Effects of dam construction on the planimetric changes of downstream rivers

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ABSTRACT

The construction of dams affects water and sediment supply to the downstream river reach, which then adjusts itself to the new state by changing its slope, planimetry, reference width, and water depth. This work deals with the assessment of the long-term planimetric adaptation of meandering rivers after upstream dam construction. In particular, the work, which is now in its preliminary phase, aims at anticipating the changes that will occur on the meandering Ribb River (Ethiopia) a long time after the completion of the Ribb Dam. To analyze the effects of dams and generalize the results, two additional case studies are considered: the Tana River (Kenya) and the Blue Nile River (Sudan). These two rivers have been affected by dams for a long time already, whereas more dams are planned or in construction. The effects of large dams on these three rivers will be analyzed and compared, and based on the findings a methodology for the prediction of the effects of planned dams on the downstream river planimetry will be developed. The method includes field and historical investigations, GIS, image analysis and numerical modelling.

Keywords: downstream effect of dams; meandering rivers, Ribb River; River planimetric change; Tana River; Blue Nile River

1. INTRODUCTION

1.1 General aspects

The increased demand of water for agriculture, industries, domestic, and power generation in the basin of Lake Tana (Ethiopia) requires proper planning and management of water resources. These days, there are several ongoing (Ribb, 234 Mm^3 and Megech, 181 Mm^3) and planned (Jema, 173 Mm^3; Gumera, 223 Mm^3; and Gilgel Abbay, 563 Mm^3) large and medium-scale dams for the development of irrigation around Lake Tana and to prevent the river floodplains from flooding (BRLi & MCE, 2010).

Construction of dams affects the morphological process of the downstream river reach by storing water and sediment, by changing the water discharge regime of the river and by releasing relatively clear water to the downstream. This produces significant geomorphological effects, by changing the pattern of erosion and deposition of the main channel of the river, banks and floodplains. The impacts vary according to size of the river and dam, hydrologic regime, environmental setting, history, initial channel morphology, purpose and operation of the impoundment (Graf, 2006; Petts & Gurnell, 2005; Williams & Wolman, 1984; Yang et al., 2011). The downstream effects of dams have been studied by a number of scientists already (e.g. Khan et al., 2014). However as river natures vary, the response to dam construction varies with a number of variables (Brandt, 2000).

1.2 Ribb River

The Ribb Dam (Figure 1, Ethiopia), now in construction on the River Ribb, will have 73 m height to impound 234 Mm^3 of water for irrigation, the goal being to be able to irrigate around 15,000 ha of the Fogera floodplain (BRLi & MCE, 2010).The Ribb River has been subjected to prolonged water withdrawal for agriculture without conserving natural resource. Forest degradation, biodiversity and habitat loss and soil degradation are common problems in the area (Garede & Minale, 2014). Abate et al. (2015), who studied the geomorphological changes of the nearby Gumera River (sharing the same flood plain and having similar characteristics) to water withdrawal and alteration of Lake Tana level, showed that the carrying capacity of the lower reach of the river is reduced due to deposition of sediment. Due to this, there is a recurrent flooding on the floodplain killing people and animals and destroying crops and infrastructures.

The knowledge of the river dynamics prior to dam construction, together with the analysis of the historical water and sediment inputs, land use land cover change, river bed and bank material, will be used to forecast the effects of the dam construction on the downstream river reach. Even though numerous researches have been made on this topic, it is not possible to generalize the effects as the effects vary according to the river nature (Brandt, 2000). Hence, further understand on different rivers, spatial and temporal scales, and climatic conditions will contribute to develop a wide understanding.

2. ADDITIONAL CASE STUDY SITES

Based on the availability of information and the presence of upstream dams for a relatively long time, the Blue Nile River in Sudan and the middle Tana River in Kenya are selected as additional case study areas. Analyzing the effects of dams on these two meandering rivers for which a long record of data is available allows for generalization of the results by the identification of differences and similarities among rivers.

2.1 Tana River

The Tana is a 1,000 km long river running through the arid and semi-arid lands in the eastern part of Kenya to enter the Indian Ocean through a fan-shaped delta. The water of the Tana River are heavily utilized for hydropower. Five major reservoirs have been already built on the upper reaches of the river: Kindaruma (1968), Kamburu (1975), Gitaru (1978), Masinga (1981) and Kiambere (1988). New hydropower schemes, Mutonga and Karura (Grand Falls dams), have been recently proposed for construction on the Tana River downstream of the existing dams. The construction of these two additional dams will create a major influence on the river's downstream flow by decreasing the frequency and magnitude of flooding, which will consequently affect the river planimetry change (Emerton, 2003). Figure 2B shows part of the study river reach, which is located in the middle course of the river.

2.2 Blue Nile River

The 1,650 km long Blue Nile River originates from the Lake Tana (Ethiopia) and flows to Sudan to join White Nile in Khartoum. The Lake Tana basin, to which the Ribb River belongs, is actually a sub-basin of the Blue Nile. The study area is the 274 km long reach of the Blue Nile River between the dams of Rosaries and Sinnar, in Sudan, where the river has a meandering planform. The reach has been already subjected to morphological changes in response to the construction of Roseires dam (1966). In particular, the river shows channel incision and enhanced bank erosion (Ali, 2008; Ali et al., 2014a and 2014b).

