Land use/Land cover Changes and Associated Impacts on Water Yield Availability and Variations, Mereb-Gash River Basin in the Horn of Africa

Authors: Simon Measho, Baozhang Chen, Petri Pellikka, Lifeng Guo, and Huifang Zhang

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Summary

- There was a rapid land use/land covers changes in the Horn of Africa during 2000-2015.
- Annual water yield increased in the catchments of Merb-Gash river basin.
- There was significant correlation between land cover changes and water yield variations.

Introduction

- Climate change variability due to anthropogenic drivers has been certainly increasing.
  - An increase in land surface temperature, changes in rainfall patterns, fluctuations in the frequency and intensity of drought conditions in Africa (Midgley & Bond, 2015).
- Land Use/Land Cover (LULC) changes in the Horn of Africa are occurring quickly.
  - Impacts on water yield variations, and hydrological fluxes (Guzha et al., 2018).
  - Overall effect on water scarcity with less ground water and food insecurity (drought).
- Simplified models such as InVEST can be helpful to estimate water yield variations and identify the drivers, and support water resource management at local and regional levels.
- The study aims to quantify the LULC changes in the Horn of Africa and Mereb Gash river basin, and assess associated impacts on water yield in the basin during 2000-2015.

Study Area

- The evaluation of LULC changes in the Horn of Africa includes: Eritrea, Ethiopia, Djibouti, Kenya and Somalia.
- The Mereb-Gash river basin is one of the five major river basins of Eritrea.
  - It also covers northern parts of Ethiopia.
  - Its outlet goes to Sudan, where it connects to the Nile Basin.

