TIGER-NET – ENABLING AN EARTH OBSERVATION CAPACITY FOR INTEGRATED WATER RESOURCE MANAGEMENT IN AFRICA

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ABSTRACT

As part of the TIGER initiative [1] the TIGER-NET project aims to support the assessment and monitoring of water resources from watershed to transboundary basin level delivering indispensable information for Integrated Water Resource Management in Africa through:

1. Development of an open-source Water Observation and Information Systems (WOIS) for monitoring, assessing and inventorying water resources in a cost-effective manner;
2. Capacity building and training of African water authorities and technical centers to fully exploit the increasing observation capacity offered by current and upcoming generations of satellites, including the Sentinel missions.

Dedicated application case studies have been developed and demonstrated covering all EO products required by and developed with the participating African water authorities for their water resource management tasks, such as water reservoir inventory, water quality monitoring, water demand planning as well as flood forecasting and monitoring.

1. BACKGROUND OF THE PROJECT

Despite experiencing more than 10 years of economic growth, Africa today faces great challenges with water resource management. With 10% of the world's renewable water resources, more than 60 trans-boundary basins, low level of water development and utilization and increasing population, Africa's future economic growth will continue to be driven by the development of its water resources. Today, in many African countries, water policies and management decisions are based on sparse and unreliable information. In this challenging context, water information systems are fundamental for improving water governance and implementing Integrated Water Resource Management (IWRM) successfully. This water information gap is a major limitation to put in practice IWRM plans to face the current and coming challenges of the African water sector. Recognizing the utility of satellite data for IWRM, the European Space Agency (ESA) through its Committee on Earth Observation Satellites (CEOS) launched the TIGER initiative in 2002. The TIGER initiative supports water authorities, technical centres and other stakeholders in the African water sector to enhance their capacity to collect and use water-relevant geo-information to better monitor, assess and inventory their water resources by exploiting EO products and services [2]. Currently the TIGER initiative consists mainly of the TIGER Capacity Building Facility (including support for selected research projects) and the TIGER-NET project.

The aim of TIGER-NET is to build pre-operational capacity for water resources monitoring based on EO technologies at mandated African water authorities, which currently includes three major river basin authorities and three national ministries: Nile Basin

initiative, Lake Chad Basin Commission, Volta Basin Authority, Department of Water Affairs South Africa, the Ministry of Water of Namibia and the Department of Water Affairs of Zambia.

TIGER-NET builds on the 10 years of experience gained within TIGER demonstration and capacity building activities in order to develop practices and tools required for an eventual transfer of EO information into the day-to-day work of water authorities. A steering committee consisting of experts from the African Water Facility, AMCOW-TAC, the Water Research Commission of South Africa, UN-ECA and UNESCO IHP, provides guidance with regard to the African water sector priorities. Major focus is on developing, demonstrating and training a user-driven, open-source Water Observation and Information System (WOIS), which enables the production and application of a range of satellite EO based information products needed for IWRM in Africa. Importantly, a necessary local capacity shall be developed to access and exploit historic satellite data as well as future Sentinel observations [3]. Free data access, free licensing, processing capacity and integrate ability with existing systems are key advantages of the WOIS, which shall enable extension to other countries and regions in Africa and encourage user-driven sustainability in terms of funding and operation.

The project was officially kicked off at the World Water Forum in Marseilles in March 2012 and achieved development, system installation, data access, full demonstration and training of the first WOIS version to the involved users in the first project cycle. The second project cycle will see continuation of the development and training efforts and an expansion of the user base through uptake of 3 more water authorities.

2. Requirements of African Water Authorities

The first phase of TIGER-NET was focused on an extensive consultation, review and analysis of the user needs in terms of their current technological and human capacity, application specific monitoring demands as well as geo-information and system needs. In general, the common requirement was for an end-to-end system enabling a full capacity to establish water related information for monitoring, analysis and reporting (Map and Tabular) per sub-watershed for IWRM. While the system requirements were found to be very common among the host institutions, the specific application requirements and information demands varied according to the variety of IWRM challenges faced in the different river basins of Africa.

