Improving the Groundwater Monitoring Network in Africa: contribution to an integrated approach for assessing the impact of climate change and socio-economic developments on groundwater resources in Africa

N. Kukuric & M.T.H. van Vliet
IGRAC - International Groundwater Resources Assessment Centre, Utrecht, The Netherlands

ABSTRACT: Together with several partners, IGRAC (International Groundwater Resources Assessment Centre) has started an initiative to improve groundwater monitoring in Africa. Among others, the initiative includes support of collaboration among groundwater specialists, improved access to relevant monitoring information and an interactive, on-line monitoring database. The simplicity of the web-based database (only a browser required) and its ownership structure (data provider retains a full control over data) will hopefully encourage groundwater specialists to join the network. Besides terrestrial monitoring, remote sensing observations and global hydrological modelling will also be used to provide estimation of groundwater recharge on regular basis. The estimation will be compared with terrestrial observations and made available via the common groundwater monitoring portal. Integration of the Groundwater Monitoring Network with remote sensing and regional hydrological modelling provides a multiple-scale approach for assessing the impact of climate change and socio-economic developments on groundwater resources in Africa.

1 INTRODUCTION

Groundwater is an important primary source for agriculture, domestic and industrial water supply in many African countries. A demand for groundwater in Africa is likely to increase in the future, primarily due to population growth. Additionally, groundwater demand may increase in some regions because of the need to offset declining summer surface water availability due to climate change. Hence, groundwater can be considered as buffer resource, coping with climate change.

On the other hand, groundwater is - as part of the hydrological cycle - also affected by climate and its changes. In comparison to surface water impacts, there has been little research on the potential effects and vulnerability of groundwater systems to climate change, because of the invisibility of acting processes and complexity in the evaluation of responses, which are generally indirect and slow.

In order to learn more on possible impact of climate change and socio-economic developments on groundwater, additional information on state of groundwater in Africa is required. Therefore, IGRAC (International Groundwater Resources Assessment Centre) is setting up an African Chapter of the Global Groundwater Monitoring Network (GGMN). The network is part of UNESCO GRAPHIC initiative (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change). The main characteristics of the GGMN are described in chapter 2.

At regional and global scale, remote sensing observation can be used for estimation of groundwater variables and their change in time. These observations are often assimilated with output of global hydrological models in order to yield more accurate groundwater estimates. Chapter 3 briefly introduces two remote sensing approaches that IGRAC intends to use in conjunction with terrestrial GGMN measurements.

Introduction of an African Chapter of the GGMN is the main purpose of this paper (chapter 4). IGRAC would like to support improvement of groundwater monitoring network in Africa. Several ways of support are suggested, among them to provide an interactive, on-line groundwater monitoring system. The paper is rounded off with some concluding remarks (chapter 5).

2 GLOBAL GROUNDWATER MONITORING NETWORK (GGMN)

Groundwater is monitored in many parts of the world, mainly by measuring groundwater levels, groundwater abstraction, spring discharge and water quality. The results of these point measurements are sometimes interpolated and combined with other information to produce various groundwater (related)

maps covering aquifers, regions and whole countries. There is, however, no systematic monitoring and assessment of groundwater change on global scale.

IGRAC (advised and supported by Global Groundwater Monitoring Group) is establishing a sustainable Global Groundwater Monitoring Network (GGMN), aiming to use monitored data for a periodic assessment of the global groundwater resources (Kukuric & Vermooten 2007). It should be noted that intention is not to create a new, separate global network of monitoring wells. Likewise, no redesign of existing groundwater monitoring networks should be expected. The GGMN is a "network of networks", that uses information from existing networks in order to represent a change of groundwater resources at the scale relevant for the regional and global assessment.

Accordingly to the scale of the assessment, GGMN uses aggregated values rather than point observations, latter having a limited areal representativity and the limited accessibility. A sound regional aggregation of the point groundwater measurements is much more than a numerical interpolation and averaging procedure. It needs to be carried out by regional experts, making use of their knowledge of hydrogeological conditions, measurement practice, historical records, socio-economical setup, and other factors relevant for derivation of reliable figures. Therefore, establishing of a sustainable GGMN People Network composed of skilled regional and/or country representatives is the main challenge of this initiative.

IGRAC is developing a web-based application to assist the aggregation procedure, as well as the gathering and dissemination of information (see Figure 1). The GGMN application enables the user to periodically produce on-line maps showing a regional change of groundwater variables in time.

