Assessment and Monitoring of Soil Erosion Risk Parameters in the Trans-Boundary Region of Lake Kivu and the Ruzizi River Basin

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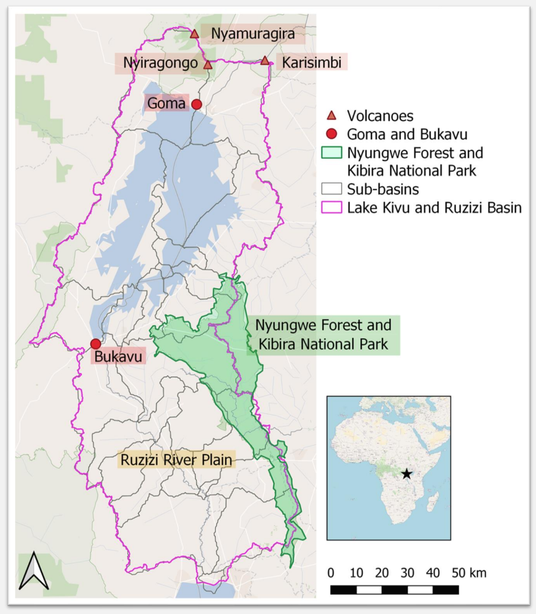
Motivation

In their *Main Report on the Status of the World's Soil Resources*, the FAO states that land degradation is believed to be expanding in an alarming rate, especially in Africa, where 65% of the soils on agricultural lands have become degraded since the middle of the twentieth century [1]. The most widespread cause of soil degradation for African soils is water erosion [1]. The trans-boundary region of lake Kivu and the Ruzizi basin has been affected by strong decrease in natural land cover within the last decades [2]. According to IPCC scenarios, an increase of November, December and January precipitation between 11% and 19% is likely for the region together with a decrease in precipitation of around 2% in July [3].

The presented work shows the analysis of water erosion using a combination of Earth Observation data for a study area in the tropical Africa. An erosion risk index is created taking into account extreme precipitation events and the seasonal cycle of vegetation dynamics. Those land cover classes are identified which lead to a low vegetation cover during wet and dry season. The results are compared to the erosion totals derived from a RUSLE simulation performed for the same region [3].



Study area of Lake Kivu and the Ruzizi Plain and location of most important features for the analysis.

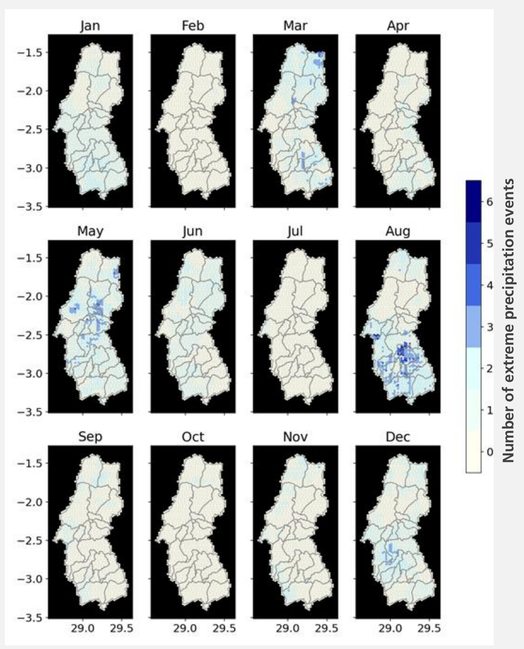
Study Area

The study area covers the trans-boundary region of the Republic of Rwanda, the Republic of Burundi and the Democratic Republic of Congo. The area is characterized by an intense topography: In the north, the volcanoes Nyiragongo, Nyamuragira and Karisimbi reach altitudes above 4000 m a.s.l. In the southeast and southwest further mountain ranges are located, the latter ones forming the natural preserves Nyungwe Forest and Kibira National Park. South of Lake Kivu, the Ruzizi river plain is located. Here, the main agricultural production in the area takes place. South and north of lake Kivu, the cities of Bukavu and Goma are located, respectively, which are the main agglomerations in the area.

