The impact of climate change and land use/ land cover change on water resources in a data-scarce catchment in Tanzania

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Overview of content

We like to guide you through our display using the following questions (for a quick read answers are provided):

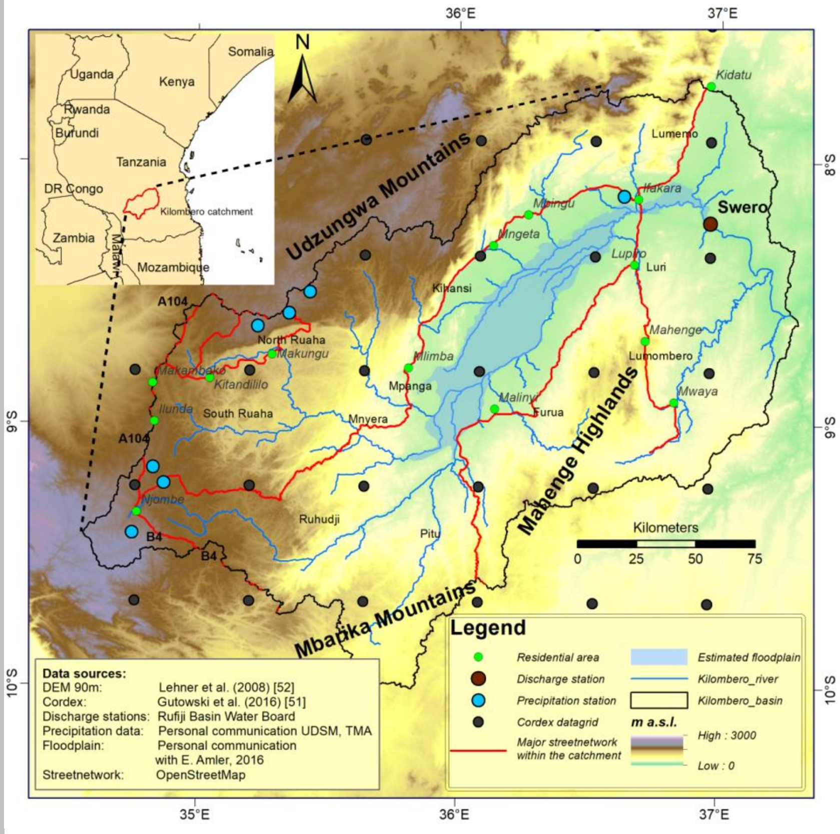
What is at stake?	What did we do?	What about climate change?	What about land use/ cover change?	What about combined impact of LULCC and climate change?	Why is this of concern?	What do you think?
Sustainability of the socio-ecological system is jeopardized by climate change and land use/ land cover changes	*Hydrological modeling with SWAT under various climate change and land use/cover change scenarios*	*The seasonality is likely to be amplified*	*Conversion from natural vegetation to cropland is obvious and fosters fast runoff components*	*Land use/ land cover changes in combination with climate change is likely to aggravate flooding intensity*	*It is an example how to setup a model in data-scarce catchments and foster management decisions*	*Please leave your comment to further advance our research or in order to collaborate in the future*

What is at stake?

UNIVERSITÄT BONN

WATER GEOGRAPHIE

The Kilombero catchment is a meso-scale catchment of 40,240 km² in south central Tanzania and is characterized by overall **data scarcity** like many other African catchments. The catchment consists of a **highly dynamic floodplain** system of about 7,967 km² at its center, that is sustained by **water from the surrounding uplands**. It also contains a Ramsar site giving evidence to its valuable ecosystem and importance concerning biodiversity conservation. **Nevertheless, the increasing pressure on natural resources jeopardizes the sustainability of the socio-ecological system.**



Overview map of the study area, including available precipitation and discharge stations (Swero). The estimated floodplain area is based on visual interpretation of Landsat and Sentinel-2 images.