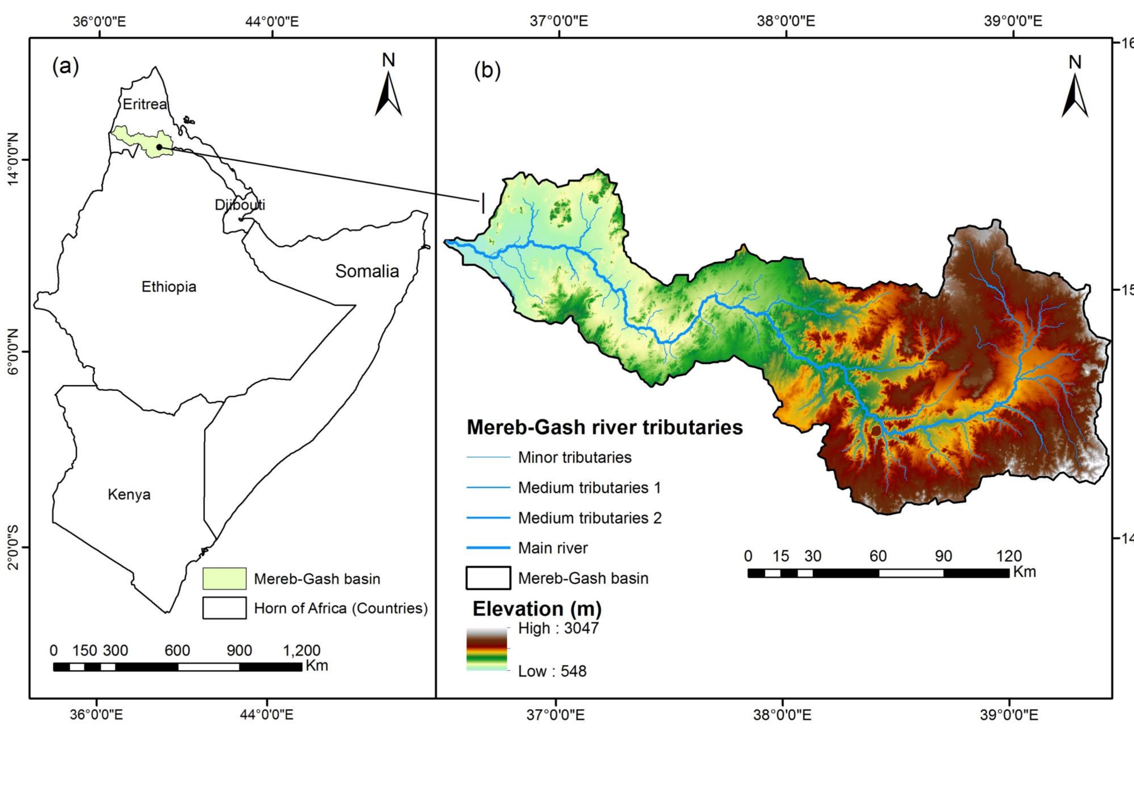

Figure 1. The site and location of Mereb-Gash river basin in the Horn of Africa (a), Elevation and tributaries of the Mereb-Gash river basin (b). DEM Source: SRTM.

Materials and Methods

Datasets

- Annual LULC data (2000, 2005, 2010 and 2015) were accessed from high-resolution Landsat images (Landsat 7 ETM+) and Google Earth Engine cloud computing method (Midekisa et al., 2017).
- Inputs for the InVEST annual water yield model were prepared from different sources:
  - Average annual precipitation and reference evapotranspiration from Climate Engine powered by Google Earth Engine (Huntington et al., 2017).
  - Soil depth and plant available water content extracted from Africa SoilGrids of World soil information service (Hengl et al., 2017).
  - Biophysical table of root depth, evapotranspiration coefficient (Kc) and plant cover proportions for each LULC in the basin based on guidelines of the Food and Agriculture Organization.

Methods

- Annual LULC images (dataset) were masked and reclassified into five major classes using ArcGIS software (ESRI, 2011) and further processed.
  - The images were spatially adjusted in QGIS software (version 2.18) with MULUSCE plugin to evaluate changes and generate transition probability matrix.
  - Land-use dynamic index (K) from initial and final LULC covers between each period was generated in a large table (Lin et al., 2018).
- The annual water yield model (version 3.6.0) was run separately for the years by changing both LULC and climate variables, and keeping constant the other parameters.
- The calibration and performance of the model were compared using long-term average stream-flow records of a gauge station in Mereb-Dubarwa.
- Pearson correlation (r) and its significance (p-value) between the changes in LULC area and annual water yield was computed.

References and Data

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University of Chinese Academy of Sciences

Results

LULC changes in the Horn of Africa (2000-2015)

- There was a rapid decrease in forests and barren lands (-K) while a drastic increase in built-up area.
- Highest transition probability from forested land to low and very low biomass areas (51.13% and 16.7%).