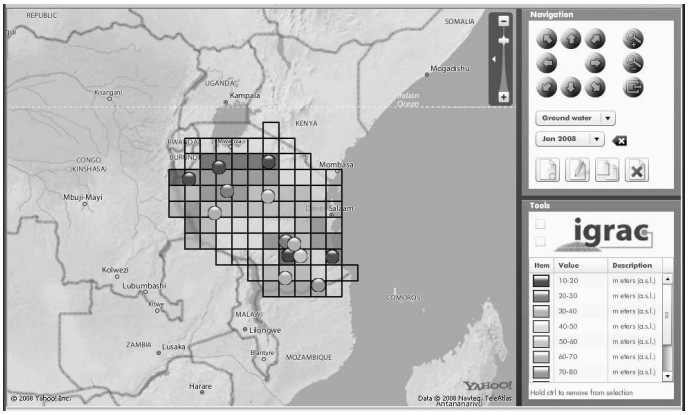

Figure 1. A web-application for Global Groundwater Monitoring Network.

Representative groundwater point measurements and proxy information (such as precipitation and demography) can be uploaded in the application to assist the aggregation procedure. Once the aggregation is completed, the information is stored in the GGMN database to be combined with information from other monitoring regions and eventually disseminated via the IGRAC portal.

The use of the GGMN application requires only a browser and the access to the Internet. Further on, the user has a direct access to the database and a full control over own data. The simplicity of the application and the clear information ownership are provided to encourage the groundwater specialists in supporting and joining the network.

In most of the cases, the country-based information will need harmonisation in the boundary regions before a regional or global overview is produced. IGRAC will use WHYMAP's (World-wide Hydrogeological Mapping and Assessment Programme) Hydrogeological Map of the World, IGRAC's Groundwater Regions Map, various transboundary aquifer maps and other information sources to carry out this task. The resulting maps will be used for comparison with the outcome of remote sensing observations and as an input for global hydrological models (see next chapter).

3 REMOTE SENSING FOR THE GROUNDWATER MONITORING

As complementary to the terrestrial measurements, IGRAC is exploring possibilities to use remote sensing observations to monitor the change of global groundwater resources.

The most promising method is GRACE (Gravity Recovery and Climate Experiment) that deals with gravity field change and the change in terrestrial water storage. NASA has launched two satellites in a tandem, 170-270 km apart, measuring very precisely change in distance between the satellites for the period of 2002-2007. GRACE generates data of water mass storage changes at a spatial resolution of ~ 200-300 km (Remillien et al. 2004).

The change in distance is in principle the result of the change in gravity field caused (among others) by change in terrestrial water storage (soil moisture, groundwater, wetlands) on Earth. Therefore, if the contribution of other factors to gravity variation is known, it may be possible to monitor change in groundwater storage. In order to assess added value of GRACE measurements, those results should be compared with terrestrial measurements. Once correlated, GRACE measurements could be used complementary to terrestrial measurements for both:

- assessment of current groundwater resources and
- prediction of groundwater resources by means of global groundwater models.

The main challenge for potential use of GRACE in global monitoring of groundwater resources is quantification of other factors (than groundwater) in-

fluencing GRACE measurements and their removal from data series. Those are primarily instrumental errors, atmospheric mass (pressure), redistribution of mass like tides, post-glacial rebound and the other terrestrial water storage (soil moisture, river, lakes, snow and ice and water contained in biomass). The second main limitation of GRACE at the moment is the scale of implementation; It has been concluded that terrestrial water storage changes are likely to be detectible by GRACE in 200.00 km^2 and larger regions (Rodell & Famiglietti 2001; the authors are also members of the Global Groundwater Monitoring Group).

An other approach is to use a satellite derived evapotranspiration and soil moisture field as an input for a global hydrologic model. Together with a several partners, IGRAC has developed a proposal for assessing groundwater recharge by means of operational satellites. Soil moisture will be derived on daily basis and tuned using historical ERS-Scatterometer (De Lange et al. 2008). Use of MODIS-data will enable estimation of evaporative flux on a daily basis. Eventually, evapotranspiration and soil moisture data will be assimilated with output of a global hydrological model of Utrecht University (Figure 2) in order to produce better estimates of recharge (at the scale of 0.5° x 0.5°). It is proposed to disseminate and test the modelling result in a region on the African continent (see also next chapter). After testing and estimating the current groundwater recharge, climate change scenarios can be used as input in the global hydrological model in order to assess climate change impacts on future groundwater recharge in Africa.

