Determining tributary sources of increased sedimentation in East-African Rift Lakes using a combination of sediment tracing and radioactive dating.

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1. Introduction

- Anthropogenic land use and cover change (LUCC) is a significant cause of the accelerating rates of global soil erosion and downstream siltation [1].
- These processes are potentially amplified by natural rainfall variations.
- Increased sediment delivery to East-Africa's Rift Lakes (EARL) causes siltation and eutrophication, which threatens water quality, quantity and ecosystem health [2].
- A historical dearth of environmental monitoring in EARL catchments impedes the linking of upstream erosion processes with downstream increases in sedimentation [3].
- Aim to fill the knowledge gap in EARL sediment source-to-sink dynamics by applying sediment tracing and -dating techniques as synergistic environmental diagnostic tools.

2. Applied environmental forensics in the Lake Manyara catchment

- Deposited sediment from major tributaries, lake (42 samples) and 5 sediment cores
- Laboratory analysis:
  - ➢ Gamma spectrometry on cores: Fallout Radionuclides ($^{210}Pb_{ex}$ and ^{137}Cs)
  - ➢ WD-XRF: broad spectrum geochemical tracers (<63µm fraction)
- Sediment dating and sedimentation modelling:
  - ➢ Constant rate of supply [4]
  - ➢ Confirmation with allogenic tracer maxima and autogenic tracer minima
- Bayesian mixing model [5, 6]:
  - ➢ Test for conservative behaviour (rangetests) and spatial fingerprint (PCA)
  - ➢ Informative prior build from remote sensed model [7]
  - ➢ Lake location as fixed categorical effect to test for spatial sedimentation effects
  - ➢ Age as fixed categorical effect in core to test for changes in sources over time

