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Dryland Vulnerability and Ephemeral Streams Response To Global Change: Example From The Raya Graben, Northern Ethiopia

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Introduction

In the last two decades the frequency of ephemeral streams high floods has increased in the Raya Graben in northern Ethiopia (Fig. 1), causing fatalities and property damage. These floods occurs commonly because at the main road bridges high sedimentation rates tend to obstruct the bridge spans thus substantially decreasing its flow conveyance capacity (Fig. 2). The high sediment transport and sedimentation rates have caused also channel widening (Fig. 3) and lateral shifting (Fig. 4) that destroy cultivations. Aim of this study is to understand the reasons for such recent worsening of river dynamics hazard.

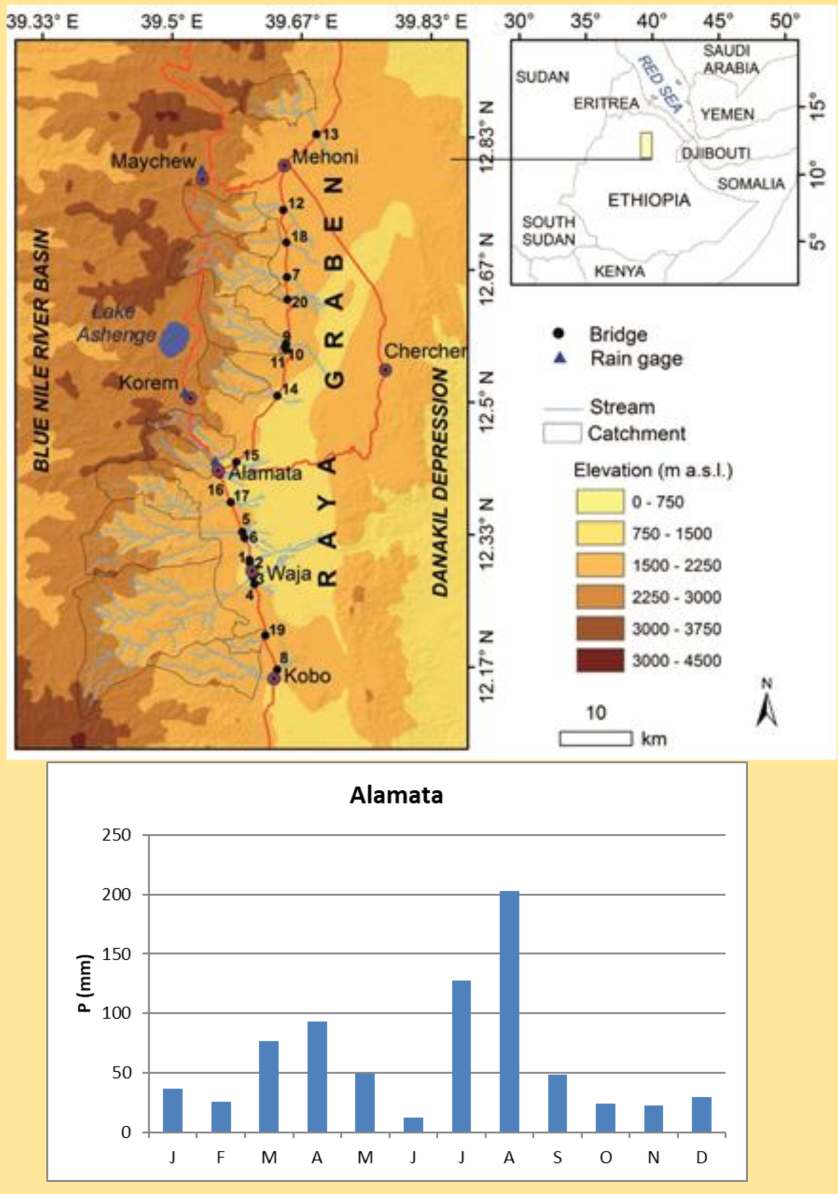

Fig. 1 Study area and monthly rainfall distribution at Alamata

Fig.2 Bridge clogging

Study area

The Raya Graben is a structural marginal basin of the northern branch of the Ethiopian Rift Valley (Fig 1 a). It is characterised by a high relief contrast with the highest peaks in the western margin reaching 4000 m asl and the basin floor at an elevation around 1400 m asl. The Raya Graben is a closed basin since all the rivers but a couple of them dry up in the basin floor. The climate is characterised by three seasons: the dry spell from October to February, the short rains from March to May and the big, monsoon type rains from July to September (Fig. 1b). Annual precipitation ranges from 700 mm in the basin floor to 1000 mm in the highlands. Rainfall occurs as very intense and short downpours (maximum daily intensity range between 50 and 100 mm/day), therefore, all rivers but one, are dry for the largest part of the year. At Alamata, mean monthly minimum and maximum temperatures range from 12.4 and 26.9°C in January to 18.5 and 34.1 °C in June, respectively. Unfortunately, none of the Raya Graben rivers is equipped with a flow gauge and, hence, no river flow data is available.
The basin shoulders are covered by sparse bushy vegetation with large portions of bare soil and very small terraced cultivations, whereas the basin floor is totally cultivated.

Fig. 4 Cultivation affected by channel lateral shifting

Sediment transport

Bed and suspended load were measured in the field in a representative ephemeral stream, the Gereb Oda (Fig. 5). Data indicate a very high sediment transport values close to hypercontentrated flow conditions. Peak suspended sediment concentration SSCp is as much as 136 gl^{-1}, equivalent to 4375 t day^{-1} km^{-2} and bedload peak rate was 2041 t day^{-1}, equivalent to 30 t day^{-1} km^{-2}

