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The changing hydro-ecological dynamics of rivers and deltas of the Western Indian Ocean: Anthropogenic and environmental drivers, local adaptation and policy response

Stéphanie Duvail [a,*], Olivier Hamerlynck [b], Paolo Paron [d], Dominique Hervé [c], Wanja D. Nyingi [b], Michele Leone [e]

[a] IRD (Institute of Research for Development), UMR 208 PALOC "Patrimoines Locaux et Gouvernance" (IRD-MNHN), Muséum national d'histoire naturelle, Sorbonne Universités, 75231 Paris cedex 05, France
[b] KENWEB "Kenyan Wetlands Biodiversity Research group", National Museums of Kenya, P.O. Box 40658, 00100 Nairobi, Kenya
[c] IRD, UMR 220 (IRD–UPV)/GRED "Gouvernance, Risque, Environnement, Développement", BP 434, 101 Antananarivo, Madagascar
[d] IHE Delft "Institute for Water Education", Westvest 7, 2611AX Delft, The Netherlands
[e] IDRC "International Development Research Centre", P.O. Box 62084, 00200 Nairobi, Kenya

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ABSTRACT

The rivers flowing into the Western Indian Ocean have steep headwater gradients and carry high sediment loads. In combination with strong tides and seasonal rainfall, these rivers create dynamic deltas with biodiversity-rich and productive ecosystems that, through flooding, have sustained indigenous use systems for centuries. However, river catchments are rapidly changing due to deforestation. Hydropower dams also increasingly alter flood characteristics, reduce sediment supply and contribute to coastal erosion. These impacts are compounded by climate change. Altogether, these changes affect the livelihoods of the delta users. Here, based on prior works that we and others have conducted in the region, we analyse the drivers of these hydro-ecological changes. We then provide recommendations for improved dam design and operations to sustain the underlying delta-building processes, the ecosystem values and the needs of the users.

1. Introduction

1.1. Background

When a river slows down, the balance between the turbulent forces in the water column and gravity changes, and this change leads to the sediment it carries being deposited. This happens at many scales and under many circumstances but most prominently where a river meets the ocean. Here, the river gradient approaches zero and any significant change in river flow results in floodwaters spreading over a wide area and offloading its sediment. As the regularly flooded areas build up as new sediment deposits and adjacent areas sink because of sediment compaction, dewatering and oxidation of organic matter, the flooded areas will shift position and the process restarts elsewhere. Typically, this creates a triangular or fan-shaped delta. However, depending on the balance between river and ocean dynamics, other delta types exist, e.g., wave or tide dominated (Anthony, 2015; Reading, 2009).

Unique and highly productive ecosystems have developed in these deltas, primarily flooded grasslands and salt-adapted vegetation such as mangroves at the marine fringes. These ecosystems support diversified livelihoods

* Corresponding author. UMR 208 PALOC, Museum national d'histoire naturelle, 57, rue Cuvier, CP 51, 75231 Paris cedex 05, France.
E-mail address: stephanie.duvail@ird.fr (S. Duvail).

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adapted to the flooding patterns. Traditionally these include fishing, livestock keeping, flood-recession agriculture and tidal rice cultivation, hunting and gathering, utilization of woody and non-woody forest products and beekeeping among others (Hamerlynck et al., 2017). Deltas are important, well beyond their physical perimeter, as carbon sinks, as coastal defence and land-building systems and as nursery areas where the juveniles of fish and crustaceans grow before entering neighbouring coastal waters where they are the targets of valuable fisheries (e.g., Lee et al., 2014). The total economic value of all the services provided by coastal wetlands including deltaic systems with mangroves is estimated around 200,000 US$/hectare/year (de Groot et al., 2012). This is the second most valuable ecosystem globally, only surpassed by coral reefs valued at around 350,000 US $/hectare/year, mostly because of tourism.

Being wet, flat and fertile, deltas have been targeted for large-scale land conversion including the building of embankments to establish large-scale irrigation or aquaculture. Such human interventions interfere with the very processes that form deltas, causing them to become vulnerable to oceanic salt water intrusion compounded by sea-level rise and the capture of sediments by upstream dams (Syvitski et al., 2009). Thus, under these pressures, coastal wetland systems are rapidly losing their value: between 1997 and 2011 swamps and floodplains lost 64% of their surface area while tidal marshes and mangroves lost 22% globally. With additional losses of flood-dependent ecosystem services, the total decline in the aggregated flow of services from these two wetland types characteristic of the lower reaches of river basins amounts to 9.9 trillion US$ per year corresponding to about 13% of global Gross Domestic Product (GDP) (Costanza et al., 2014).