2.1. System requirements

- Cost and license free – Open Source
- Easily transferable – Easy to operate
- Capable of
  - retrieving, storing and processing EO satellite data as well as integrating in-situ data
  - producing EO-based water related information products
  - integrating hydrological modeling functions
  - supporting decisions based on full GIS framework
  - mapping and reporting functionality
  - integrating and linking to existing user systems
  - scaling up for future applications and demands
  - supporting the full observational capacity of the upcoming Sentinels

2.2. EO product requirements

- High to medium land cover, change and degradation mapping (incl. vegetation indices)
- Water body mapping (small/large, shoreline changes, wetlands)
- Water quality monitoring (lake surface temperature, chlorophyll and sediment load)
- Hydrological monitoring (precipitation, evapotranspiration, soil moisture, water level)
- Hydrological modelling (scenario analysis and operational forecasting)
- Flood forecasting, monitoring, historical and vulnerability assessment
- Water Demand related change detection
- Erosion potential mapping
- Urban sanitation planning support

3. A WOIS designed to fulfil operational needs

In response to the system and EO product requirements a WOIS has been developed with the capacity to perform the required processing steps from the EO data to the final water information products. The system is expected to provide a much faster and more cost effective monitoring capacity than compared to the traditional methods of data collection and analyses, the latter still being an invaluable source.

3.1. The WOIS

The WOIS can be seen as a multipurpose system consisting of a storage container for the geodata, extraction and processing of the EO data through customized processing facilities, and integrative tools and models aimed at decision support e.g. Hydrological modelling and GIS embedded visualisation and analysis tools. The WOIS is designed around Quantum GIS (QGIS) [4], which acts as the front-end Graphical-User-Interface (GUI). The other components of WOIS are: GRASS GIS (large toolbox of raster and vector analysis

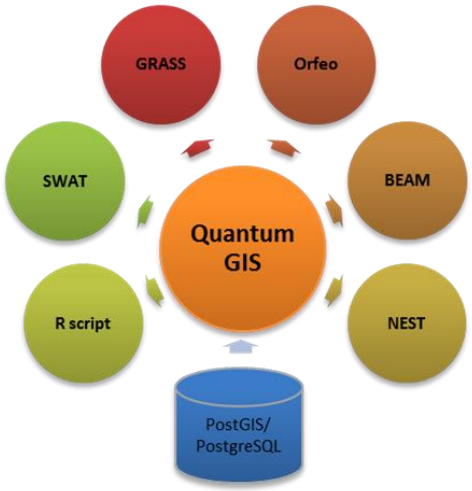

Figure 1. Open-source software packages integrated as part of the Water Observation and Information System (WOIS) plugin for QGIS.

algorithms) [5], BEAM and NEST (processing of optical, thermal and radar ESA data products) [6,7], Orfeo Toolbox (high resolution image processing) [8], Soil Water Assessment Tool – SWAT (hydrological modeling) [9], R scripts (statistical and graphical tools) [10] and PostGIS (spatial database) [11]. The functionality from the different software components are integrated using the SEXTANTE spatial data analysis library [12] which provides a framework for incorporating algorithms from the various providers (such as GRASS GIS, BEAM, etc.) into QGIS (Figure 1). A key advantage of SEXTANTE is the ability to seamlessly use functionalities from different providers for data processing and analysis, and via a unique QGIS plugin it is possible to sequentially combine algorithms from the different providers into wizard-based processing i.e. standardised workflows of complex tasks with instructions (Figure 2).

The plugin has been used to generate a workflow library with step-by-step guidance for the users to extract specific water information products. The workflows are first and foremost a help for the novice and intermediate users, while the more advanced users may choose to explore the full suite of algorithms and tools available from SEXTANTE in order to create their own workflows. Moreover, pre-parameterized SEXTANTE models for certain products are provided to enable an automatized production for operational usage.

As part of the WOIS framework a PostGIS database is provided, enabling de-centralized operation of multiple user identities. A library of import/export function further ensures the integrate ability and/or connection to existing IT infrastructures and databases.

The EO portfolio and demonstration projects

The operational and practical use of the WOIS to support IWRM in Africa is demonstrated via a series of user specific demonstration cases. The demonstration cases have several elements: First, customized end-to-end processing workflows are developed for the requested product group(s). The developed workflow is subsequently used for product derivation over significant areas and time periods as requested by the users, and in a final step the workflow (i.e. stability/performance and ease of use) as well as the product outcome is being evaluated in close dialogue with the users.
The demonstration projects being defined, produced and evaluated together with the initial user group are as follows:

- Historic and operational information on water quality and water surface temperature for Lake Chad and Lake Victoria using a combination of ENVISAT and MODIS data.
- Assessment of land degradation and desertification processes for Volta and Lake Chad basin from trend analysis of SPOT VGT NDVI time-series data and corresponding rainfall data.
- Full basin mapping of the state and change in land cover/ land use from annual time-series of MERIS FR and MODIS data.