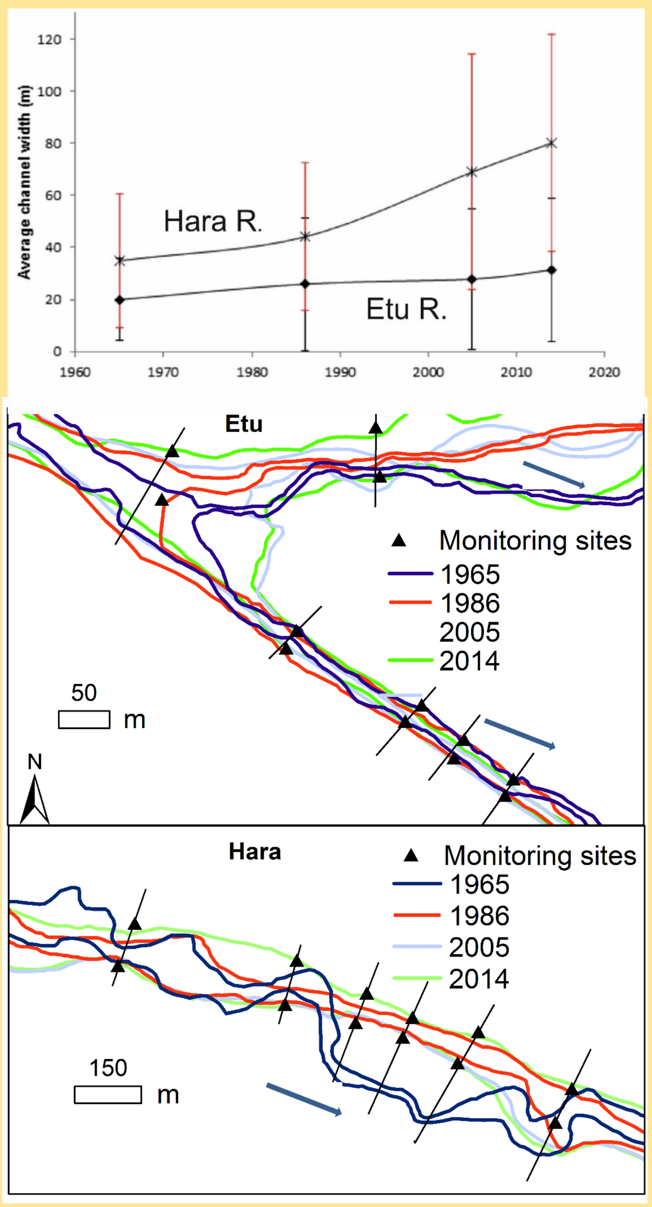

Fig. 3 Channel dynamics and widening in two study streams

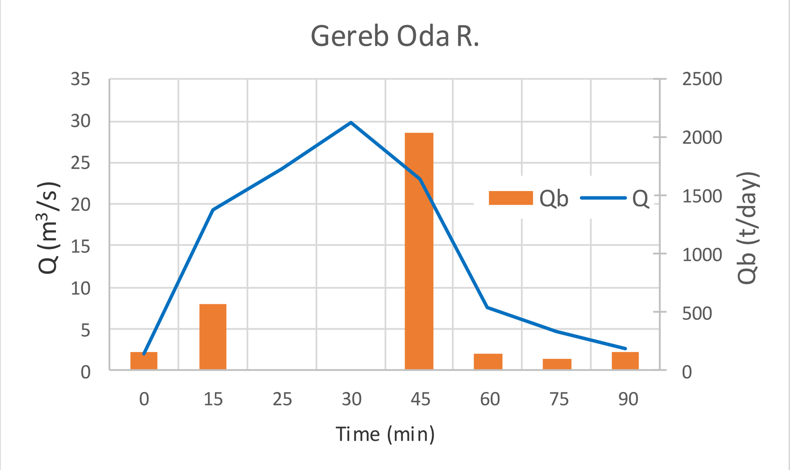

Fig. 5 Sediment transport in the Gereb Oda R.

Rainfall

Annual precipitation shows a moderate decreasing Fig 6 a), whereas the yearly maximum rainfall intensity in 24 hours shows an increase in the river headwaters and no substantial change. through time in the basin floor (Fig. 6 b).

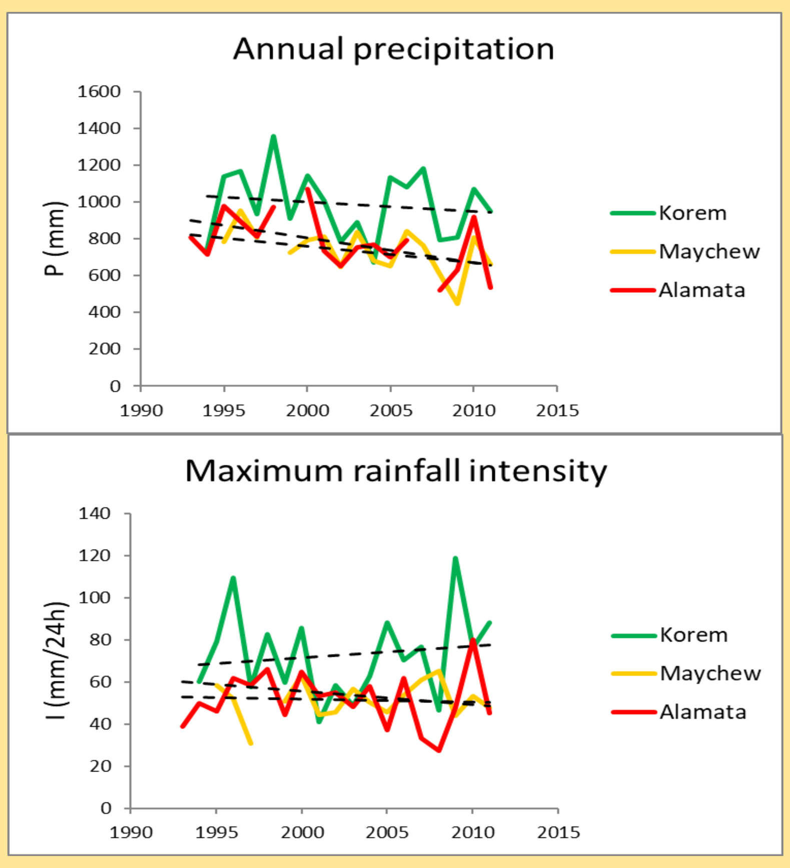

Fig 6 Time variation of annual precipitation (a) and daily maximum intensity (b)

Land use change

NDVI was measured in 16 watershed draining the Raya Graben across the 1972-2014 interval. Vegetation cover has increased since 1970, though with some oscillation. In the last decades (Fig. 7). However, halving of farmland, followed by soil erosion control structures abandonment, remarkably contributed to increase soil erosion and sediment supply.