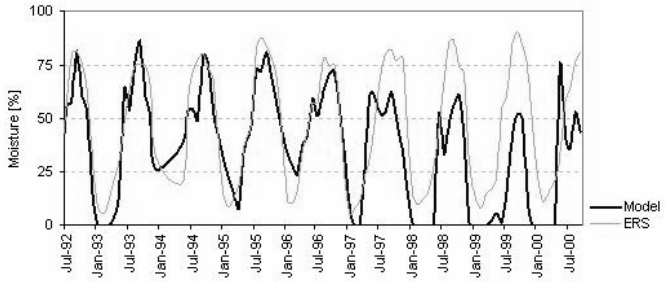

Figure 2. A comparison of soil moisture estimated using GLOBWB and ERS data for a single model cell in Africa over an 8 year period (a preliminary assessment)

4 AFRICAN GROUNDWATER MONITORING NETWORK (AGMN)

African groundwater monitoring network already exists; groundwater levels are monitored in (most likely) each country of the continent. Although it can be argued over (insufficient) temporal frequency and special density of existing networks, or data (in)accuracy and (poor) processing, there is no purpose of creating a new network. Hence, the African Groundwater Monitoring Network (AGMN) should be seen as an initiative to improve existing groundwater monitoring network in Africa. The role of IGRAC in this initiative is to:

- facilitate collaboration among groundwater specialists from various African countries
- improve access to relevant information and knowledge on groundwater monitoring
- provide a participative, interactive and web-based groundwater monitoring application

For the Kampala conference IGRAC will organise a side-event dedicated to groundwater monitoring in Africa. Regional groundwater specialists will be engaged to share their monitoring experience (success stories, problems, lesson learned, needs). IGRAC will introduce GGMN and the initiative to set up the African Chapter of this global network. The main purpose of the side-event is to strengthen the links among the network nodes (i.e. country representatives). After the conference, IGRAC will continue to support this cooperation both on-line (in an on-line collaborative environment) and on-site (by organising further GGMN People Network meetings).

The Kampala conference will be a part of the inventory on needs regarding the groundwater monitoring in Africa. IGRAC cannot cover the costs of monitoring wells, but it can support development of a specific monitoring guidelines or setting up of a monitoring help-desk.

The GGMN web-based application will be made available to African groundwater specialists to support data collection, storage, processing and presentation. The special attention will be paid to synchronisation of the GGMN initiative with already existing country or regional groundwater monitoring programmes.

IGRAC proposal to employ remote sensing and global modelling in estimation of groundwater recharge will also be promoted during the Kampala conference. The country representatives will be approached with request to join this project. When the first results become available, IGRAC will organise a workshop for the African partners in order to present and test the outcome of the project. Prior the workshop, a joint effort will be made to provide a set of terrestrial groundwater observations relevant for comparison with remote sensing recharge estimates. This will be a difficult task since the availability of groundwater related observations is in general rather poor. Nevertheless, the workshop will provide a procedure for future testing of remote sensing estimates and their comparison with terrestrial observations. The procedure will be made available via a web-based portal, together with actual recharge estimates and the link to GGMN web-application.

5 CONCLUDING REMARKS

Assessment of the global groundwater resources is the core activity of IGRAC. The change of groundwater in time makes the groundwater assessment a dynamical process and the groundwater monitoring a necessary precondition for the assessment.

IGRAC has started with the GGMN initiative in 2006 with support and participation of about 30 organisations world-wide (please read further on http://www.igrac.nl/publications/281). The GGMN application is now fully operational and will be offered to the African colleagues during the Kampala conference.

The application is developed to support regional and global monitoring and assessment of groundwater resources. Nevertheless, more intensive cooperation among experts and the improved access to the relevant sources of information could also improve local monitoring activities. For example, IGRAC Guideline and Protocols database contains information on 28 documents related to groundwater monitoring (http://www.igrac.nl/publications/128). A world-wide inventory on groundwater monitoring practices is available as well.

People Network is seen as crucial for success of the initiative. Active participation of regional groundwater specialists and their commitment to the African Groundwater Monitoring Network is required to ensure the future of the network. The responsibility over the monitoring network in Africa lies with the regional specialists and decision-makers. The role of IGRAC is to facilitate.

6 REFERENCES

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