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Groundwater quality characterization to protect biodiversity in SADC region (Southern African Development Community)

Stefania Vitale[1], Maurizio Barbieri[1], Giuseppe Sappa[2]

[1]Department of Earth Sciences, Sapienza University of Rome, Italy
[2]DICEA, Department of Civil and Environmental Engineering, Sapienza University of Rome, Italy

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Abstract

The following paper describes the first phase of a study held in the context of the SECOSUD Phase II project, called "Conservation and equitable use of biological diversity in the SADC region (Southern African Development Community), which aims at promoting biodiversity conservation and sustainable economic development in the SADC [1]. The Southern African Development Community (SADC) is an inter-governmental organization, with 15 member states: Angola, Botswana, Democratic Republic of Congo, Lesotho, Mauritius, Malawi, Mozambique, Namibia, Madagascar, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. Its aim is to increase socio-economic cooperation and integration among the community. It is one of the richest area in terms of biodiversity.

The main goal of the Project is to contribute to stop biodiversity loss by supporting the development of conservation strategies.

Biodiversity or biological diversity is formally defined by the Convention on Biological Diversity (CBD) as: "the variability among living organisms from all sources including, among others, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (UN 1992 Article 2) [2].

Biodiversity is affected by the interaction of multiple drivers and pressures including demographic, economic, socio-political, scientific and technological ones, which are leading to further decline, degradation and loss.

The principal pressures on biodiversity include habitat loss and degradation, overexploitation, alien invasive species, climate change and pollution.

These pressures are continuing to increase. To use biodiversity and to keep it in a sustainable way, it is necessary to study it, assess its economic value, develop a global strategy and a global network to monitor its status in the biosphere.

An important step in developing conservation of biodiversity requires a successful groundwater characterization and protection. Conservation of biodiversity depends on groundwater needs strategies that allows for the use of groundwater in a way that is compatible with the persistence of ecosystems in natural area, such as Limpopo Transfrontier Park, in the Southern African Region, which is an area rich in term of biological diversity and ecological complexity. In particular the quality of ground water in some parts of the country, especially shallow ground water, is changing as a result of human activities.

The goal of the following study is to provide an assessment of the actual groundwater quality-monitoring network and in consideration of the growing demand for water, there is a need to understand the effects of planting on water resources to estimate crop water requirement for the focus area, as last step of the methodology.

Keywords: *Secosud; groundwater; Limpopo National Park; GIS.*

Introduction

Groundwater is a key element in the SADC region. Groundwater is the primary source of water for people living in the SADC region, because it is used extensively throughout the southern African region, including the Limpopo River basin, supplying a large percentage of water for irrigation, rural water supply schemes and mining. The province has limited surface and ground water resources. Increased demand, population growth and climate change are increasingly putting pressure on groundwater resources in SADC Region. Lack of a management have already led to contamination and overexploitation of aquifers in some areas and could result in additional water supply problems, land subsidence and deterioration of groundwater dependent ecosystems.

The first step is to assess the hydrologic balance by estimating the evapotranspiration over study area.
This information is important in assessing water resource development and management options.
Evapotranspiration (plant transpiration and surface evaporation) is one of the largest outflow components of the hydrologic budget.
There is a need to understand the effects of planting on water resources to estimate crop water requirement for the focus area, as last step of the methodological strategy.

Figure 1. Map of the study focus area

Study area

The Limpopo National Park, in the Limpopo Basin, is the study focus area. (**Figure 1**). Limpopo National Park, one of the jewels in the crown of Mozambique's protected areas, came into existence in November 2001, when the area encompassing a former hunting reserve, was reclassified as a national park.

Although the technical aims and the recommendations of the Limpopo Watercourse Commission (LIMCOM, established in 2003) on the use of the Limpopo River basin and its water resources [5], the background to water resources shows a low understanding of the meaning of groundwater resources protection, an undervaluing of the groundwater potential. There aren't expertises and funds to understand key environmental issues water uses. Groundwater database management in Mozambique is poorly developed. Inter-institutional relationships regarding database management do not yet exist [6].

The basin

Limpopo River Basin is located in Southern African Development Community. It is situated in the East of southern Africa between about 20 and 26 °S and 25 and 35 °E. Its catchment area covers about 416,296 km2, and it is shared by Botswana, Mozambique, South Africa and Zimbabwe.

