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Analysis of Ribb River channel migration: Upper Blue Nile, Ethiopia

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Introduction

The Ribb River is one of the components of the Blue Nile River system located in the North Western part of Ethiopia. It drains to Lake Tana, the source of the Blue Nile River. The Ribb has a length of 130 km, with a catchment area of 1,812 km^2. The average yearly rainfall of the catchment is 1300 mm, with 80 % occurring between the months of June and September. The average and daily maximum discharge of the river are 15 m^3/s and 220 m^3/s, respectively. A large dam and a diversion weir 30 km downstream of the dam are under construction to irrigate 15,000 ha of Fogera flood plain (WWDSE and TAHAL, 2007). Downstream of the dam location, the Ribb is a meandering river with slope ranging from 0.18% to 0.03%. The river bed material is dominated by sand with a gravel component in its upper reaches. Intensive agriculture without any natural resources conservation, deforestation, dike construction, pump irrigation and sand mining are the most impactful activities in the Ribb watershed (Tarekegn et al., 2010; Garede and Minale, 2014). The Lake Tana level is regulated since 1995 for hydropower production, which enhances flooding along the lower river reach. During the 2006 event, 45 people died, 30,000 persons were displaced and 5371 ha of agricultural land were inundated (ENTRO, 2010). To prevent flooding, dikes have been constructed in the lower reach of the river.

This study aims to describe current river morphodynamic trends, including planimetric changes for the definition of the pre-dam conditions of the river. The first part of the work is presented here with some preliminary results, focusing on the river planimetric changes. This paper describes the initial state of the study.

Methodology

The planimetric evolution of the river is assessed by means of satellite images, aerial photographs and observations complemented with field recognition. Aerial photographs of the years 1957 and 1982, SPOT satellite images of the years 2006 and 2016 and a Google Earth image of the year 2016 are used for the study. ENVI 4.3 is used for orthorectification of aerial photographs. Ground control points, which are collected from SPOT satellite image of the year 2012 and elevations, which are collected from 30 m resolution digital elevation model are used for orthorectification of aerial photographs. ArcGIS is used to digitize the river centrelines and to visualize the super-imposed images. The one/two dimensional physics-based model, MIANDRAS, (Crosato, 1987, 2008) is applied to study the river bed topography and planimetric changes. The governing equations are derived by coupling the 2D momentum and continuity equations for water (de Saint Venant equations) to sediment transport and sediment balance equations and are linearized. To simulate the river planimetric changes, the model assumes that the lateral shift of the channel centreline is a function of near-bank velocity and water depth excess with respect to reach averaged uniform flow. The input parameters are collected from the field and derived from satellite images. The model is first used to analyse the river bed topography configuration. Hence, the model is calibrated for the bed topography (comparing the simulated and observed bed forms). The model is then also used to analyse the planimetric dynamics of the river. This part of the study is not presented here. The study river reach has a length of 77 km from the dam site to Lake Tana. It is divided in three parts: the Upper reach (from the dam to the weir), the Middle reach (from the weir to the main road to Gondar) and the Lower reach (from the main road to Gondar to Lake Tana) (Fig. 1).

Preliminary results

Daily discharge data are available at the gauging station located near to Woreta-Addis Zemen Bridge. The bankfull discharge of the river has been estimated in 115 m^3/s, based on the frequency analysis of the annual maximum values with a return period of 1.5. The reach-averaged river characteristics are shown in Table 1.

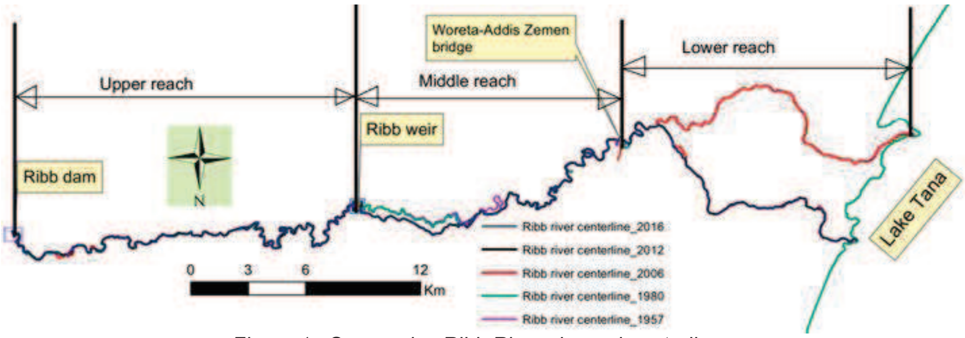

Figure 1. Successive Ribb River channel centrelines.

Table 1. Reach averaged river characteristics.

Reach	Average river width (m)	Sinuosity (-)	Valley slope (%)
Upper	58	1.77	0.32
Middle	46	1.76	0.1
Lower	38	1.5	0.05

The analysis of satellite images shows that the river width reduces in downstream direction. This may be due to dike construction, decree-sing natural bank erodibility and sediment inputs. A channel avulsion event occurred downstream of the weir between 1982 and 2006 when the river occupied an old channel for a length of 7.5 km. Another channel shift occurred 4 km downstream of the bridge (Fig. 1).This may be related to anthropogenic activities, since it happened during a flood event due to high discharge and backwater caused by an artificially increased level of Lake Tana (Abate et al., 2016; SMEC, 2008).

The model MIANDRAS has been used to study a 6.5 km long reach located in the Middle reach where the river is free from dike construction and flooding. The average width is 46 m (Table 1). To calibrate the model, an area having visible point bar formation is selected (Fig. 2) and the results compared to the observed bed topography (Fig. 3).

Figure 2. Part of the study reach showing river bed topography, Google Earth image of the year 2016.

The computed equilibrium bed topography resembles the observed one quite well, but does not always match it. This may be due to sand mining activities occurring during low flow conditions on bar tops.

Future work & Acknowledgements

The research is a part of PhD work of the corresponding author, who is currently working at UNESCO-IHE, Delft.

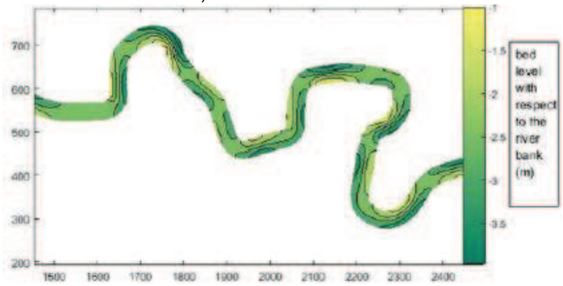

Figure 3. MIANDRAS model output bed topography for calibration coefficients of σ = 2.3, E= 0.8 and α_1= 0.1.The flow direction is from left to right.

His work deals with the effects of dam construction on the planimetric changes of downstream rivers. He would like to thank NUFFIC for financial support.

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