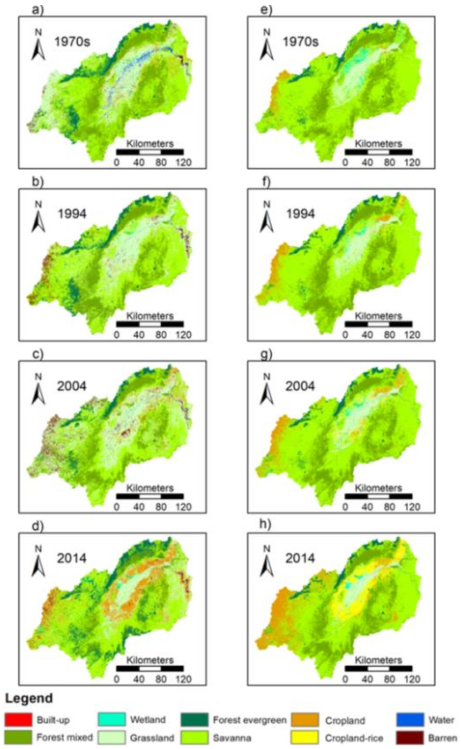
Näschen, K. et al. (2019). The Impact of Land Use/Land Cover Change (LULCC) on Water Resources in a Tropical Catchment in Tanzania under Different Climate Change Scenarios. *Sustainability, 11*(24), 7083.

What did we do (1/2)?

In the last decades land use and land cover changes (LULCC) accelerated drastically towards an agriculturally-shaped landscape, especially at the fringes of the wetland. The wetland system provides fertile soils, water and other water-related ecosystem services.

In this study, **methods of hydrology, meteorology and remote sensing were used to overcome data-scarcity** and gather a sound representation of natural processes in the catchment.

Historical LULC by Landsat images



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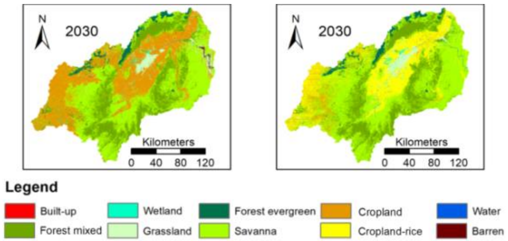
We utilized Landsat images from several decades to **simulate the impact of LULCC from the 1970s until today**. Furthermore, we applied the **Land Change Modeler (LCM) to simulate potential LULCC until 2030** and their impact on water resources.

Land use and land cover classifications for four time steps ranging from the 1970s (a and e), 1994 (b and f), and 2004 (c and g) up to 2014 (d and h). Some differences among the LULC maps in the right and in the left column exist due to the classification process: Only the maps in the left column contain "barren" as a land use class, but they have only one LULC "cropland", whereas the maps in the right column differentiate in between "cropland" and "cropland-rice" as a specific crop.