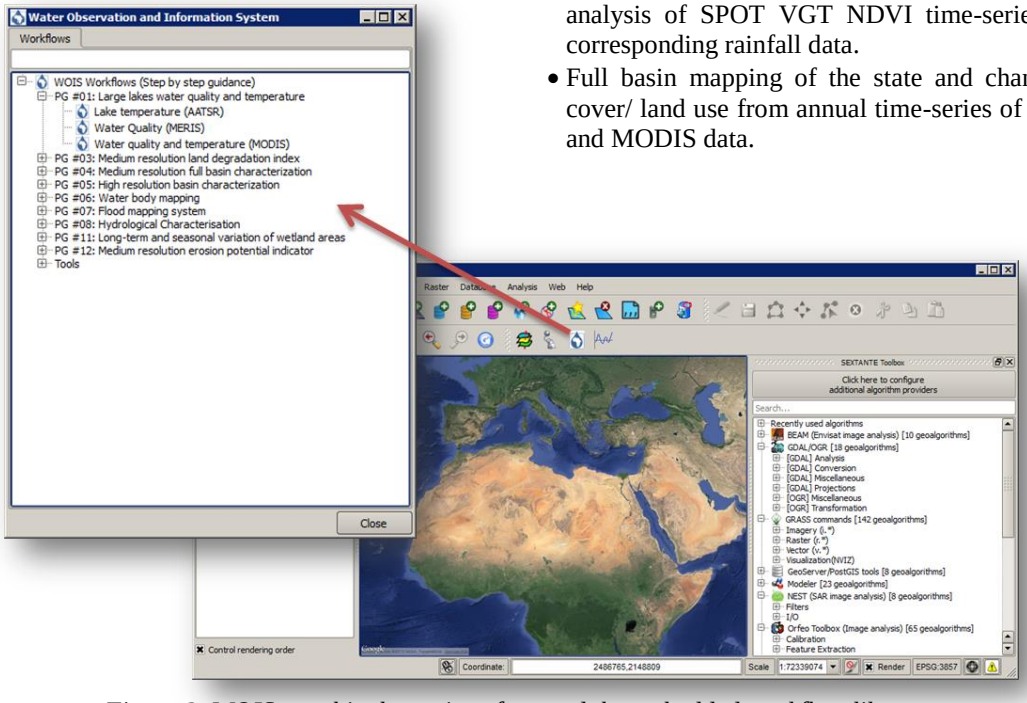

Figure 2. WOIS graphical user interface and the embedded workflow library.

- Landscape seasonal monitoring using decadal vegetation anomalies as derived from time-series of biophysical SPOT VGT products i.e. Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).
- High resolution land cover and land cover change mapping for water management related land cover classes in South Africa and land cover change mapping for the retreat area of Lake Chad based on SPOT, RapidEye and Landsat data.
- Detailed mapping and monitoring of open small water bodies and their seasonal changes in the northern part of the Volta basin based on SPOT, RapidEye and Landsat data.
- A flood mapping system consisting of two products: the historical flood mapping product for the Komadougou-Yobe sub-basin in the Lake Chad catchment, the Lake Tana region and the Gambella region based on Envisat ASAR data and the dynamic flood mapping product for the Zambezi Flood Plains in Caprivi in Namibia (Figure 3), the Eastern Nile and Lake Tana and the Gambella region based on Radarsat-2 and RapidEye tasking.
- Hydrological modelling using the semi-distributed, physically based hydrological simulation software SWAT for River Chari and Logone basins in Lake Chad; Operational river discharge forecasting for Kavango basin (Figure 3) and Mokolo catchment (South Africa).

