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Groundwater recharge studies in irrigated lands in Nigeria: Implications for basin sustainability

A. Sobowale [a,*], A.A. Ramalan [b], O.J. Mudiare [b], M.A. Oyebode [b]

[a] Department of Agricultural Engineering, Federal University of Agriculture, PMB 2240, Abeokuta 110001, Nigeria
[b] Department of Agricultural Engineering, Ahmadu Bello University, Zaria, Nigeria

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ABSTRACT

The potential of managed aquifer recharge (MAR) in semi-arid areas of Nigeria was evaluated using the Kano River irrigation Project (KRIP) as a case study. Groundwater recharge was evaluated daily for 3 years (2009–2011) using the water level fluctuation (wlf) method. Temporal and spatial analyses of recharge were carried out using Microsoft Excel® spread sheet and ArcGIS® 9.0 software. Results show that recharge range from 17 to 32 mm daily on the farmland. Further analysis showed that an average of 8 mm of water is added to storage daily from both rainfall and irrigation. The observed waterlogging problems has implication for salt build up in the area and could be ameliorated by conjunctive use of both surface water and groundwater from the farmland. This will lead to huge water savings that could be released from the Tiga dam to recharge the Chad formation aquifers downstream of the Hadejia River in a systematic MAR implementation via infiltration basin. However, additional modelling studies and aquifer characterization are required to implement this.

1. Introduction

Water is important for life and livelihood. It shapes the earth's landscape through soil erosion, transportation and deposition by rivers, glaciers, and ice sheets; through evaporation, water drives the energy exchange between the land and atmosphere, thus controlling the Earth's climate (Falkenmark, 1997; Molden, 2007). The availability of water is limited in space and time, this limitation calls for an integrated approach in the development and management of both surface water and groundwater resources. At the basin scale, the influence of climate change has led to increased variability of freshwater resources especially in sub Saharan Africa leading to surface water scarcity, groundwater depletion and environmental degradation (IPCC, 2007). This worrisome scenario will be more devastating in basins where the practice of unsustainable surface water and groundwater development prevails.

A good example is the Yobe River basin in Northern Nigeria which has been reported to contribute about 2.5% of the inflow to Lake Chad (UNEP, 2004); an important tributary to the Yobe River is the Hadejia River which was also reported to be responsible for about 48% of the flow in the Yobe River (HNWCP, 1997; Sobowale et al., 2010). Goes (2005) reports that millions of cubic meters of water is recharged into the quaternary sediments of the Lake Chad formation via stream channel seepage at the hydrogeological divide between the upstream basement complex areas and the downstream Chad formation, this occurs at the middle course of the Hadejia River downstream of Wudil town just before the river bifurcates and enters

* Corresponding author. Tel.: +234 8062101020.
E-mail addresses: Sobowalea@funaab.edu.ng (A. Sobowale), ramalanaa@aol.com (A.A. Ramalan).

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the Hedejia-Nguru wetlands. Increased surface water abstraction and diversion for large scale agricultural use especially at KRIP and urban water supply in the upstream areas coupled with increased evaporation in downstream areas has exerted stress on water availability in downstream areas (UNEP, 2004). The two major dams in the area (Tiga and Challawa gorge dam) have a combined active storage capacity of 2, 187 million m^3; this huge amount of water locked up behind a dam implies heavy losses to evaporation. The numerous developments in the upstream areas of the basin for irrigation and water supply is creating problems of water scarcity in downstream areas of the basin especially in the area of urban water supply. Most towns and villages in downstream areas depend on groundwater from the Chad formation which is being recharged mainly at the hydrogeological divide. Literature shows that the upper zone aquifer of the Chad formation is rapidly depleting following reports of lowering ground water level in the area (UNEP, 2004). It is therefore pertinent to begin to work towards reversing the negative trend by considering the implementation of a managed aquifer recharge (MAR).