Potential future LULC by Land Change Modeler



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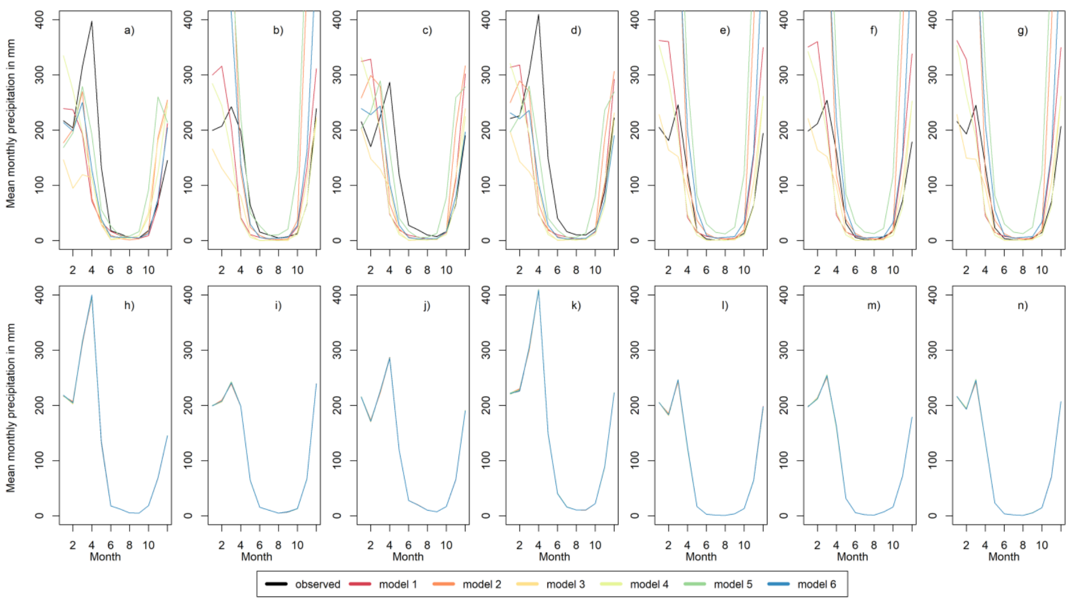
What did we do (2/2)?

The **Soil and Water Assessment Tool (SWAT)** was applied to represent the hydrological processes in the catchment.

To account for climatic changes, a regional climate model ensemble of the Coordinated Regional Downscaling Experiment **(CORDEX) Africa project was analysed and bias-corrected to investigate changes in climatic patterns until 2060**, according to the RCP4.5 (representative concentration pathways) and RCP8.5 scenarios.



Average monthly precipitation from 1951–2005 for the seven datagrids of CORDEX Africa before bias-correction in (a–g) and for the same stations after bias correction in (h–n). The lines representing the precipitation for the observed precipitation, as well as for models 1 to 5, are superimposed by the lines for model 6 due to their similar precipitation after bias correction (h–n).

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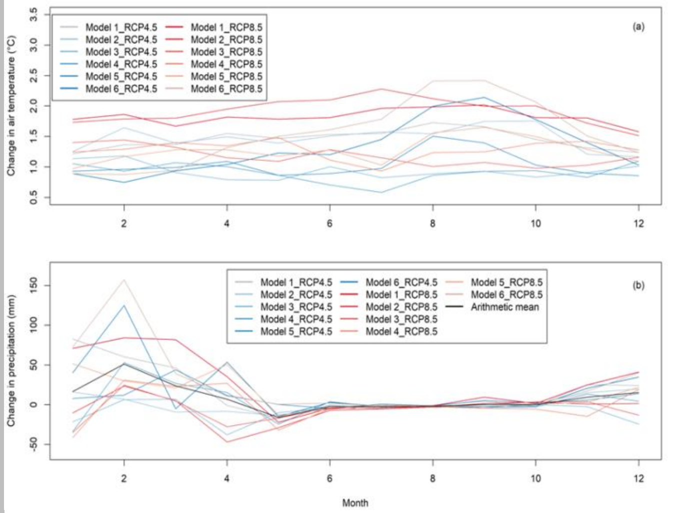
What about climate change?



Climate change signal among the bias-corrected historical model runs for (a) mean temperature (1979–2005) and the bias-corrected scenarios RCP4.5 and RCP8.5 (2010–2060), and (b) precipitation changes among the bias-corrected historical model runs (1951–2005) and the bias-corrected scenarios RCP4.5 and RCP8.5 (2010–2060). All values represent the monthly spatial averaged temperature and precipitation for the given periods, respectively.

