Groundwater potential assessment in Kompienga dam basin using multiple methods

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Abstract

Water scarcity constrains socio-economic development in the sahelian country of Burkina Faso. During dry periods, residents have utilized groundwater to secure access to drinking water. Groundwater is accessed via hand-dug wells and, since the 1970's, first via modern wells and later on boreholes equipped with manual pumps provided by governmental and non-governmental organizations. Insufficient knowledge of groundwater resources has led to low success rates in exploitation, however, and groundwater resource evaluation appears to be a prerequisite for sustainable water management. This article presents an evaluation of groundwater potential within a watershed of 5911 ha in Eastern Burkina Faso. The results are derived from 18 months of field work in which water was sampled monthly during the rainy season from rain gauges, piezometers and boreholes with hand pump. Deep groundwater from boreholes was also collected during dry season. More than 100 samples were collected from four characteristic sites in the research watershed and sent for laboratory analysis for chloride ion concentration.

Stream discharges were measured using divers, precipitation and other climatic data were collected from rain gauges and weather station. The water levels in piezometers were daily monitored on the four sites from 2004 to 2005. These data have supported an estimate of groundwater potential using chloride mass balance method, which has been supplemented and validated using the equations of water table fluctuation method. The recharge flow process within the basin has been revealed by the collected field data. The groundwater potential, which reflects the annual recharge estimates currently quoted for the region crystalline basement aquifers, will assist in efforts to provide sustainable and reliable water supplies management within the basin and the country.

Key words: **groundwater potential, chloride mass balance, water table fluctuation**

Introduction

Water resource management is a key issue in African development and most of the governments and donors have emphasized on this resource since the first sahelian droughts in the 1970's with their corollaries of famine and deaths. Groundwater, the hidden water resource is the most concerned resource in this management process as water supply to population is often through this means (Aureli, 2006). Water resource management requires availability of reliable data and information for setting up sustainable management plans. Groundwater potential assessment in Kompienga dam basin in Burkina Faso is a contribution to the national need of reliable data for planning sustainable water resource management for the benefit of the living populations. Scientists have developed many practical methods for groundwater potential estimation. However, inaccuracies observable in hydrology field data due to equipments indicate that the recharge estimation to be reliable through multiples methods (Lerner et al., 1990). The Kompienga basin groundwater potential has therefore been estimated using Chloride Mass Balance method and the Water Table Fluctuation method based on 18 months of field data collection.

Site presentation

The study site is located in the Kompienga watershed of 5911 km² hosting an important national hydropower dam of 2.05 billions m³ of water. The site is on the Volta river basin part of Burkina Faso and therefore belongs to the research zone of the GLOWA Volta project for which framework the actual activities were conducted. Rainfall at the site has a monomodal pattern of 5 months of rainy season completed by a long dry season where no baseflow is observable. The geological formations are mainly crystalline rocks basement consisting of granites and amphibolites covered by relatively thick regolith of lateritic, sandy clay loam, sandy loam, clayey and silty soils. Initially well vegetated with sudanian savannah species (Dipama, 1997), the basin vegetation has been cleared for the dam construction and remains continuously cleared for cropping lands and settlements by new farmers.

