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Effects of the floodplain on river discharge into Lake Tana (Ethiopia)

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SUMMARY

This paper presents a study on an extensive floodplain adjacent to Lake Tana (Ethiopia) and its lowland tributaries, to enhance our understanding of the water of the lake and to better manage the natural resources in the floodplain. Discharge measurements were made at 12 stations. The effects of the floodplain on river discharges were investigated using the upstream and downstream discharge observations of the Gumara, Rib and Megech Rivers. The total annual runoff coefficients ranged between 0.23 and 0.81 in 2012 in the basin. Discharge varied depending on drainage density ($r = 0.75$), lithology ($r = -0.72$ for percentage of Tertiary igneous rocks) and land use/land cover conditions ($r = 0.61$ for dominantly cultivated land with no significant other land use types). Analyses revealed that the floodplain abstracted 809 mm of water with a corresponding increase in floodplain storage of 992 mm during the beginning of the rainy season (June to July) and released stored water starting from August until the middle of September. However, the annual water balance indicated that the runoff contribution from the Rib and Megech floodplains is negligible. But the floodplain downstream of the Gumara River showed a considerable runoff contribution to the river, also in relation to the presence of springs. The floodplain acts as storage of flood water, and consequently the magnitude of peak floods was on average 71% smaller downstream than upstream in the floodplain.

1. Introduction

Many diverse natural functions and services can be attributed to floodplains such as providing fish and wildlife habitat, supporting natural vegetation, buffering peak floods (Prach et al., 1996; Kingsford, 2000): hence they are vital landscape elements. Moreover, they are areas of intense human activities. The repeated erosion and deposition of sediments, inundations during overbank floods, and complex groundwater–surface water exchange processes make floodplains dynamic systems (Tochner et al., 2008). They have a major impact on the transfer of water and sediments from upland catchments through river systems to the lakes or seas (Dunne et al., 1998; Hamilton et al., 2002; Meade et al., 1985). Hydrological processes and inundations in the floodplain have remained important areas of research to understand the ecology of floodplains and interactions with associated river-floodplain systems (Hughes, 1980; Richey et al., 1989; Coe, 2000; Loveless et al., 2000).

Lake Tana, in the northwestern highlands of Ethiopia, is associated with an extensive floodplain adjacent to the lake and its lowland tributaries. The floodplain is the hydrological connector between the lake and the upper catchments, and affects the water balance and sediment flux of the lake. Given the importance of the lake with respect to different water resource development projects, fishery, biodiversity, transport and tourism, several studies have been made to understand its water balance (Kebede et al., 2006, 2011; Wale et al., 2009; Chebud and Melesse, 2009; SMEC, 2007). Kebede et al. (2011) estimated the runoff contributions from the floodplains using an isotopic hydrological approach. They demonstrated that the waters in the floodplains originate from local rainfall and river overflows and that there is nearly no linkage between the surface waters in the floodplains and the shallow groundwater in alluvio-lacustrine sediments, suggesting that after the rainy season the floodwater disappears by evapotranspiration or surface drainage rather than seepage to the subsurface. Studies