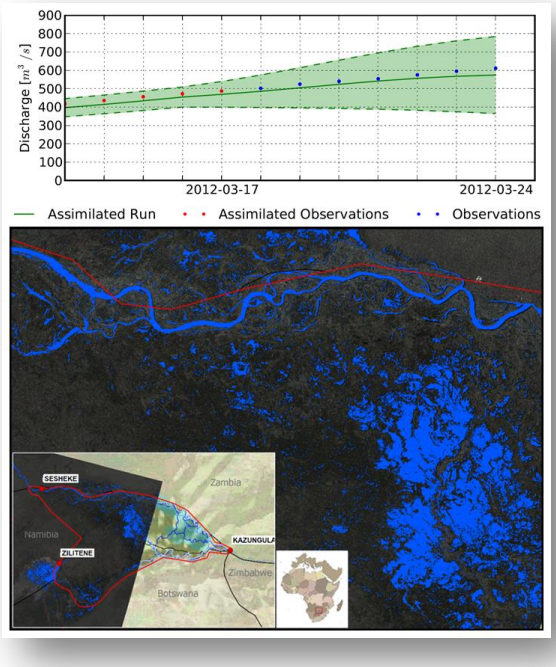

Figure 3. showing WOIS hydrological model 7-day ahead forecasts for the Kavango river at Rundu (top) and downstream WOIS enabled near-real time flood monitoring of Zambezi floodplain in Caprivi, Namibiaon 24.03.2012 employing Radarsat-2 data (high resolution optical and SAR satellite sensor data can be ingested and processed).

- Mapping and modelling tool to estimate the water demand for water supply and sanitation associated with urban environments in Africa based on very high resolution satellite imagery land cover data and census data for N'Djamena, Chad.
- Mapping and monitoring of historic long term (2 wet seasons in time) and seasonal extent and variation of major wetland areas (Sudd, Baro-Akobo-Sobat and Kagera wetlands) in order to better understand and quantify the water balance of wetlands.
- Modelling of medium resolution, anthropogenic caused erosion potential for the Lake Victoria catchment and Kagera area in the Nile Basin based on land cover, rainfall, soil data as well as on a digital elevation model for the slope to identify highly potential erosion areas and changes for prioritizing watershed restoration activities and planning.

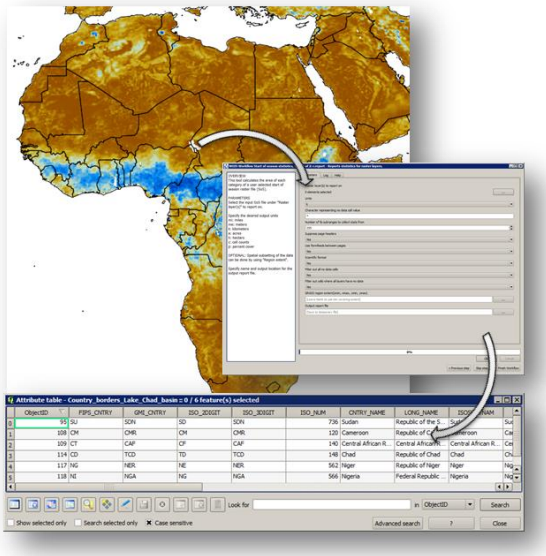

Figure 4. *Screenshot of WOIS derived water stress anomaly product and single step workflow example for generating report on affected areas / population.*

The final evaluation concerning the assessment of the WOIS including actual utility and impact of the generated demonstration case products is currently on-going. Still, the preliminary experience and feedback from the system installation and demonstration is a system that meets expectations and the performance, stability and user friendliness of the WOIS processing workflows have been acknowledged by all current users.

4. OUTLOOK

The initial user evaluation of the WOIS has been very encouraging and bodes well for the continued development of the WOIS, which includes general updates with the latest software developments and adaptations in response to continued user requirements. A particular focus will also be to ensure support and development of processing capacity of the upcoming Sentinel satellite systems, which will turn the WOIS into an operational monitoring system. Furthermore, the core elements of the WOIS development framework (i.e. QGIS/ SEXTANTE) may function as a regional joint and general repository and access platform for EO data processing and training and thereby facilitate the wider use of EO data in the African community.
Through provision of this license-free, powerful and extendable system, continued capacity building and training efforts, the project thrives to build the basis for an extension, i.e. roll-out to other countries and regions in Africa. Another major aim is the continued support of the users and stakeholders to reach sustainability by attracting external funding opportunities to enable operational utilization of satellite data for Integrated Water Resource Management in Africa.

Acknowledgement
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