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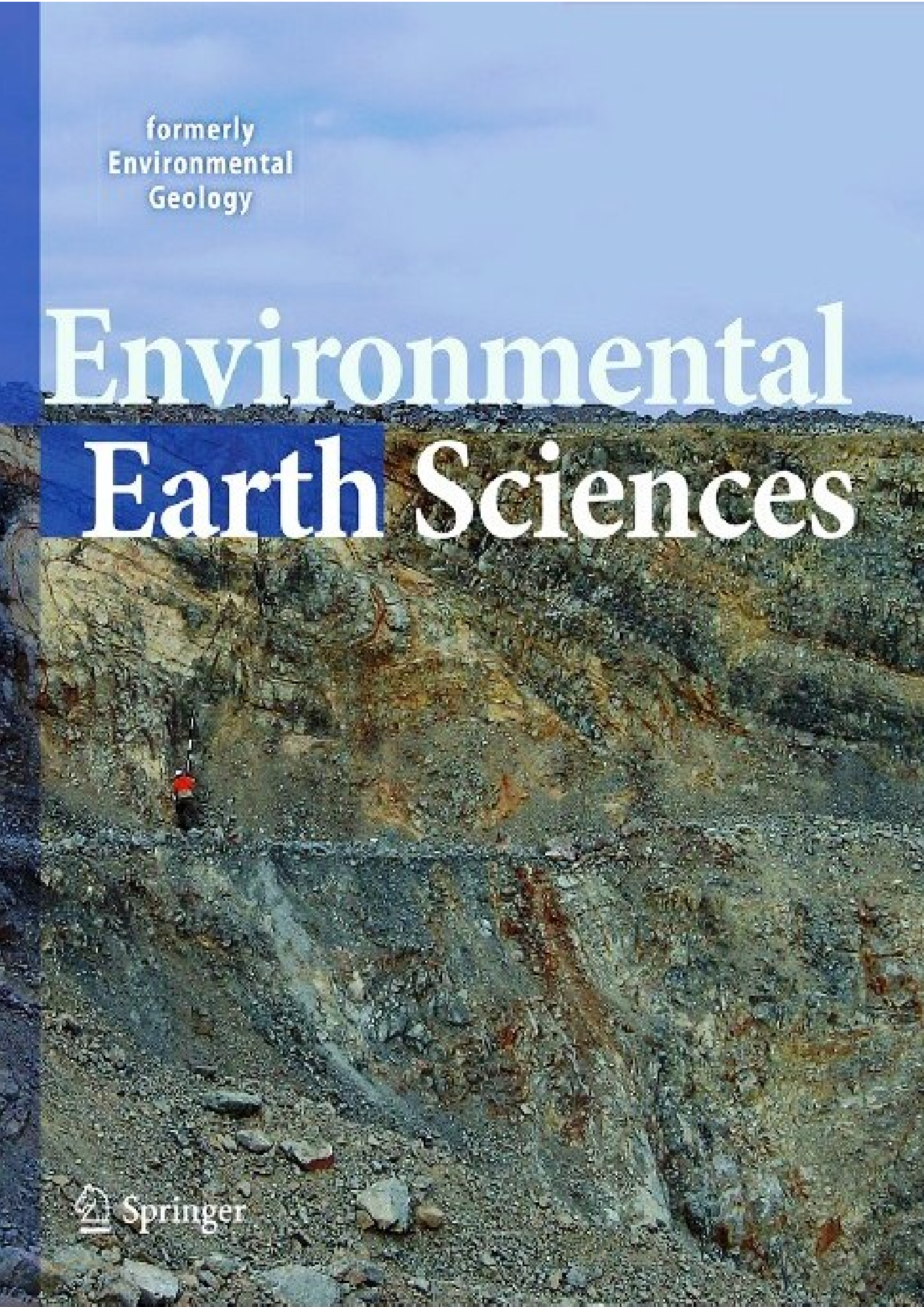

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ORIGINAL ARTICLE

Combination of remote sensing, GIS and palaeohydrologic remarks for promoting the exploitation of water resources in the Sahara: cases from the Red Sea Coast, Egypt

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Abstract
The current work presents an integrated approach to maximize groundwater exploitation under Sahara conditions. The approach includes investigation of palaeohydrology, remote sensing data, field verification and geophysical datasets (gravity, aeromagnetic and geoloelectrical data). Results reveal the existence of palaeohydrologic remarks such as; palaeodriange, terraces, tufas, gorges and alluvial fans. The hydrogeological investigation reflects that the Quaternary groundwater existed under free water table conditions with water depths range between 5.06 and 50 m from the ground, while the Miocene aquifer has water depths vary between 22 m (of shallow wells) and 108 m (of deep wells). The study illustrates the presence of the tectonic fallen zones (TFZ) where the Precambrian rocks show throw down blocks associated with a set of faults and covered by thick sedimentary succession. The TFZ, with their faults (NW–SE and NE–SW), are attributed to the regional Red Sea rift, where these faults can provide groundwater recharge opportunities. The groundwater occurrences in the TFZ indicate saturation thickness ranges between 75 and 175 m for Miocene aquifer and between 50 and 180 m for Nubian sandstone aquifer. A total of 22 basins were analyzed where their morphometric parameters indicate the possibility of groundwater accumulations. The obtained stable isotopes compositions of hydrogen (δD %) and oxygen ($\delta^{18}O$ %) reveal that aquifers were recharged throughout the previous wetter climate with reasonable contributions during intervening arid periods. Due to the continued and urgent need for water in the Sahara, the obtained results can be utilized to develop applied recommendations for future groundwater exploration.

Keywords Palaeohydrology · Groundwater · Remote sensing · Geology · GIS · Hydrogeology

Introduction

Water scarcity is globally recognized as one of the crises which affect the environment, human life and impede sustainable development plans. This is typically shown in Sahara (Sahara is a term that means "Desert" and refers to the regions around North African desert (Al-Gamal and Hamed 2014) which are characterized by climate change and natural variations resulting from the existence and distribution of water resources. Countries (such as Egypt) that fall in Sahara face challenges to water supplies as a result of rapid population growth and lack of a comprehensive understanding of the effect of hydrogeologic and geologic controls on the preservation and development of water resources (Sultan et al. 2011). Such an understanding is necessarily required to achieve sustainable exploitation of these resources. Water resources in the arid Sahara region refer primarily to groundwater where rainfall is very limited. However, it could be subject to some irregular flash floods as in the case of the Red Sea coast. In Egypt, particularly the Red Sea coast, it is believed that groundwater aquifers have been recharged during the previous wet periods, i.e. Pluvial times (Sturchio et al. 2004; Yousif et al. 2018) but they may also still receive recent meteoric recharge through the seasonal flash floods (Sultan et al. 2007). These aquifers represent a great significance to countries in which an arid environment prevails due to the increasing demand for

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