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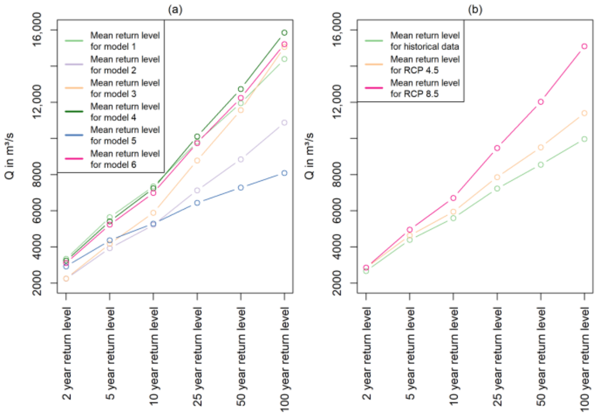
The climate change signal indicates **rising temperatures, especially in the hot dry season**, which reinforces the characteristics of this season. However, the **changes in precipitation signals among the analysed RCMs (from 1951-2005 compared to 2010-2060) vary between -8.3% and +22.5%** of the annual mean values (left figure). The results of the hydrological modelling also show increasing flood intensity (right figure).



Arithmetic mean for each model across the two RCP scenarios for the return levels of discharge at the outlet (a) and arithmetic mean for each scenario across all six models for the return levels of discharge at the outlet (b).

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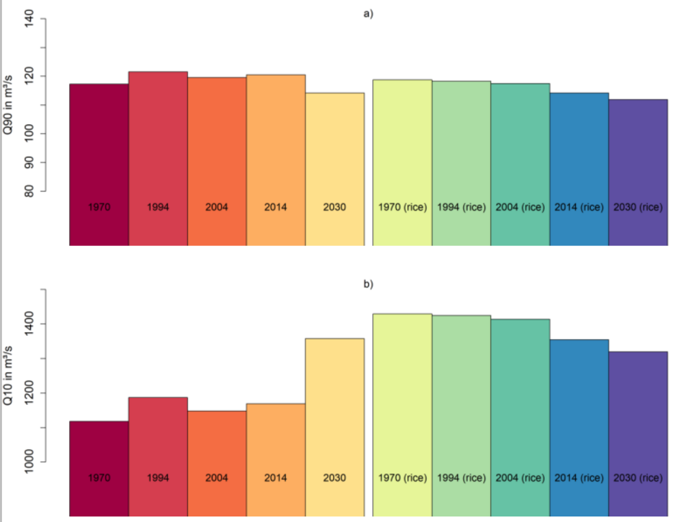
What about land use/cover changes?

LULCC simulations show an **increase of the seasonality** due to conversion into cropland. The consideration of rice crops shows decreasing high flows for conversions into paddy rice. The impact on **catchment scale** (left figure) is moderate compared to changes in water balance components on **subcatchment scale** (right picture).



Distribution of Q90 (a) and Q10 (b), representing the flow exceeded in 90% or 10% of the time for Q90 and Q10, respectively. The reddish columns on the left represent the setups with cropland, whereas the blueish columns on the right display the modeling results for the setup with cropland and cropland-rice differentiated. Data is based on simulations from the period 1958–2005 and all inputs except for the LULC maps are not modified

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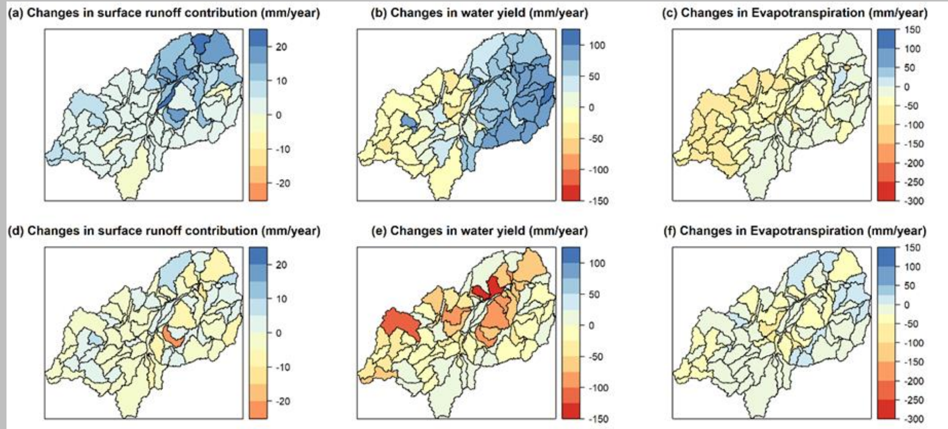

