Short Project Summary

Ecosystem responses to changing rainfall patterns

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In semi-arid regions, rainfall and soil water supply are crucial determinants of plant growth, and by their transpiration plants in turn are important factors for catchment water balance. In addition, semi-arid ecosystems have also been found to account for the largest fraction of the global interannual variability of net carbon uptake, and to contribute notably to the current carbon sink in terrestrial ecosystems.

In the SaWaM project, we investigated the interplay of seasonal weather and vegetation net primary productivity (NPP) and ecosystem water balance using the advanced dynamic vegetation model LPJ-GUESS (Ahlström 2015, Smith 2014). We analyzed long-term trends and seasonal patterns of vegetation, responding to precipitation data from reanalyses and seasonal forecasts. We compared NPP and absorbed radiation (fPAR) with satellite remotely sensed NDVI. Differences were compared between modelled and monitored variables. We further investigated simulated changes in soil water content, runoff and ecosystem water consumption. We focused on regions in Iran and Brazil as case-study regions.

Methods and Data

The LPJ-GUESS model is a process-based dynamic global vegetation model (DGVM), which simulates large-scale dynamics in vegetation distribution and biogeochemical cycles under coupled C-N dynamics. Model input data are climate variables, such as temperature, precipitation and radiation, atmospheric CO_2, soil texture, nitrogen deposition and fertilization, and land-use information. Short term plant processes are calculated on a daily time step (e.g. photosynthesis, plant respiration, stomatal regulation) and long-term processes on an annual time step (e.g. plant reproduction, establishment, growth). They simulate the ecosystem state represented by variables related to the productivity of the vegetation and various nutrient cycles (water, C, N). Simulations were done on a 0.1° x 0.1° grid.

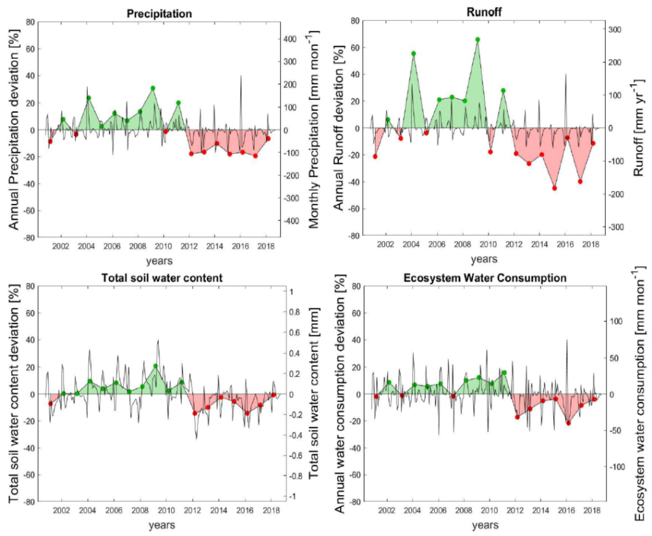

Figure 1: Annual deviation of precipitation, runoff, total soil water content (top soil layers until 1.5m depth) and water consumption for the example of the Rio São Francisco basin in Brazil. Black lines are absolute deviations of monthly means above or below the average, corresponding to the right y-axis. The green areas show positive, red areas show negative relative deviations, i.e. by how many percent higher or lower the annual values are compared to the average, referred to the left y-axis. Timeline is from 2000-2018 for each hydrological year (Oct-Sept).

Results and Conclusions

Results show reduced plant growth in both regions in Brazil and Iran, especially due to severe droughts over the last years. The reduced growth also affected the water balance. NDVI followed the spatial and temporal patterns of precipitation better than NPP and fPAR, which indicates that drought resistance may not be represented sufficiently well in the model. Nevertheless, also the accuracy of NDVI may be variable, and depends on several factors such as atmospheric conditions. For an accurate method development, it is therefore advisable to access both modelled and monitored variables.

For the example of the case study area in Brazil (Figure 1), positive deviations in water-related variables were found for the year up to 2011, with maximum values of 30% precipitation, 60% runoff, 20% soil water and ecosystem water consumption (except 2001, 2003, 2005, 2010 with negative deviations), before the overall trend became the negative period up to 2018. The hydrological variables confirmed the long-term trend towards drier years, with less rainfall and reduced runoff. Furthermore, deviations in runoff mirrored rainfall patterns.

Vegetation responded with strongly reduced growth as a result of reduced amount of precipitation. Not only natural vegetation is affected but also crops, which results in large yield losses during driest years. During drought periods, simulated ecosystem water consumption was less affected than precipitation such that the fraction of water consumed by the ecosystem increases (Figure 2). This exacerbates the scarcity of water potentially used by humans.

However, these results should not be interpreted as removal of vegetation being positive for human water availability. Ecosystems and evapotranspiration are crucial parts of the water cycle and for cloud formation, and removal of vegetation leads to negative feedbacks, enhancing droughts.

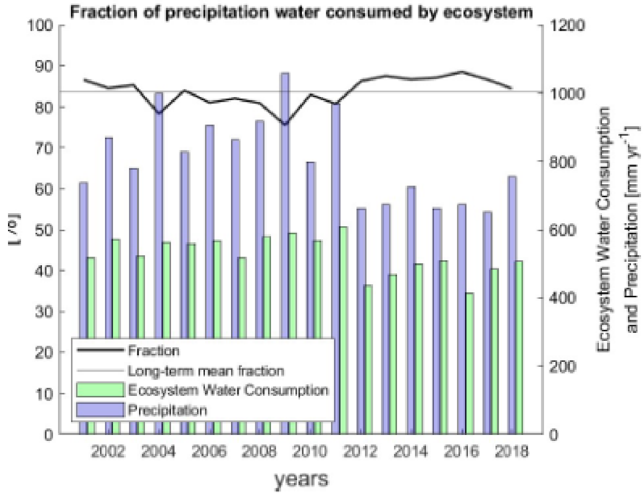

Figure 2: Annual totals of ecosystem water consumption (green bars) and precipitation (blue bars), referred to right y-axis. Black line is the fraction of precipitation water that is consumed by the ecosystem, thin line is the long-term mean fraction for hydrological years in the Rio São Francisco basin.

References

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