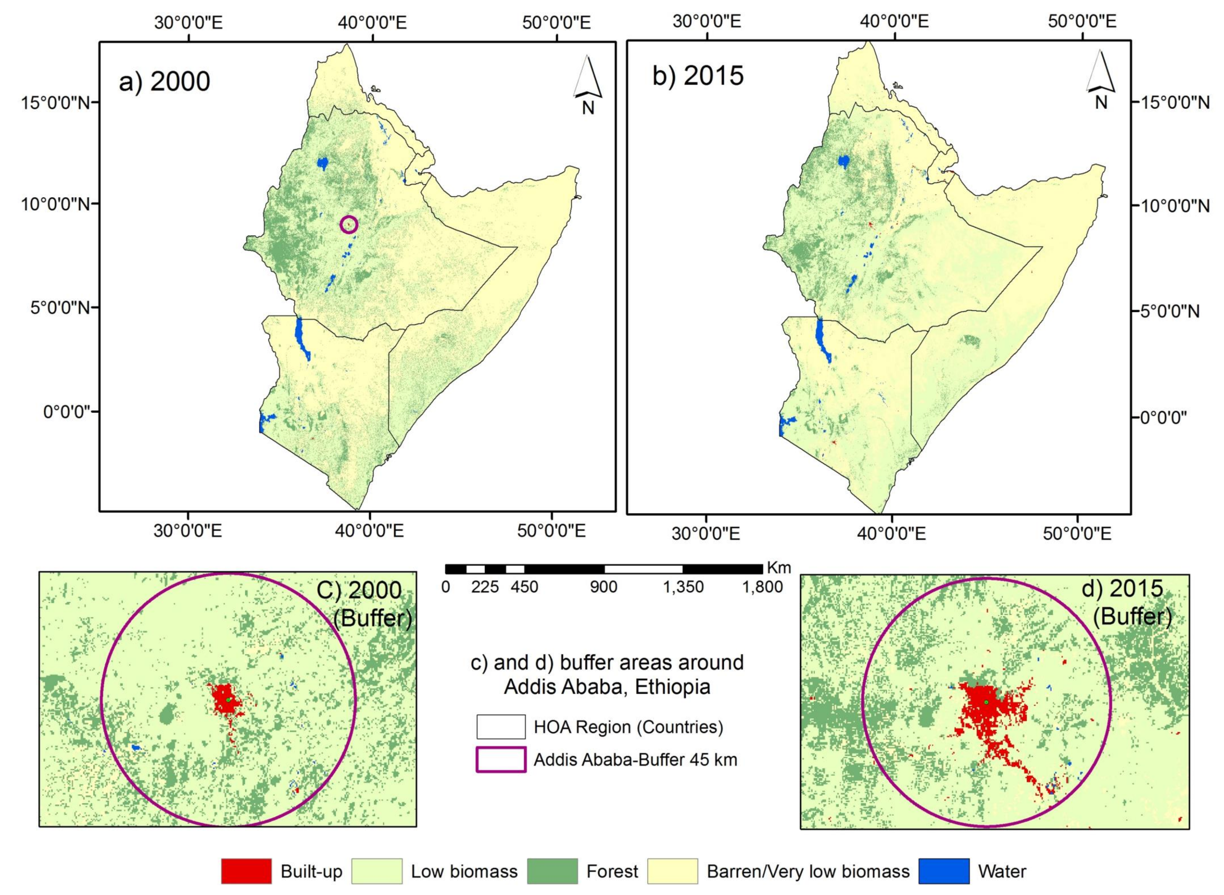

Figure 2. Land use/land cover changes between 2000 and 2015 in the Horn of Africa.

LULC changes in Mereb Gash River Basin (2000-2015)

- Sharp decline in forests from 12.89% in 2000 to 1.27% in 2015, and slight decrease in low biomass area.
- Largest conversion from forested land to low biomass (59.67%) and very low biomass areas (36%).