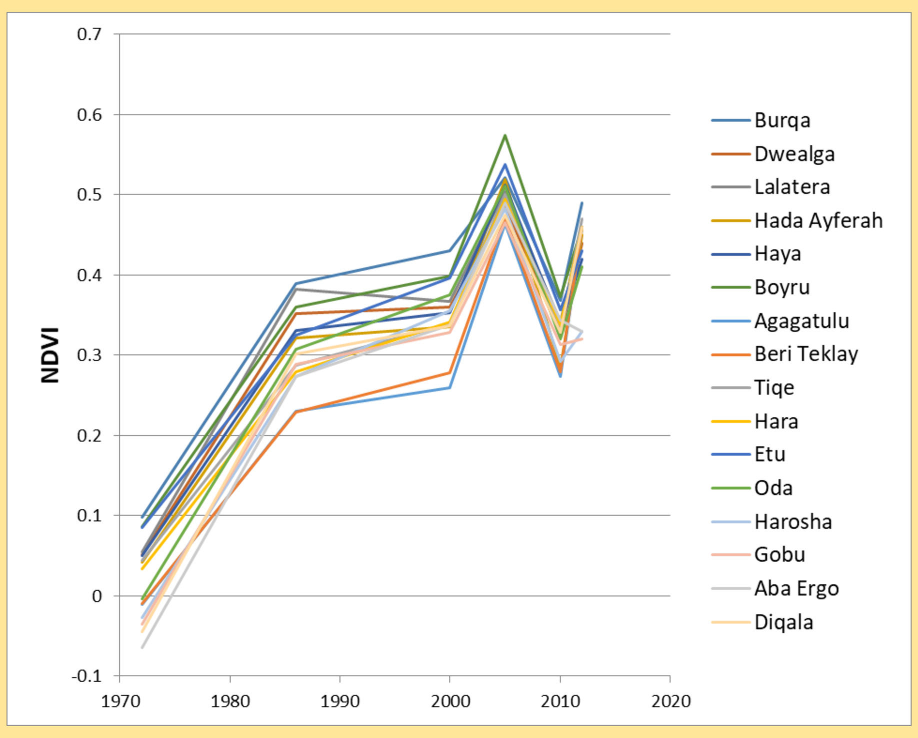

Fig. 7 Time variation of NDVI in the study area

Bridge span size

The width of many river channels upstream of the main road bridges is substantially larger than the bridge span (Fig. 8). This causes back flow during high floods and thick sedimentation at the bridges, the flow conveyance of which is therefore remarkably reduced (Fig. 2). The forced channel narrowing at the bridges results in overbank flow, further channel widening and avulsion upstream of the bridges (Fig. 9), affecting cultivations and small villages along the main road (Fig. 10).

Fig. 8 Gereb Oda R. and road bridge in 2008

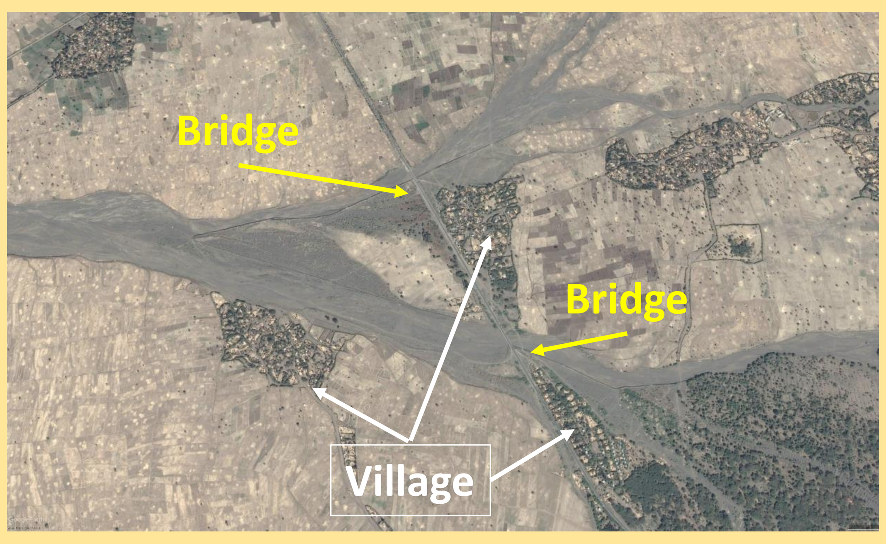

Fig. 10 Endangered villages and croplands

Fig. 9 Gereb Oda R. and road bridge in 2015

Conclusion

A moderate increase in the maximum rainfall intensity in the headwaters and the abandonment of soil erosion control structures substantially increased the sediment supply and deposition rate of flash floods. That contributed to channel avulsion, widening and lateral shifting resulting in crop damages. Hyperconcentrated flows and thick sedimentation at the undersized bridges increased the frequency of overbank flow and flooding of adjoining villages and croplands, resulting in fatalities ad property damage.