falls under the dry zone, which is frequently subjected to droughts. Occasional droughts also occur in the wet zone. Floods are usually associated with monsoon rainfall. The Kalu, Kelani, Nilwala, Gin and Mahaweli rivers, originating from the wet zone, are the major flood- prone rivers in Sri Lanka (Imbulana et al. 2006). Eight districts in the central highlands are at risk of land slides (Ralapanawe – website). Though tsunamis are not a frequent disaster in Sri Lanka, in 2004 most of the coastal districts were hit by a tsunami, which caused severe damage. Information of water-related disasters would be useful to plan for prevention, mitigation and rehabilitation.

Figure 13. Tsunami affected areas.



Climate Change

The change in precipitation patterns, caused by climate change, might have a high impact on the availability and distribution of water resources in Sri Lanka. Climate change may also impact the rise in sea level and saline water intrusion in the rivers. Information on these subjects would be useful for adaptation planning.

Multi-lingual Features

The interface of the system will be translated into the Sinhala and Tamil languages to promote the use of the system at local level (Figure 14).

Figure 14. Sinhala interface of the system.

Conclusions and Recommendations

The present system for water resources audit is to demonstrate a prototype framework for organizing, accessing and sharing water resources related data and information. The system is currently a 'work in progress' and only an illustration of what can be achieved. It is envisaged that through cooperation with national agencies, the system will be enhanced into a unified

platform for maintaining and sharing data by various participating agencies and will be used to conduct a systematic assessment of water resources in Sri Lanka. By developing the concept of a comprehensive and national water audit, Sri Lanka may provide as an example to other developing countries too.

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