The Limpopo river flows for a distance of 1,750 km from its headwaters near the border between South Africa and Botswana, and Zimbabwe. Then it flows through Mozambique before discharging into the Indian Ocean. Its catchment area is spread among South Africa, Botswana, Zimbabwe and Mozambique is 45%, 20%, 15% and 20%, respectively [4]. The Limpopo River can be divided into three major reaches: the upper Limpopo, down to the Shashe confluence at the South Africa-Botswana-Zimbabwe border, forms the border between Botswana and South Africa, runoff from South Africa and Botswana; the middle Limpopo, which forms the border between South Africa and Zimbabwe between the

Shashe confluence and the Luvuvhu confluence at the South Africa-Zimbabwe-Mozambique border (at Pafuri); runoff from Botswana (Shashe), Zimbabwe and South Africa; the lower Limpopo, which flows entirely in Mozambique, downstream of Pafuri to the rivermouth in the the Indian Ocean; runoff from Zimbabwe (Mwenezi), South Africa and Mozambique [7]. The bed of the Limpopo River is dry for most of the year.

The Limpopo river basin (**Figure 2**) is almost circular in shape with a mean altitude of 840 m above sea level. The Limpopo river has a relatively dense network of more than 20 tributary streams and rivers, though most of these tributaries have either seasonal or episodic flows. In historical times, the Limpopo river was a strong-flowing perennial river but is now considered as a weak perennial river. The basin consists largely of undulating terrain between ranges of hills and mountains.

Figure 2. Limpopo River Basin

The Mozambique portion of the Limpopo basin consists of gently undulating terrain with numerous small tributary streams and pools forming part of the Changane drainage system. This tributary rises close to the Zimbabwe-Mozambique border, meanders across the Mozambique coastal plain and joins the Limpopo river very close to its mouth on the coast near the town of Xai-Xai. The rich biodiversity of Limpopo can be attributed to its biogeographical location and to diverse topography. The climate is semi-arid with two distinct seasons. The rainy and hot season occurs from October to March while the dry and cold season is from April to September.

The mean annual rainfall during the rainy and hot season varies from 650 to 760 mm. In the dry and cold season rainfall varies from 260 to 360 mm. Average temperatures ranges from 21-31 0C and 15-27 0C during the rainy and dry seasons, respectively.

Geological and hydrogeological setting

The African Continent preserves evidence for major crust-forming events dating back to 3.8 Ga. The African continent (and Madagascar) comprises a mosaic of old, stable, mostly crystalline, crustal blocks (called cratons) surrounded, and welded together, by an interconnected network of younger orogenic belts comprising deformed metamorphic rocks and granites, called mobile belts.

Seven major cratonic nuclei form the foundation of Africa: the Kaapval craton, the Zimbabwe Craton, The Tanzania Craton, The Congo Craton, the Man Shield, The Reguibat Shield and the East Sahara or Nile Craton. During the Neoarchean and Paleoproterozoic these Archean nuclei merged into three major cratons referred to West Africa, Central Africa(Congo-Tanzania) and Southern African(Zimbabwe-Kaapval) cratons [8].

The Southern Africa Craton comprises the Zimbabwe Craton to the N and the Kaapvaal Craton to the S, merged across the high gneisses of the Limpopo Belt. The Limpopo Belt has been interpreted as an Archean collisional orogeny and comprises the North Marginal Zone, Central Zone and South marginal Zone.

The geographic position of Mozambique in the framework of Gondwana, makes the country a geologically important terrain particularly because it contains boundaries between cratonic and mobile belt terrains. The prominent geological features of the Limpopo river basin are the Limpopo Mobile Belt, the Kalahari Craton, the Archaean Craton, the Karoo system and the Bushveld Igneous Complex.

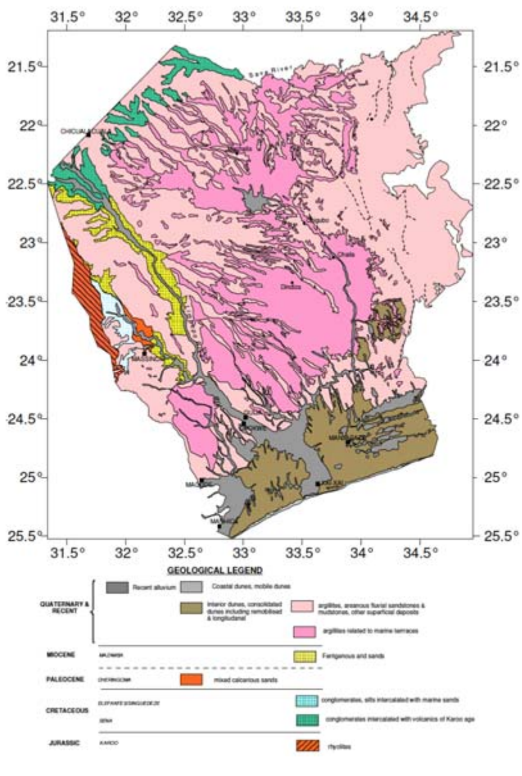

Figure 3. Geological Map

The crystalline basement of Mozambique belongs to three major ‘building blocks’ or terranes, East, West and South Gondwana, that collided and amalgamated during the Pan-African orogeny to form the Gondwana Supercontinent.