Average annual changes in selected water balance components on subcatchment scale. a–c) compares the cropland LULC maps of 1994 and 2030, while (d–f) compares the cropland-rice LULC maps of 1994 and 2030 on. All model runs used identic climate data from 1958 to 2005 and differences in water balance components refer only to changes in LULC.

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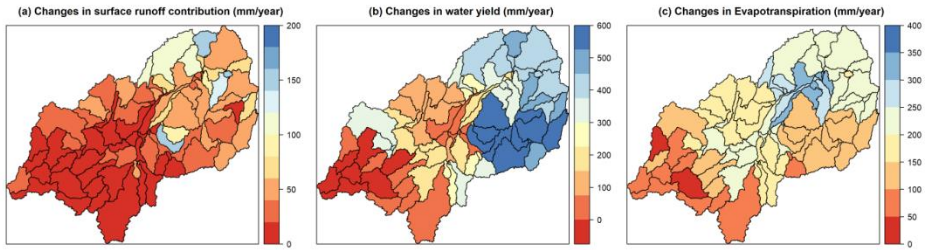
What about the combined impact of LULCC and climate change?

High flows increase by up to 84% for combined LULCC and climate change scenarios. The effect of **climate change is more pronounced** compared to the effect of LULCC, but also **contains higher uncertainties**.



Average annual shifts in selected water balance components on subcatchment scale with a comparison of the LULC setup of 1994 and 2030 (both without consideration of rice). The LULC 1994 is using the "dry model" climatic data with the RCP 4.5 scenario as input, whereas the 2030 LULC setup is driven by the "wet model" and the RCP 8.5 scenario data. All model runs were performed with climate data for the period of 2010 to 2060. Differences in water balance components refer to changes in both LULC and climate change.

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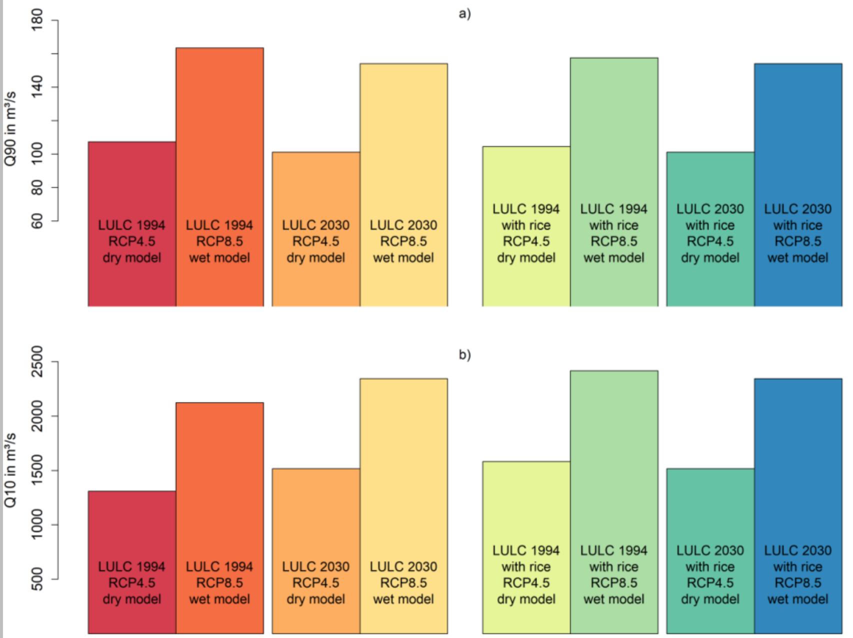

Bar plots showing the distribution of Q90 (a) and Q10 (b), representing the flow exceeded in 90% or 10% of the time for Q90 and Q10, respectively. The LULC setups of 1994 (cropland and cropland-rice) as well as the scenarios for 2030 (cropland and cropland-rice) are simulated with climate data of the period from 2010 to 2060 with the "dry" and the "wet" GCM-RCM model .