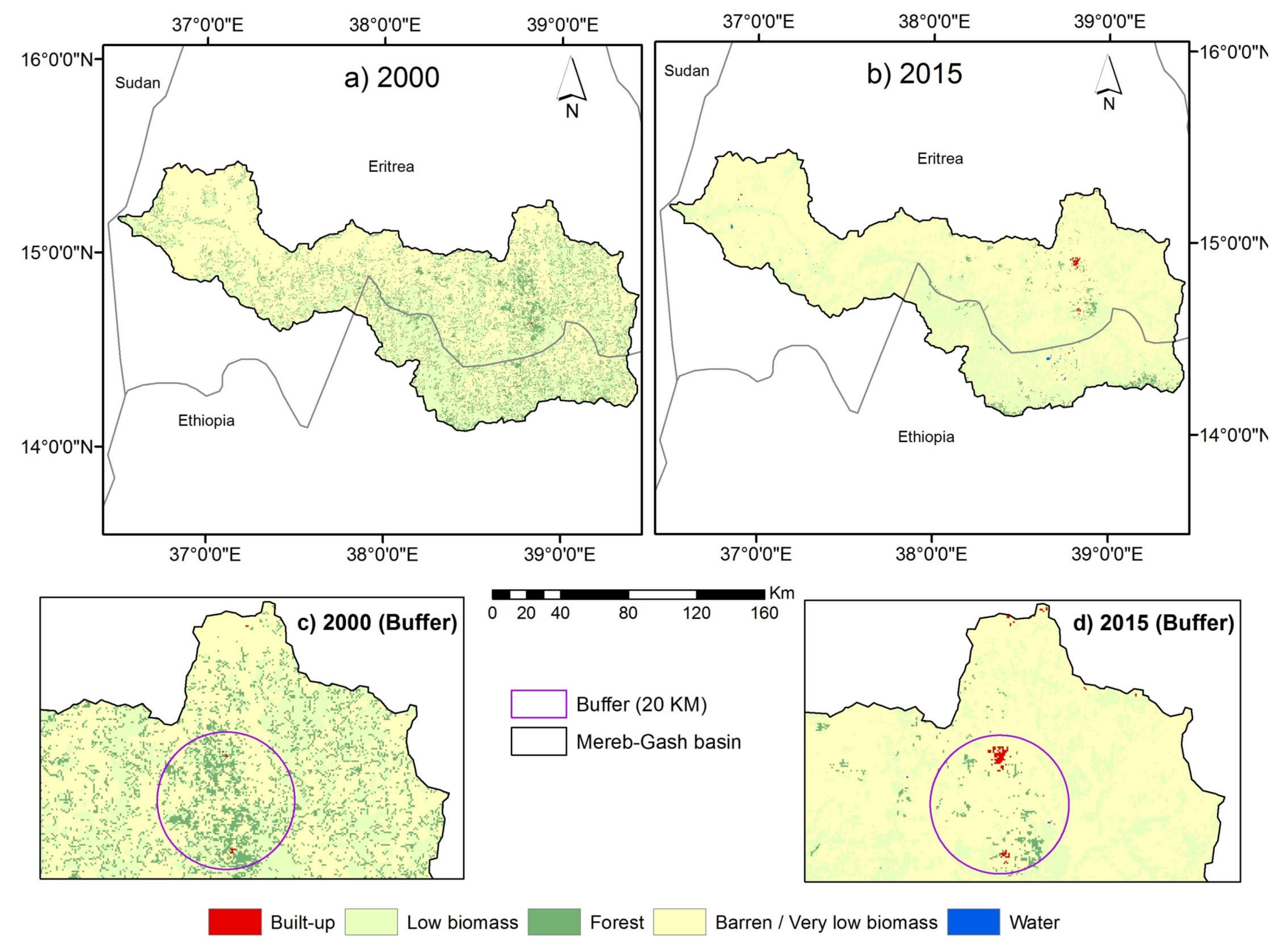

Figure 3. Land use/land cover changes between 2000 (a) and 2015 (b) in the Mereb-Gash basin, and 20 Km zoom (Medefera and Adiquala areas).

Spatiotemporal water yield variations and availability in Mereb Gash river basin

- Annual water yield increased for all the catchments during 2000-2015.
- The maximum mean annual water yield potential was in Middle Mereb (C1) with peak in 2005 per pixel .
- The highest annual water yield decreased in the forested lands from 43.18 million m^3 in 2000 to 4.1 million m^3 in 2015.