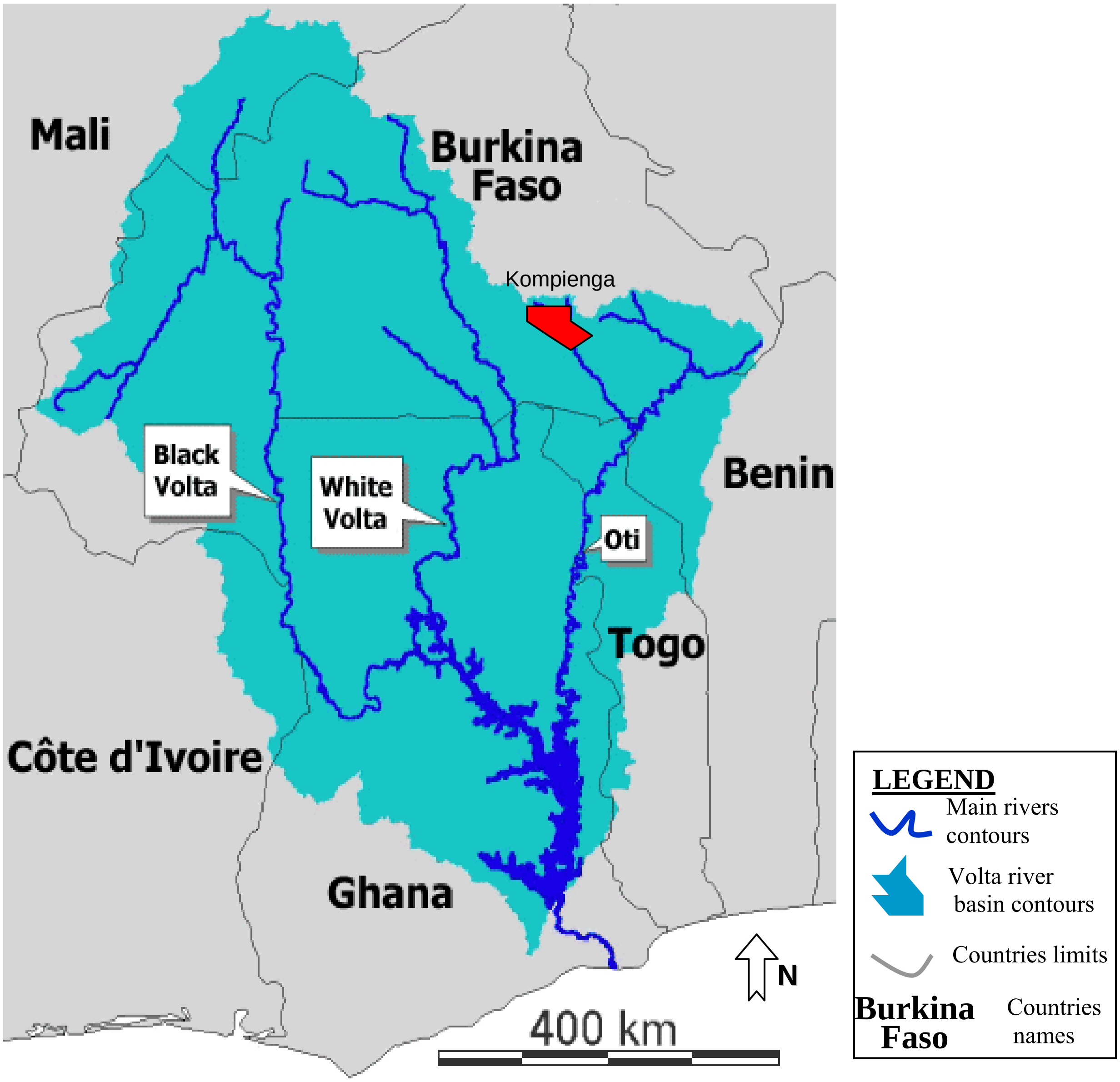

Figure 1. The study site location on the Volta river basin in Burkina Faso (modified from GLOWA Volta project)

Materials and methods

To assess the groundwater potential within the study basin, four sites spatially well distributed were selected. Rainfall, groundwater levels and chloride concentrations in both rainwater and groundwater were measured from these sites. The chloride mass balance method used data derived from laboratory analysis of water samples collected monthly from raingauges and boreholes at the four sites across the dam basin during the 2005 rainy season. The recharge was also estimated using daily water levels fluctuations data collected with piezometers at the four sites from August 2004 to November 2005.

The chloride mass balance method assessed the groundwater recharge in the basin in 2005 based on the following equation and the inherent assumptions of the method proved valid for the basin recharge estimate. The method is built on the conservative (non-reactive) and stable state of the ion chloride (Bromley et al., 1997) which is not uptaken by plants but its concentration in soil water can increase due to evapotranspiration. The recharge is then calculated in equation 1 as the product of annual rainfall depth to the ratio of the chloride concentration in rainwater and that in groundwater. The assumptions are related to the chloride origin considered solely from rainfall with no significant run-on or run-off occurring in the basin and the recharge flow process mainly vertical rather than lateral bypass flow (Bromley et al., 1997).

$$R = P.\frac{Cl_P}{Cl_{gw}} \quad (1)$$

Where R is the groundwater recharge flux (LT^{-1}); P, the average annual precipitation (LT^{-1}), Cl_P is the average precipitation-weighted chloride concentration (ML^{-3}) and Cl_{gw}, the average weighted chloride concentration in the basin groundwater (ML^{-3}). M is representing mass, T is time and L, length; all in consistent units.