Why is this important?

This study exemplarily quantifies the impact of LULCC and climate change in a data-scarce catchment and therefore contributes to the **sustainable management** of the investigated catchment. This shows the **impact of environmental change on hydrological extremes and determines hot spots**, which are crucial for more detailed analyses like hydrodynamic modelling. The information from this study are an essential part to assist local stakeholders **protecting the wetlands integrity on the one hand and to ensure sustainable agricultural practices in order to guarantee food security on the other hand.** This is especially important for a catchment that has already changed tremendously and is still target to manifold future plans.

What do you think?

We are curious about your opinion and expertise. What do you think? Do you have any further suggestions on how to complement these findings from hydrological modeling?
What would be your next steps?

Do you see potential of collaboration? We would like to discuss with you how our research can be further advanced by integrating forces of different research disciplines and different approaches. Please leave a comment or contact me directly naeschen@uni-bonn.de .

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Geophysical Research Abstract (1/2)

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The Kilombero catchment is a meso-scale catchment of 40,240 km² in south central Tanzania and is characterized by overall **data scarcity** like many other African catchments. The catchment consists of a **highly dynamic floodplain** system at its centre which is sustained by **water from the surrounding uplands**. It also contains a Ramsar site giving evidence to its valuable ecosystem and importance concerning biodiversity conservation. However, in the last decades land use and land cover changes (LULCC) accelerated drastically towards an agriculturally-shaped landscape, especially at the fringes of the wetland. The wetland system provides fertile soils, water as well as other water-related ecosystem services. Nevertheless, **the increasing pressure on natural resources jeopardizes the sustainability of the socio-ecological system**, especially in the face of climate change.

In this study, **methods of hydrology, meteorology and remote sensing were used to overcome data-scarcity** and gather a sound representation of natural processes in the catchment. The **Soil and Water Assessment Tool (SWAT)** was applied to represent the hydrological processes in the catchment. We utilized Landsat images from several decades to **simulate the impact of LULCC from the 1970s until today**. Furthermore, we applied the **Land Change Modeler (LCM) to simulate potential LULCC until 2030** and their impact on water resources. To account for climatic changes, a regional climate model ensemble of the Coordinated Regional Downscaling Experiment **(CORDEX) Africa project was analysed and bias-corrected to investigate changes in climatic patterns until 2060**, according to the RCP4.5 (representative concentration pathways) and RCP8.5 scenarios.

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The climate change signal indicates **rising temperatures, especially in the hot dry season**, which reinforces the special features of this season. However, the **changes in precipitation signals among the analysed RCMs vary between -8.3% and +22.5%** of the annual mean values. The results of the hydrological modelling also show heterogeneous spatial patterns within the catchment area**. LULCC simulation results show a 6-8% decrease in low flows for the LULCC scenarios, while high flows increase by up to 84% for combined LULCC and climate change scenarios. The effect of climate change is more pronounced compared to the effect of LULCC, but also contains higher uncertainties.** This study exemplarily quantifies the impact of LULCC and climate change in a data-scarce catchment and therefore contributes to the sustainable management of the investigated catchment, as it shows the impact of environmental change on hydrological extremes and determines hot spots, which are crucial for more detailed analyses like hydrodynamic modelling. The information from this study are an essential part to assist local stakeholders **protecting the wetlands integrity on the one hand and to ensure sustainable agricultural practices in order to guarantee food security on the other hand** in a catchment that has already changed tremendously and is still target to manifold future plans.

This research is part of the Collaborative Research Centre 228 “Rural Future Africa” funded by the German Research Foundation (DFG).