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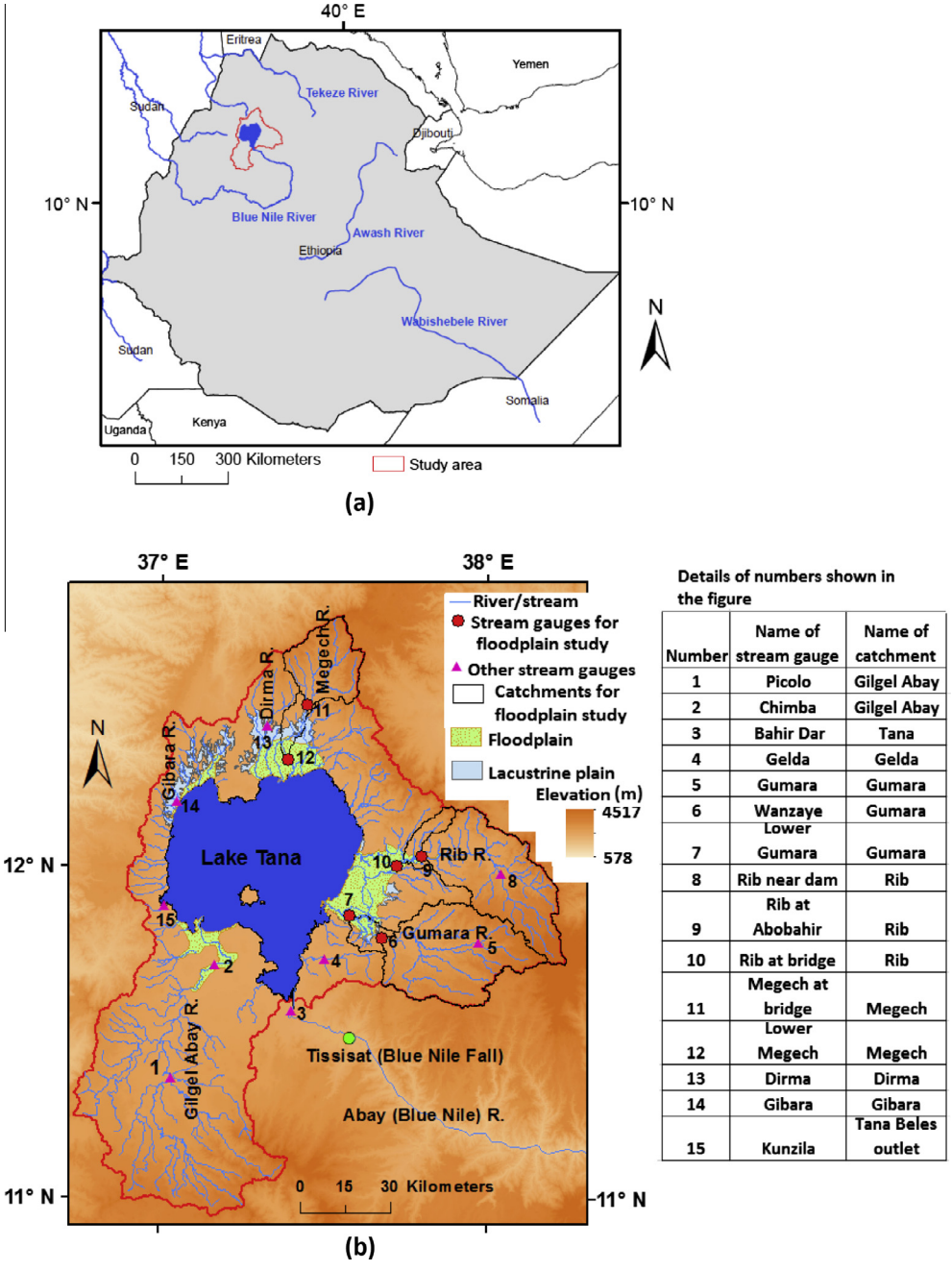
by Kebede et al. (2006), Wale et al. (2009) and Chebud and Melesse (2009) did not differentiate between the upper ungauged catchments and the floodplain when estimating the runoff contributions from the ungauged catchments including the floodplain. However, floodplains are considered as specific ecosystems, oscillating between terrestrial and aquatic phases (Junk, 1996), having different topography, soils and vegetation patterns. Due to difficulties in acquiring data for the floodplain, hydrological processes in the Lake Tana basin floodplain remain poorly understood. This has limited a more accurate determination of the lake water balance and the understanding of the ecosystem. The objective of this paper is to better understand the effects of the floodplain on the discharge of the rivers draining the hillslopes (upstream reaches) and to understand the hydrological behaviour (river and floodplain interactions) by measuring discharges at the foot of the hillslopes, at the interface of the floodplain (upstream stations), and within the floodplain (downstream stations). Spatial variations on the discharges in the main rivers in the basin are investigated and explanatory factors are suggested.

2. Study area

Lake Tana lies in a wide depression in the Ethiopian Plateau (Fig. 1) and with an area of 3077 km^2, it is the largest lake in the country. The lake is shallow with an average depth of 9 m. The outlets of the lake are the Blue Nile (natural surface outflow at the southern shore) and a tunnel hydropower outlet; its outflow contributes about 7% of the Blue Nile flow at the Ethio-Sudanese border (Shahin, 1988; Conway, 2000). Lake Tana basin is 15,077 km^2 and according to the water balance studies by Kebede et al.



Details of numbers shown in the figure

Number	Name of stream gauge	Name of catchment
1	Picolo	Gilgel Abay
2	Chimba	Gilgel Abay
3	Bahir Dar	Tana
4	Gelda	Gelda
5	Gumara	Gumara
6	Wanzaye	Gumara
7	Lower Gumara	Gumara
8	Rib near dam	Rib
9	Rib at Abobahir	Rib
10	Rib at bridge	Rib
11	Megech at bridge	Megech
12	Lower Megech	Megech
13	Dirma	Dirma
14	Gibara	Gibara
15	Kunzila	Tana Beles outlet

Fig. 1. Location map of the study area in Ethiopia (a), stream gauges, the floodplain and catchments used for the floodplain study in Lake Tana basin; topographic data from SRTM DEM (b) and (c) the rain gauge locations in and around Lake Tana basin and stations used for evapotranspiration estimation; topographic data from SRTM DEM.