The water levels fluctuation method used equation 2 below to infer the basin recharge depth for 2005. This method, mainly applicable to unconfined aquifers with shallow water table, assumes that rises in groundwater levels in these aquifers are due to recharge water arriving at the water table (Scanlon et al. 2002). The recharge equation is written as followed:

$$R = S_y.\Delta h/\Delta t \quad (2)$$

where R is the recharge; S_y, the specific yield of the aquifer; Δh, the water table rise and Δt, the time period within which the rise occurred. S_y is a dimensionless parameter while R and Δh, and Δt are respectively in consistent units of (L) and (T). Δh is expressed as the difference between the peak of the water level rise and the extrapolated antecedent recession curve at the time of the peak.

Results and discussions

From the data collected at the research sites of Kompienga in 2005, the chloride mass balance method and the water table fluctuation method have provided the recharge depth within the basin as indicated in the table below.

Table 1. The annual groundwater recharge in 2005 within the Kompienga basin based on the chloride mass balance method and the water fluctuation method

Methods	R (mm)	Percent of rainfall
Chloride mass balance	22.2	3
Water levels fluctuation	31.4	4

Plotting graphs from the collected data, the recharge flow processes in the basin have been revealed to be through preferential flow and diffuse flow as shown in the following figures. Indeed, in figure 2, representing the chloride concentration in groundwater throughout the rainy season 2005 from the 4 sites, a general lowering of the curves in August is observable. This indicates a recharge at this period (3 months after the rain started in April) in the basin. The immediate increase in the groundwater chloride concentration while rains are still falling on the basin implies that the recharge was due to preferential flow mainly occurring through soils cracks, fissures and deep roots holes as common in rock basement aquifers. This fast and localized recharge flow process has momentarily and locally lowered the groundwater chloride concentration. However, as the remaining parts of the aquifer were not concerned, later on with the mixture of the two waters in the aquifer tending to an equilibrium, a progressive increase of the chloride content in the whole aquifer's water samples for the following months is observable (figure 2).