2.1 Study site

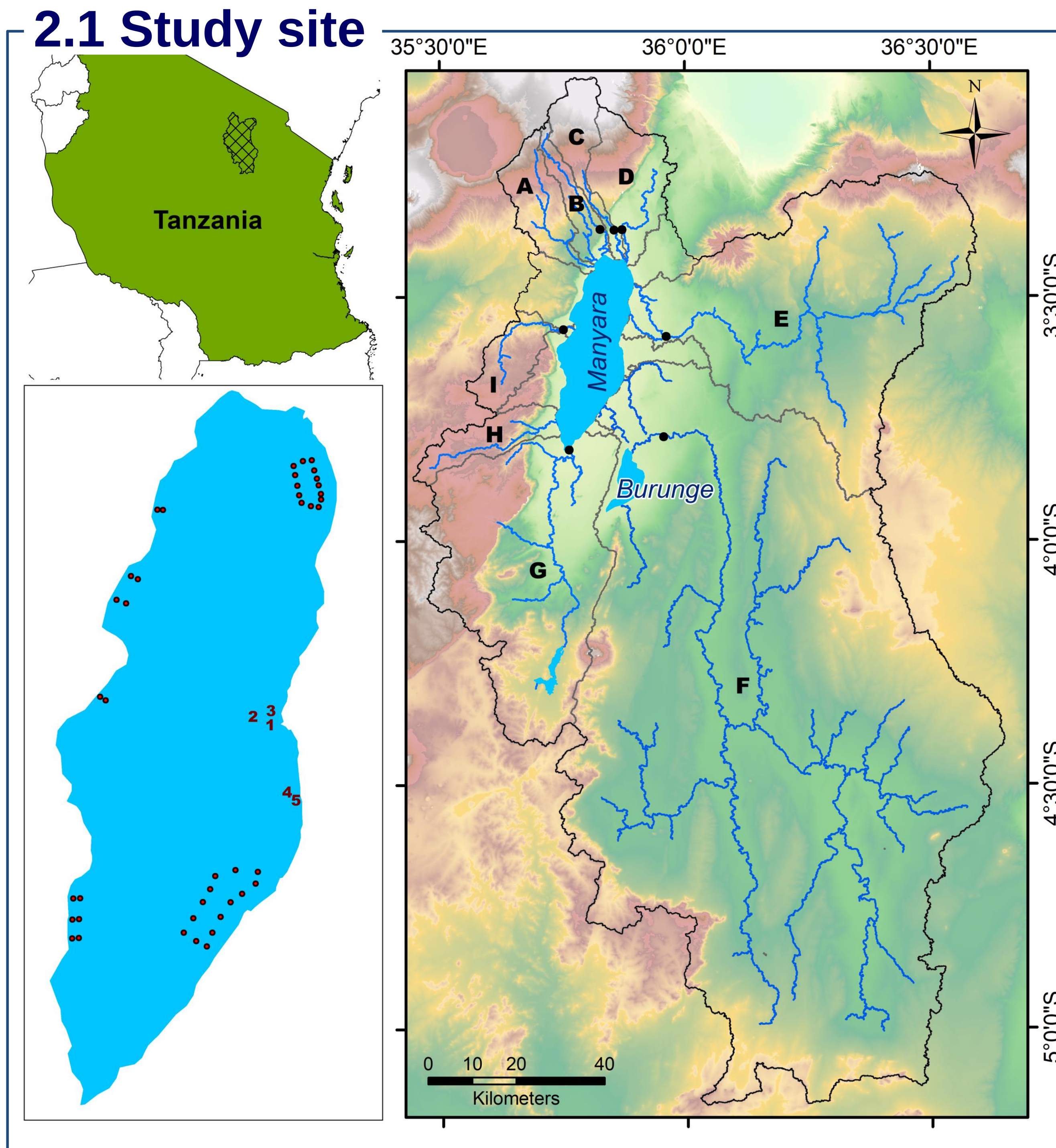
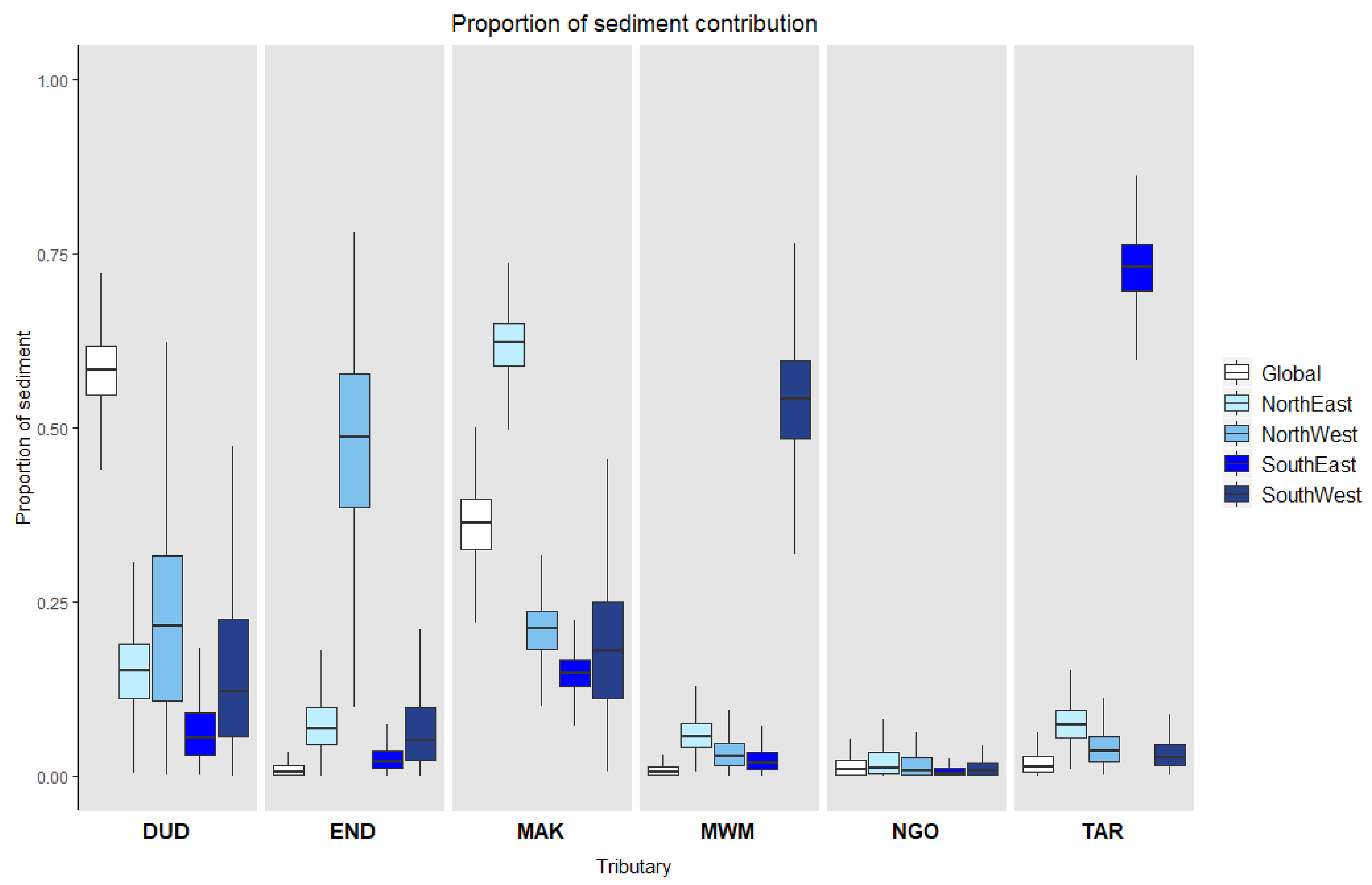