For various reasons, including comparatively low investment into hydraulic infrastructure in the postcolonial era, the deltas of the Western Indian Ocean (Fig. 1) have, until recently, maintained many of their ecosystem values (Scheren et al., 2016) as well as the traditional use systems dependent on them. However, this is set to change as several new hydropower dams and irrigation systems, including for biofuel production, are under consideration or implementation as Africa, following over a decade of high GDP growth rates, is being promoted as the next investment frontier (Taylor, 2016). Unfortunately, these new investments are primarily targeting provisioning services such as food, water and energy to be developed in the short term (within the next 5 years). They fail to support the underlying flood-dependent regulatory services that need to be maintained or enhanced. Additionally, at a global policy level, the 17 goals of the 2030 Agenda for Sustainable Development, adopted at the UN summit in September 2015, promote a sectoral approach. In order to mitigate these two weaknesses (short-term vision and sectoral approach) a more evidence-based and functional approach, integrated across sectors has been proposed by Griggs et al. (2013). This requires an improved understanding of the changes affecting the Western Indian Ocean deltas and a thorough analysis of the conditions under which ecosystem functions can sustainably benefit the delta users.

This paper focuses on the area between the Equator and the latitude 25° South (slightly south of the tropic of Capricorn) (Fig. 1). We endeavour to describe the common characteristics of the rivers flowing into the Western Indian Ocean as well as their specificities, the changes affecting their hydro-ecological rhythms and their consequences downstream, especially in the deltas.

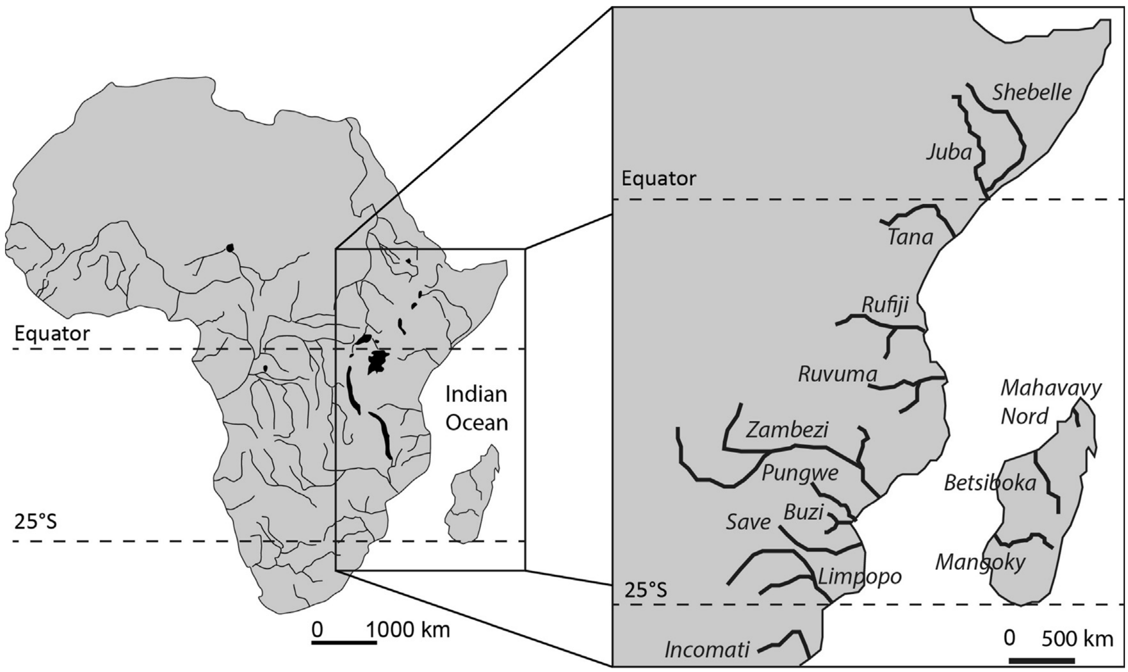

Fig. 1. Map of main rivers of the Western Indian Ocean.