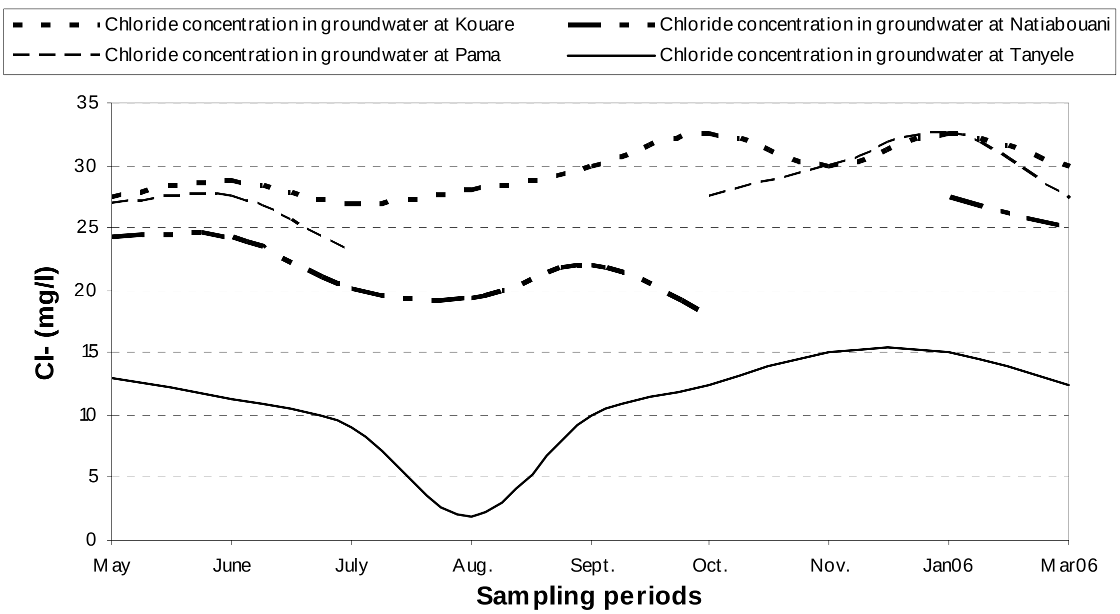

Figure 2. Monthly chloride concentration (mg/l) in groundwater samples from boreholes during 2005 rainy season

The monitoring of the water levels inside a piezometer (Figure 3) from August 2004 to November 2005 showed the first water table rises around the third month after rains started falling on the basin. Since that, the water table continued to behave according to the rainfalls events till the end of the rainy season. This water table fluctuation following the rainfall pattern describes a diffuse flow in the basin recharge process with the wetting front created by the rains progressing in the unsaturated zone to fill the soil moisture to its field capacity for percolation to the deep saturated zone of the water table.

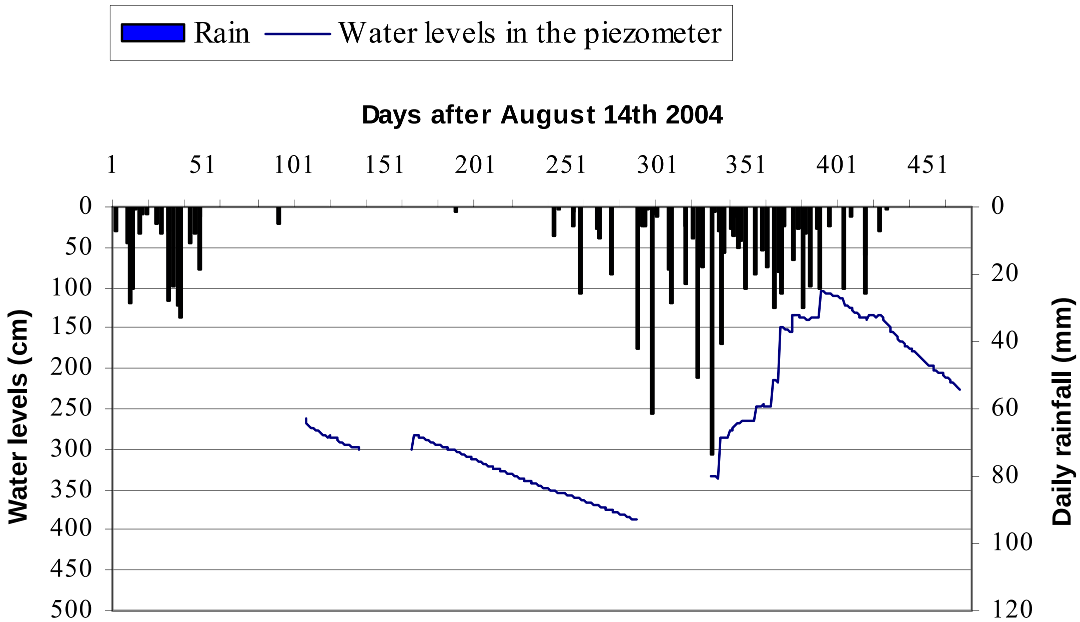

Figure 3. Water levels fluctuations in a piezometer on the monitored sites of the Kompienga basin and daily rainfall depths from August 2004 to November 2005.

Conclusion

Groundwater recharge assessment in the Kompienga dam basin using chloride mass balance method and water table fluctuation method has provided in 2005 a recharge rate of 3 to 4 % of the basin annual rainfall. This recharge in the range of previous studies within similar research zone of crystalline basement rocks consisted of fractured porosity has been revealed to be occurring through preferential and diffuse flow. These two parameters of the recharge rate and flow mechanisms are key parameters to the kompienga groundwater resource management profitably to the living population.

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