Figure 1: Location of the Lake Manyara catchment within Tanzania. Detailed topographic map of the Catchment with its major tributary systems: A) Marera, B) Kirurumo, C) Simba, D) Mto Wa Mbu, E) Makuyuni, F) Tarangire, G) Dudumera, H) Magara, I) Endabash, and riverine sediment sampling locations (black circles). Focus of Lake Manyara with locations of the sediment grabs (red circles) and cores (numbers correspond with core numbers).

3.Results and discussion



- CRS output from cores show a general trend of increasing sedimentation over time with two distinct peaks, one in the 1960s and one in 2010.
- Extrapolation of the sedimentation rates to the entire lake area estimated the sedimentation delivery to Lake Manyara in 2010 between 3.27 and 7.95 Megatonnes.
- Peaks in sedimentation correspond with peaks in elements linked to allogenic sediment origins and minima in elements linked to autogenic aquatic origin.
- Mutual confirmation of both evidence bases.
- Recent extreme sedimentation rates are likely driven by increased erosion and sediment transport in the catchment.
- Wetter periods do not necessarily result into sedimentation peaks.

- Peak in sedimentation during the 1950s and 1960s seems to be mainly driven by increased delivery from Dudumera and to a lesser extent Endabash and Makuyuni.
- Most recent sedimentation peak seems to be disproportionally driven by the Makuyuni tributary.
- These peaks can be linked to deforestation after independence and increasing cropland conversion and grazing pressure.
- Potential overlap between the spatial tributary and quantitative sedimentation geochemical signals can be a limitation.

Figure 2:

- Outputs from the BMM, without spatial effects, are distinct, attributing 58% of the recently deposited lake sediment to the Dudumera tributary and 36% to the Makuyuni tributary.
- Inclusion of 'spatial' factors gives a more nuanced picture, demonstrating the importance of localised sedimentation in the lake. Tributaries that were not identified by the 'total' analysis, sometimes dominate localised depositions.
- The Makuyuni River dominates the northeastern sediment and significantly contributes to other lake areas, further highlighting its importance.

4. Conclusions

- Sediment dating and fingerprinting tools are synergistic.
- Lake Manyara experienced increasing sedimentation with two distinct maxima.
- Sedimentation linked to increases in specific tributary sediment delivery.
- Recent lake sedimentation was dominated by two tributary sources.
- Complex interaction exists between upstream sediment delivery and rainfall variability through sediment (dis)connectivity.
- Solid foundation for targeted land and water management strategies.

