Journal of Hydrology: Regional Studies 5 (2016) 179–199

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

Challenges in groundwater resource management in coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya and Tanzania

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ARTICLE INFO

Article history:
Received 5 October 2015
Received in revised form
26 December 2015
Accepted 29 December 2015
Available online 4 February 2016

Keywords:
Groundwater
Coastal aquifer
Eastern Africa
Environmental change
Governance
Community engagement

ABSTRACT

Study region: Coastal areas of Kenya (Kilifi County), Tanzania (Kilwa district) and Comoros (Ngazidja island), East Africa.
Study focus: Research aimed to understand the physical and societal drivers of groundwater accessibility and identify critical aspects of groundwater access and knowledge gaps that require further monitoring and research. Interdisciplinary societal, environmental and hydrogeological investigations were consistently undertaken in the three areas considered as exemplars of the diversity of the coastal fringes of the wider region. This paper focuses on the hydrogeological outcomes of the research, framed within the principal socio-environmental issues identified.
New hydrological insights: Results confirm the fundamental importance of coastal groundwater resources for the development of the region and the urgent need to match groundwater development with demographic and economic growth. Hydrogeological knowledge is fragmented, groundwater lacks a long-term monitoring infrastructure and information transfer from stakeholders to users is limited. Current trends in demography, climate, sea-level and land-use are further threatening freshwater availability. Despite possessing high-productivity aquifers, water quality from wells and boreholes is generally impacted by saltwater intrusion. Shallow large-diameter wells, following the traditional model of these areas, consistently prove to be less saline and more durable than deeper small-diameter boreholes. However, promoting the use of large numbers of shallow

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http://dx.doi.org/10.1016/j.ejrh.2015.12.065

wells poses a significant challenge for governance, requiring coherent management of the resource at local and national scales and the engagement of local communities.

1. Groundwater in coastal regions of East Africa

Africa is the continent with the fastest growing populations (United Nations, 2011) with coastal regions projected to experience the highest rates of population growth in coming decades (Vafeidis et al., 2011). At the continental level, East Africa has the second highest rate of population growth, after the Central African region (Ashton and Turton, 2009), while having the lowest renewable freshwater resource of Sub-Saharan Africa (Braun and Xu, 2010). In the Mozambique Channel region, the populations of the Comoros Islands, Kenya and Tanzania have quadrupled in the last 50 years (World Bank, 2014a), twice the global average and growing. Most of the population increase is in urban areas, which are already densely populated and where water resources, particularly groundwater which is often the only source of water of acceptable quality, are already under intense pressure (Steyl and Dennis, 2010; MacDonald et al., 2012; Walraevens et al., 2015). Recent papers have shown the importance of groundwater resources that are under growing pressure in developing regions elsewhere, but crucial for economic development (e.g., Mukherjee et al., 2015; Watto and Mugera, 2015). Adequate provision of water is central to human health and economic development in these regions where water scarcity is a serious impediment to growth and poses a threat to political stability.

In a demographic context within Sub-Saharan Africa, groundwater resources are heavily relied upon and the focus of strategic development (Ashton and Turton, 2009) because of both the relative resilience of aquifers to anticipated climate change and the widespread contamination of surface water resources. However, as exemplified by findings from previous inter-African reviews of regional and national groundwater management frameworks (e.g. Robins et al., 2006; Adelana et al., 2008; Braune and Xu, 2008, 2010; Knüppe, 2011), groundwater resources, except in countries totally dependent on them, (i) still suffer from an under-evaluation of their importance and significance, (ii) are often managed separately from surface water and (iii) management institutions (governments, communities, NGOs, consultants) are largely fragmented and lack a central strategy. Groundwater information services, i.e. databases and systematic long-term monitoring, are non-existent or of inadequate quality and fragmented. The involvement of stakeholders, including communities, in decision-making processes and resource utilisation is insufficient, under-acknowledged by managers and governments and requires urgent capacity building of all parties, from individual to institutional (e.g. BGR, 2007; Foster et al., 2008; Braune and Xu, 2010).

Efforts towards the integration of groundwater management within holistic water management frameworks, such as river basin organisations have only emerged recently, mainly through national Integrated Water Resource Management (IWRM) frameworks (Global Water Partnership, 2000, 2002; World Water Council, 2006) that aim to address these deficiencies and contribute to the Millennium Development Goals (MDGs). Nonetheless, groundwater management appears subsumed under broader policy, legal and institutional frameworks dealing with the management of water resources; hence the integration of groundwater into national policy requires development of adequate cross-sector dialogue within government (Mumma et al., 2011; Foster et al., 2012). The management of coastal groundwater poses a further challenge due to its vulnerability to seawater contamination and the specific physical and socio-economic characteristics of the coastal zone. The review of Steyl and Dennis (2010) is one of the very few works that provides insights on common issues with regards to groundwater management in coastal aquifers of Africa. There is a notable gap in the literature regarding the inter-disciplinary aspects of the management of coastal groundwater resources in Sub-Saharan Africa and the regionally-specific socio-environmental drivers.

In the East African coastal region, demographic change has led to an overall increase in groundwater abstraction, with increased drilling of deep boreholes with higher abstraction rates than traditional dug wells and shallow boreholes. High abstraction rates and concentrated well fields are incompatible with the nature of coastal aquifers. These aquifers are mainly low-lying with shallow water tables and are susceptible to seawater intrusion if not carefully managed, regardless of aquifer productivity or recharge rates (Robins, 2013; Werner et al., 2013). The abstraction of inland groundwater, by way of contrast is generally only limited by aquifer productivity and available recharge.

The geology of much of the East African coastal aquifers is young (Mesozoic to present), composed of soft or unstable sediments and volcanic deposits, which need supporting during and after drilling to avoid collapse and bloc fall. Though slower and labour intensive to construct, large diameter traditional wells are more suited to such environments; causing less drawdown than boreholes and giving access for clearance of debris (e.g. Bourhane et al., 2015). A larger number of shallow wells widely distributed across an area is effective in minimising the risk of seawater intrusion. Such strategies, however, pose a management challenge in urban areas (Edmunds, 2012) where high densities of abstraction points may be necessary, initial drilling costs are high and risk of contamination is considerable.

East Africa is identified as one of the regions at greatest risk globally from the impacts of climate change (Hinkel et al., 2012). Most coastal areas are low-lying and will experience significant inundation even with modest rises in sea level. The most recent climate change projections (IPCC, 2014a; Cai et al., 2014) anticipate an accelerated rise in global mean sea level in coming decades (Watson et al., 2015) combined with an increase in rainfall during the wet seasons and higher annual temperatures. These may increase potential evapotranspiration and increase seawater intrusion in low-lying coastal