Erosion Risk Index

Precipitation

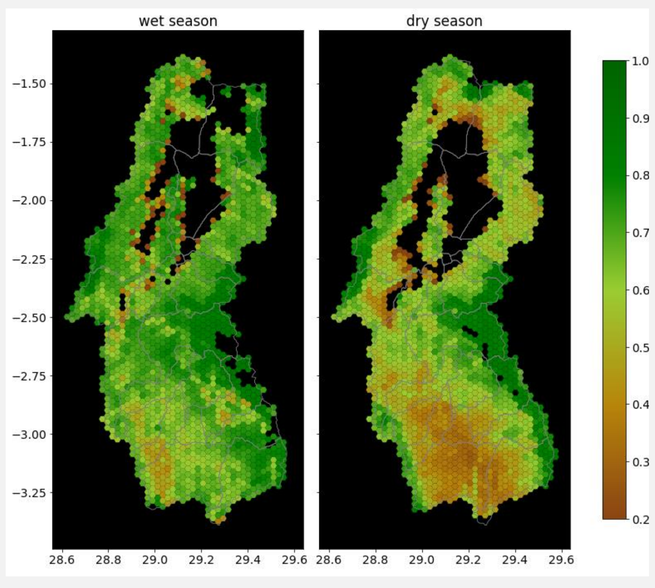
Extreme precipitation events are calculated using the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) v2.0 daily dataset [5] in a resolution of 0.05° spatial resolution. The data is resampled on a 0.025° hexagonal grid. For each grid cell, the 99-percentile for the years 2016-2020 is calculated for the wet season (Sep-May) and dry season (June-August). Each day on which precipitation exceeds the 99-percentile is considered an extreme precipitation day.



Number of extreme precipitation events per hexagon for each month of the year 2016.

Vegetation

The seasonal median NDVI for each year is calculated from the MODIS products MYD13Q1 and MOD13Q1 [6] (16 days temporal and 250m spatial resolution). The index shows a strong decrease of vegetation cover in the Ruzizi plain from wet to dry season. This is due to the agricultural use of this area and the harvesting of fields at the end of the wet season / beginning of dry season. Around the cities of Goma and Bukavu north and south of Lake Kivu, another area with strong decrease in NDVI can be found.



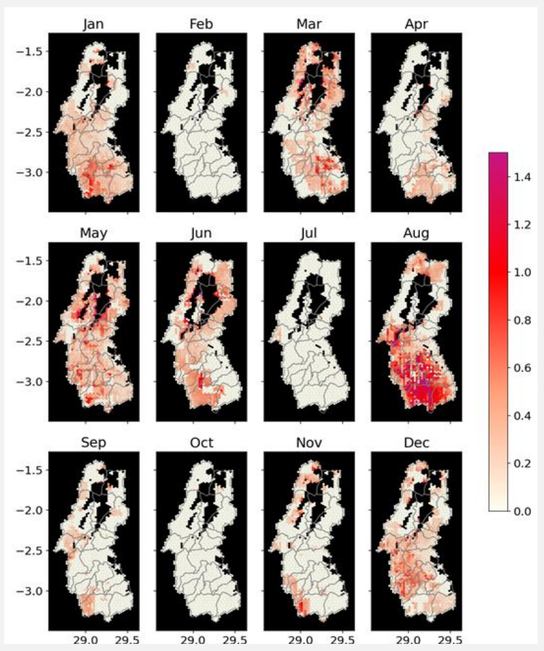
Median NDVI for wet and dry season of 2016

Erosion Risk

Water erosion risk is increased for hexagons, for which the monthly number of extreme events is high and the vegetation cover is low. The erosion risk index is calculated from these two sets of information using the following formula:

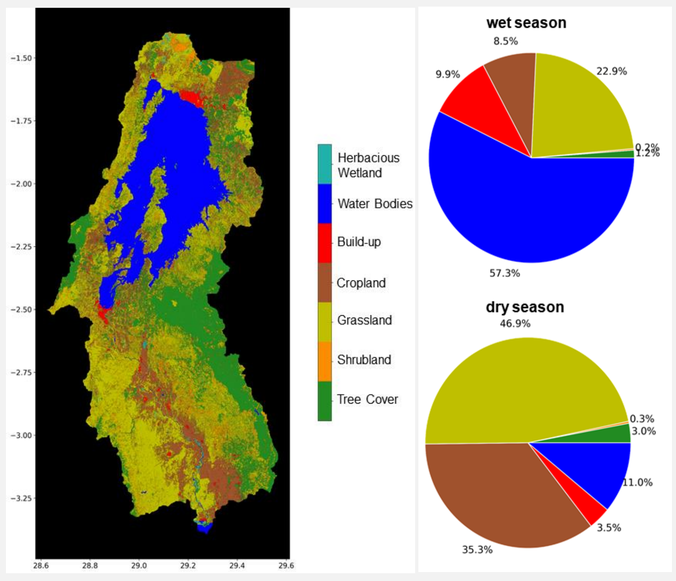
***Erosion Risk Index = Monthly # of Extreme Precipitation Events x (normalized seasonal NDVI ∗ (–1) + 1)**

For the year 2016, this results in the pattern shown by the figure below.



Monthly erosion risk for 2016 based on precipitation threats and vegetation cover.

Land Cover analysis using the ESA WorldCover map



Left: Land cover based on ESA WorldCover. Right: Land cover classes with NDVI below 0.5 during wet and dry season.

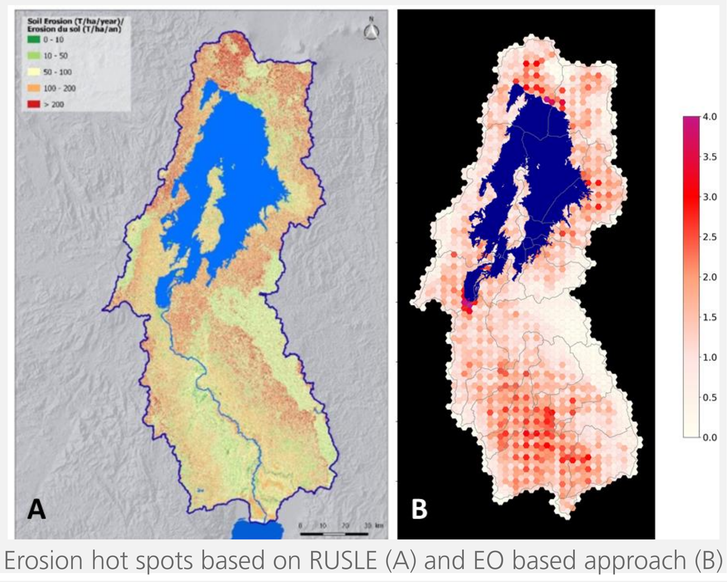
The land cover is analyzed using the ESA WorldCover 10m resolution map of 2020 based on Sentinel-1 and Sentinel-2 data [4]. The pie charts show that agricultural areas and grasslands are the main causes of low NDVI values during dry season. Adaption of land use practices may lead to a reduction of this important factor for soil erosion.

Areas covered by forests mostly found in the protected areas, show a year round high NDVI value, which leads to an erosion risk close to 0.

Erosion Risk Map 2016-2020

Figure B shows the final erosion risk map for the years 2016-2020, reflecting the sum of erosion risks for each year. This is compared to the results of a RUSLE simulation (Figure A) performed for the same region and published in [3]. The results show:

- Similar hot spot regions were identified by the two approaches
- Some hot-spot regions are a bit shifted, e.g. in the Ruzizi plain



Erosion hot spots based on RUSLE (A) and EO based approach (B)

Take Home Message

The EO based approach to identify erosion risk hot spots from vegetation and precipitation data can be used for an analysis of erosion risk over large areas using open source EO data. The presented approach can be used complementary to RUSLE simulations.

[1] FAO and ITPS (2015), The status of the world's soil resources (main report); [2] Karamage, F. et al (2016), doi:10.3390/f7110281; [3] Sher Consult (2020): Baseline Study for the Basin of Lake Kivu and the Ruzizi River, Report. [4] Zanaga, D. et al. (2021), doi: 10.5281/zenodo.5571936. [5] Funk, C. et al (2015), doi: 10.1038/sdata.2015.66. [6] Didan, K. (2021), MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061.

Deutsches Zentrum für Luft- und Raumfahrt

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