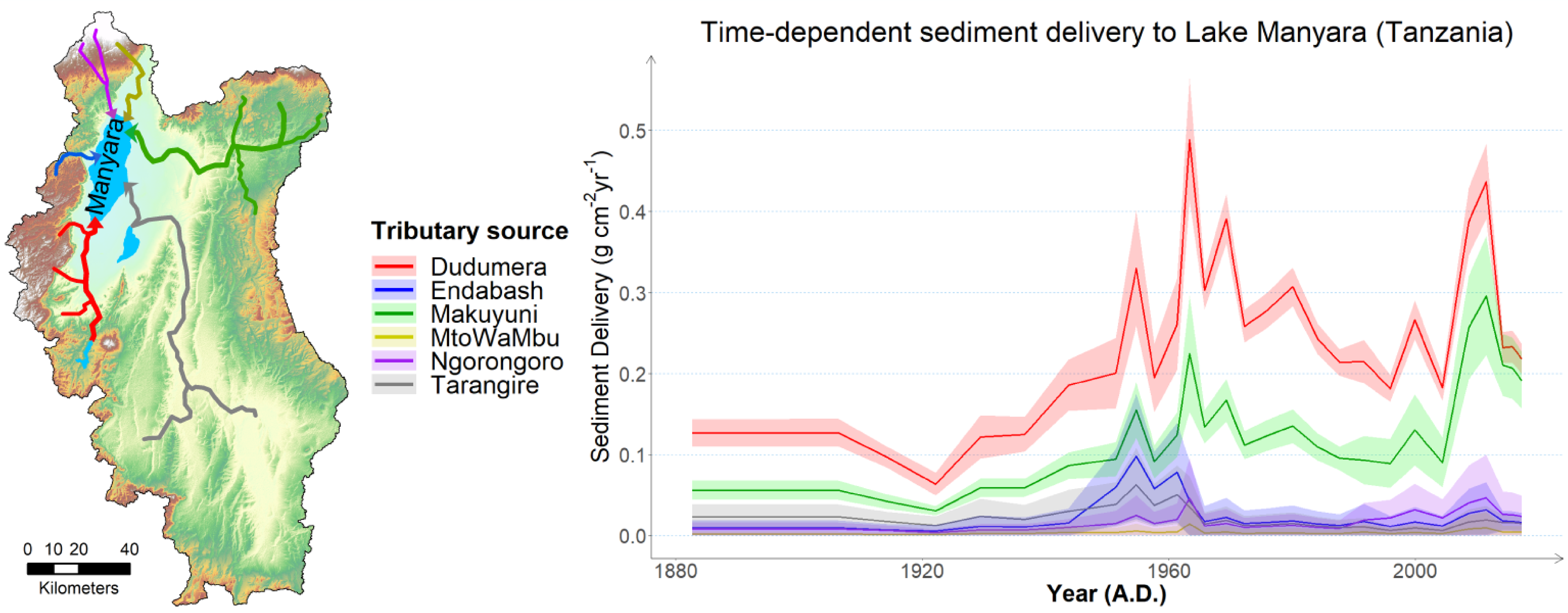


Figure 3: Changes of tributary sediment delivery to Lake Manyara over time.

5. References

[1] Borrelli P et al. 2017. An assessment of the global impact of 21st century land use change on soil erosion. Nat. commun. 8:2013 **[2]** Olago DO & Odada EO. 2007. Sediment impacts in Africa's transboundary lake/river basins: Case study of the East African Great Lakes *Aquat. Ecosys. Health* 10: 23-32 **[3]** Blake, W.H., et al. 2018. Soil erosion in East Africa: an interdisciplinary approach to realising pastoral land management change. Environ. Res. Lett. 13.12: 124014 **[4]** Appleby PG & Oldfield F. 1978. The calculation of lead-210 dates assuming a constant rate of supply of unsupported ^{210}Pb to the sediment. Catena 5: 1-8 **[5]** Stock, B et al. 2018. Analyzing mixing systems using a new generation of Bayesian tracer mixing models. *PeerJ* 6:e5096 **[6]** Blake, W.H., et al. 2018. A deconvolutional Bayesian mixing model approach for river basin sediment source apportionment. Sci. Rep. 8: 13073 **[7]** Wynants, M et al. 2018. Pinpointing areas of increased soil erosion risk following land cover change in the Lake Manyara catchment, Tanzania. *Int. J. Appl. Earth Obs. Geoinf.* 71, 1-8.

6. Acknowledgements