The stratigraphy in the basin starts with the Karoo aged volcanics at the base, which are overlain by some Cretaceous conglomerates. Cretaceous conglomerates, some intercalated with the Karoo volcanics and others with silts and marine sands, form the geology of the upper courses of the rivers and streams in the west and northwestern ends of the area.

Some intercalations of argillites (some related to marine terraces), arenaceous fluvial sandstones and mudstones and other superficial deposits form the dominant lithologies in the central part of the map, between Save and Limpopo rivers. These units are Quaternary to recent in age.

Crystalline basement rock is distributed extensively throughout Africa and underlies large parts of the semi-arid Limpopo Province in South Africa.
The development of crystalline basement aquifers as a reliable source of water supply is notoriously complex, and groundwater occurrence is spatially highly variable.

Some of the greatest groundwater needs occur in the region and groundwater is the only dependable source of water for many users.

The Karoo Volcanics of the Limpopo Basin in Mozambique are hydrogeologically quite similar to the crystalline rocks everywhere else in the Limpopo basin, where primary and secondary fractures are the most important water bearing features Cretaceous sediments form the northerly limits of the Limpopo Basin as a series of thin slivers which take up a total of only about 5% of the basin in Mozambique. These sediments consist of coarse textured arkosic sandstones, some being calcareous, as well as clays and carbonates with occasional conglomerate (WaterAid, 2002). Tertiary sediments mainly consist of marine carbonates and medium textured sandstones that are found flanking the banks of the Limpopo River in its up-stream course in Mozambique.

Materials and methods

This paper outlines the aim of the present study: to quantify the water demand of existing vegetation and provides recommendations on where to focus future research efforts. An estimation of the crop water requirements for the Limpopo National Park will be carried out through the use of remote sensing land classification and application of a simple water balance scheme in a GIS environment.

Remote sensing techniques using satellite images have been successfully used to estimate evapotranspiration across a range of spatial scales.
It was therefore considered important to set up a methodology capable of providing information for subsequent hydrogeological studies and evaluate the possible dynamic and temporal evolution of aquifer.

For istance the overall procedure to evaluate the spatial distribution of monthly crop is according to FAO approach [8]. It will take form remote sensing images interpretation a crop classification map. Then monthly crop coefficient (Kc) values will be associated to each crop class and a reference evapotranspiration map, e.g. derived from meteorological data, will be used in order to estimate crop evapotranspiration. All the procedure will be GIS supported and monthly maps of Kc values will be carried out in the aim of setting up a crop classification map, identifying homogeneous crop classes in terms of water use and assigning to each class a monthly Kc value [9]. In order to better distinguish between the different crop classes it has been decided to involve additional remote sensing data. As a consequence of it, LANDSAT ETM+ images will be acquired. Further important informations sources will be provided by land use map of the focus area.

The project includes the collection of hydrological data of the area of Limpopo National Park.
The operational network consists of at least 9 continuous weather monitoring stations, listed in **Table 1**, equipped with The Vantage Pro2™ (6152, 6153) and Vantage Pro2™ Plus (6162, 6163) Wireless Weather Stations, which includes two components: the Integrated Sensor Suite (ISS) which houses and manages the external sensor array, and the console which provides the user interface, data display, A/D conversion in the ISS, and calculations. The ISS and Vantage Pro2 console communicate via an FCC-certified, license-free frequency hopping transmitter and receiver. User-selectable transmitter ID codes allow up to nine stations to coexist in the same geographic area. A comprehensive picture of the areal distribution of precipitation can be obtained by establishing these type of rain gauges.