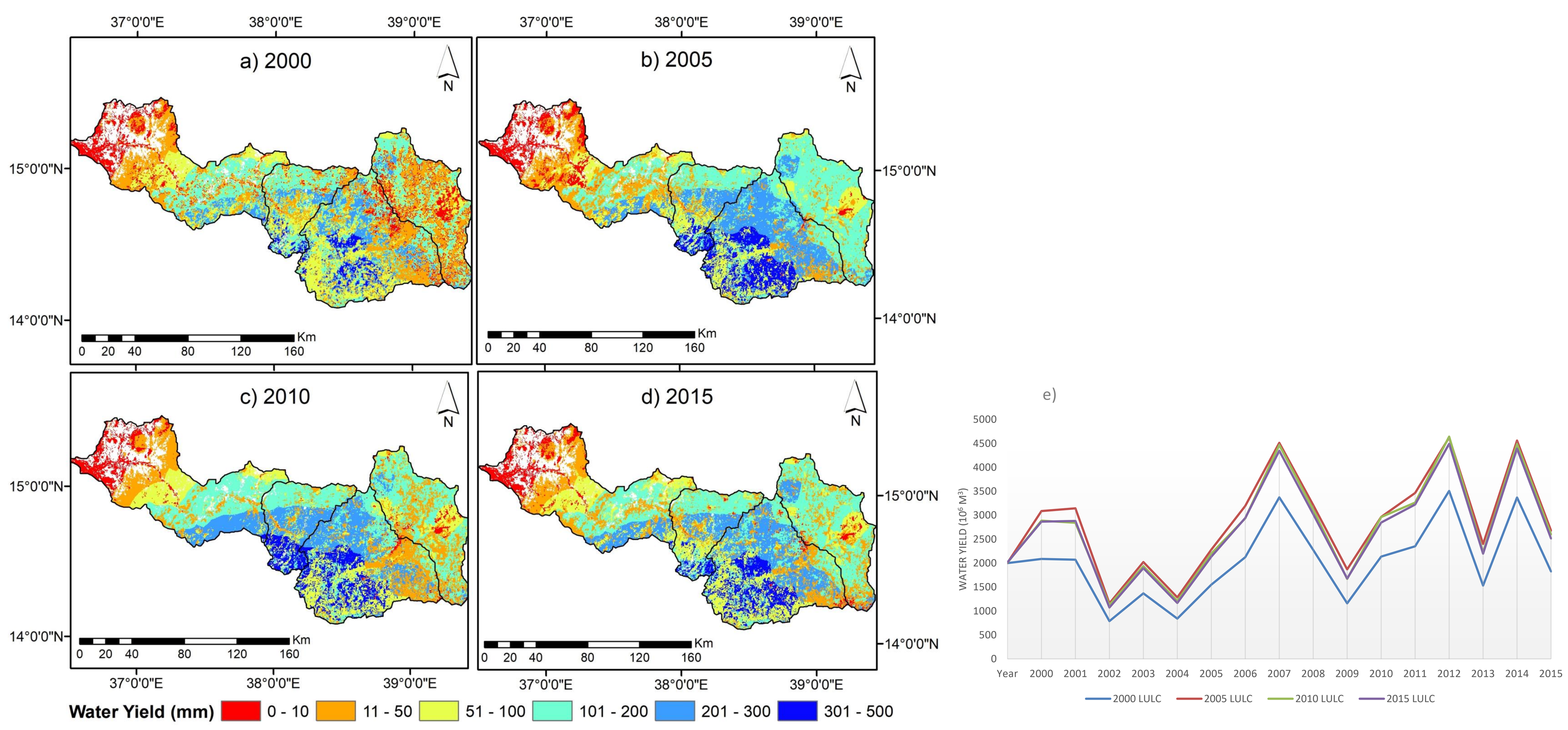

Figure 4. Mean annual water yield per pixel from 2000-2015 using 2000 (a), 2005 (b), 2010 (c) and 2015 (d) land cover types, and average water yield for each LULC and year in the Mereb-Gash river basin (e).

Conclusions

- There was strong positive correlation in all LULC types except water body, and significant positive correlation between the changes in forest and annual water yield ($p<0.01$) in the basin.
- The ME and RMSE statistics were -0.247 million m^3 and 0.497 million m^3 between modelled estimates and measured streamflow statistical values, and the bias of the calibration was 0.25.
- The main driving factor for water yield variations was LULC change in comparison to alterations in climate variables.
- The impacts on water yield variations presents strong signals for sustainable land and water resources management consideration at local and regional levels.

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