MAR refers to intentional storage and treatment of water in aquifers (Gale et al., 2006). 'Natural' recharge to aquifers occurs through infiltration of precipitation, either directly to land or through the beds of streams and rivers. Unintentional or incidental recharge due to man's activities also occurs as a result of the effects of land clearing, excess irrigation and leakage from water mains, sewers and storm drains. This water can form a major component of aquifer recharge and should be managed, both from the quantity and quality perspectives, and treated as a resource rather than a disposal problem. Managed Aquifer Recharge (MAR) has been demonstrated to offset groundwater demand in many location around the world (Arshad et al., 2013; Bouwer, 2002). Dillon et al. (2009) reports that the observed decrease in mean annual rainfall, and the increasing rainfall intensity, temperature and evaporation forecast for semi-arid parts of the world where water supplies are already stressed will require groundwater storage capacity to be increased or more stable resources to be harnessed to maintain security of water supplies at current levels. The climate change threat to groundwater (and dependent systems) in many regions of the world is reduced availability of groundwater, due to reduced recharge, increased demand on groundwater and groundwater contamination. Adaptation strategies focus around five main themes: managing groundwater recharge, protection of groundwater quality, managing groundwater discharge, management of groundwater storage and managing demand for groundwater. In the first theme, the use of MAR in its many and varied forms, is strongly recommended, but not at the expense of environmental flows (Dillon, 2005). It is noted that the economic feasibility of MAR varies widely, but as water availability becomes even more critical with climate change, then the economics will be improved. However, effective long-term adaptation to climate change and hydrological variability requires measures which protect or enhance groundwater recharge and manage water demand.

Sobowale et al. (2010) pointed out the need to manage the water resources of the Yobe River basin sustainably, of particular importance is the need to carry out studies which will evaluate the feasibility of conjunctive use of both groundwater and surface water at the numerous irrigation projects in the basin particularly the Kano River Irrigation Project (KRIP) which is the largest irrigation scheme in Nigeria. Conjunctive use in KRIP will enable millions of cubic meters of water to be released from the dams to recharge the Chad basin aquifers; this may not be possible without carrying out a study to evaluate the potential contribution of the irrigation to groundwater recharge in the area. The objective of this research was to evaluate groundwater recharge in the Kano River irrigation project in Northern Nigeria using an experimental farmland within the project as a case study. The result of the research will help elucidate the potential of implementing managed aquifer recharge in the area.

2. Materials and method

2.1. Description of the study area

The Kano River irrigation project was established by the Kano state government in 1970, with the aim of developing over 62,000 ha of agricultural land for crop production by irrigation using water from the Tiga dam. The project is located 47 km south of Kano city and lies between longitudes $8^0 30^1$ and $9^0 40^1$ E. and latitudes $11^0 30^1$ and $12^0 03^1$ N. within the Yobe River basin. As at 1999, only 14,000 ha have been developed after the Federal Government took over the project through the Hadejia-Jamaa're River Basin Development Authority (HJRBDA). The area is a portion of a dissected peneplain developed on the crystalline Precambrian rocks of the basement complex. The main rock types are granite, gneisses and schist, complex glimmer schist and quartzite. The top of the basement complex is deeply weathered and on this zone, a lateritic iron pan layer is developed. The area belong to the Sudan savannah agro-climatic zone with three distinct seasons namely: wet season (early June–late September (4 months)); cool dry season (October–mid February (4½ months)); and hot dry season (mid-February–early June (3½ months)). See Fig. 1 for the map of the basin.

The experimental area within the KRIP is made up of four irrigation blocks (F-3.4, F-3.5, F-3.6 and F-3.7) with a total area of 26.9 ha; each block is well laid out and intensively cropped with vegetables, wheat, onions, tomatoes, rice etc. The land generally slopes in the south easterly direction with water canals running along their northern side and drainage canals on the south, the water canals run over a gradient and have several drop structures along their length to control flow velocity. Soils of the experimental farm belong to the upland plain, about 60% are deep and well drained, and the remaining 40% are poorly drained and are underlain by an iron pan of Ferruginous Feldspar found at an average soil depth of 152 mm (Iqbal, 1976). The soils are mostly derived from Aeolian drift, while some are developed from colluvial and alluvial materials.