Meteorological Stations	Geographical coordinates
Mapai	22°51’7.01”S -31°58’1.99”E
Mapulanguene	24°29’25.89”S- 32° 4’55.47”E
Komatipoort	25°25’37.96”S – 31°57’7.00”E
Pafuri	22°27’0.10”S – 31°19’16.50”E
Letaba	23°51’22.72”S – 31°34’37.63”E
Combomune	23°28’8.98”S – 32°27’14.55”E
Devende	23°20’30.34”S – 32°20’53.30”E
Massingir	23°55’15.68”S 32° 9’43.05”E
Phalaborwa	23°56’51.53”S 31° 8’18.11”E

Table 1. The operational monitoring network

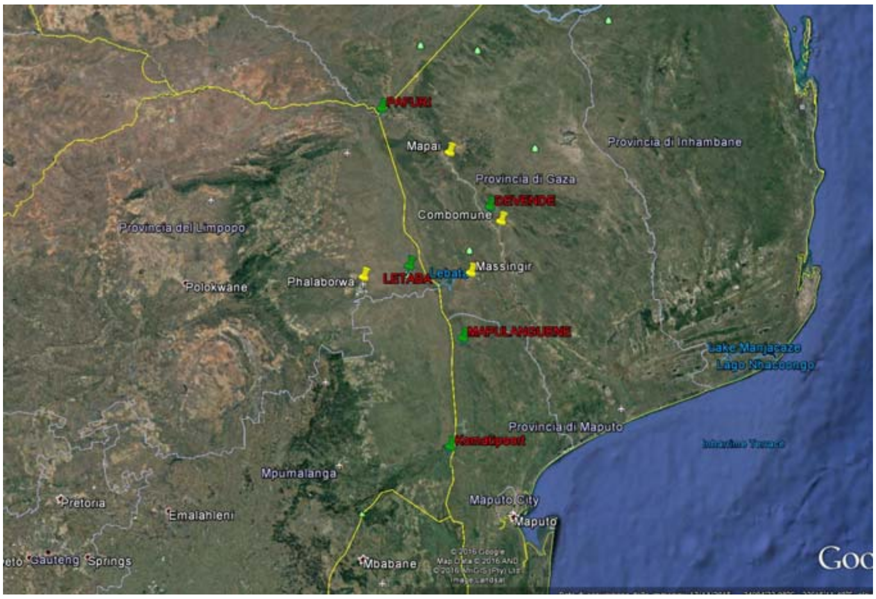

Figure 4. Location of monitoring stations

Also of importance in the consideration of the interaction of groundwater and surface water is the quality of the water body.
In recent years, the growth of industry, technology, population, and water use has increased the stress upon both land and water resources. Locally, the quality of ground water has been degraded. Municipal and industrial wastes and chemical fertilizers, herbicides, and pesticides not properly contained have entered the soil, infiltrated some aquifers, and degraded the ground-water quality. Other pollution problems include sewer leakage, faulty septic-tank operation, and landfill leaches.

Pollution is the degradation of natural systems by the addition of detrimental substances and is usually associated with industrial and agricultural development, and the rapid increase in human population density.
Generally, in the SADC region, Industrial and municipal waste, the most serious soruces of pollution groundwater are agro-chemical pollution, which is a product of the application of pesticides, herbicides or fertilisers, herbicides, and pesticides not properly contained have entered the soil, infiltrated some aquifers, and degraded the ground-water quality. Other pollution problems include sewer leakage, faulty septic-tank operation, and landfill leaches. Pollution is the degradation of natural systems by the addition of detrimental substances and is usually associated with industrial and agricultural development, and the rapid increase in human population density. Generally, in the SADC region, Industrial and municipal waste, the most serious soruces of pollution groundwater are agro- chemical pollution, which is a product of the application of pesticides, herbicides or fertilisers, discharges of toxic mine waters from abandoned mine workings, industrial and municipal waste, which can either be biodegradable or non-degradable, solid or liquid. As second step, water points will be selected for hydrogeochemical and water quality investigation, in order to develop a groundwater information system, setting the data in a spatial system.

Conclusions

This paper has presented the preliminary results of a study, which is part of the SECOSUD research project, in the aim of preserve biodiversity in some areas in Limpopo National Park included in Mozambique territory. The goal of this preliminary part of the project is to evaluate water budget of the Limpopo River Basin, included in the Limpopo National Park, and to compare it with water demand of the most present vegetation species. As a matter of fact in the last decades they have been planted many kinds of trees, in the aim of facing flooding phenomena which affected many areas of Limpopo River Basin, also included in the Limpopo National Park. Some of these trees were not autoctones, and came out to present a very large water demand.
This large water demand is now really a hazard for some bioma species safety, which are typical of these areas. At this step it has been set up a meteorological monitoring plan, aimed to give, on real time, data referred to precipitation and temperature, in at least nine places, where stations can be kept, while all registered data will be sent by GSM system to a collecting data station. On the other hand it has been identified a methodological approach to evaluate the real water demand of the most present vegetation species in the area, by the analysis of remote sensing imagines, supported by a GIS system.

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