Upstream of Roseires, the Grand Ethiopian Renaissance Dam is currently in construction to store around 63 billion m^3 of water and other upstream dams are planned for the production of electricity. Hence, the Blue Nile discharge will strongly depend on dam operations with important consequences for the river morphology.

3. EXPECTED RESULTS

This research is at its initial stage. The results will contribute to the understanding of how meandering river dynamics may change due to upstream damming, focusing at the river reach scale. A methodology will be developed for the East African region to study the damming effect on the downstream river reach allowing to take this into account in the planning phase of dams. The knowledge gained from this research will be particularly useful to Ethiopia, where the construction of a large number of dams is planned on the rivers of the Tana Basin.

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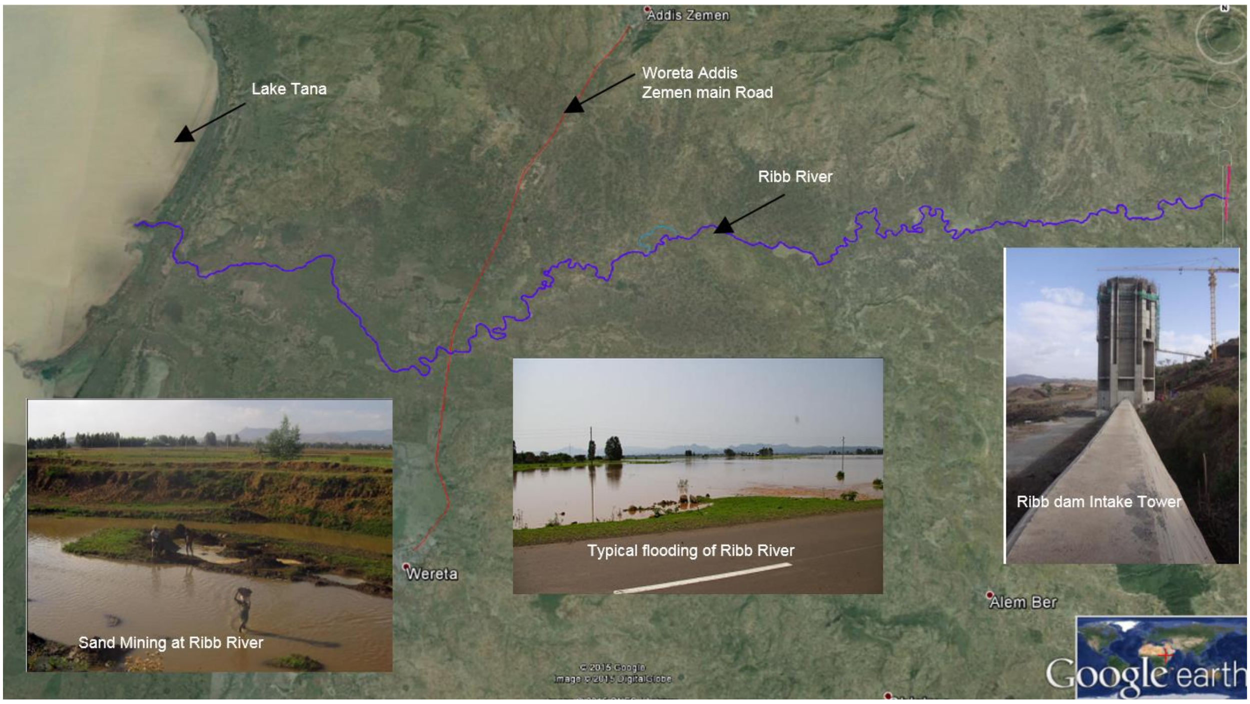
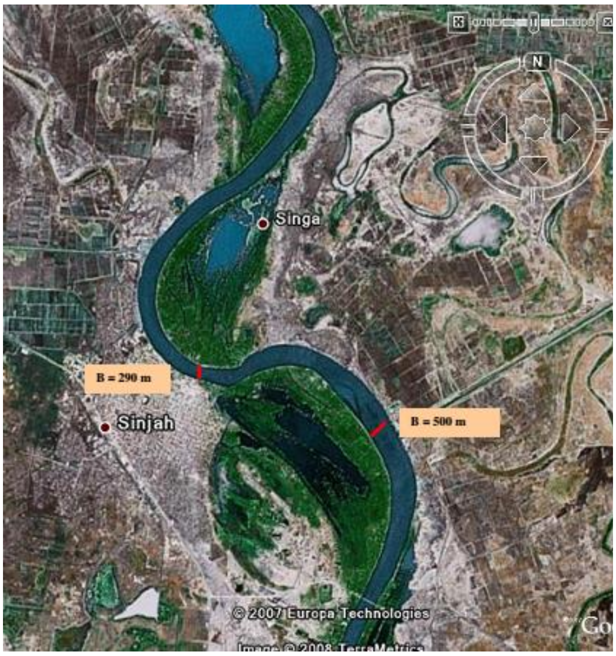


Figure-1: Ribb River study reach (Ethiopia)



(A)

(B)

Figure-2: (A) - Blue Nile River between Roseires and Sennar (Sudan). (B) - Middle course of the Tana River (Kenya) seen from Google Earth.

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