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Modeling the paradoxical evolution of runoff in pastoral Sahel. The case of the Agoufou watershed, Mali

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In the last decades the Sahel has witnessed a paradoxical increase in surface water despite a general precipitation decline. This phenomenon, commonly referred to as “the Sahelian paradox”, is not completely understood yet. The role of cropland expansion due to the increasing food demand by a growing population has been often put forward to explain this situation for the cultivated Sahel. However, this hypothesis does not hold in pastoral areas where the same phenomenon is observed. Several other processes have been suggested to account for this situation such as the degradation of natural vegetation following the major droughts of the 70ies and the 80ies, the development of crusted top soils, the intensification of the rainfall regime and the development of the drainage network.
In this work, a modeling approach is proposed to quantify and rank the different processes that could be at play in pastoral Sahel. The KINEmatic EROSion model (KINEROS-2) is applied to the Agoufou watershed, in the Gourma region in Mali, which underwent a significant increase of surface runoff during the last 60 years. Two periods are simulated, the “past” case (1960-1975) preceding the Sahelian drought and the "present" case (2000-2015). Surface hydrology and land cover characteristics for these two periods are derived by the analysis of aerial photographs, available in 1956, and high resolution remote sensing images in 2011. The major changes identified are: 1) a partial crusting of isolated dunes, 2) an increase of drainage network density, 3) a marked decrease in vegetation with the non-recovery of tiger bush and vegetation growing on shallow sandy soils and 4) important changes in soil properties with shallow soil being eroded and giving place to impervious soils. These changes were implemented independently and in combination in the KINEROS-2 model. The simulations results show a significant increase of annual discharge between the “past” and the “present” case (p value < 0.001) despite a slight overestimation of the past discharge. Mean annual discharges are estimated at 0.51×106 m3 and 3.29×106 m3 for past and present respectively.
Modification of soil properties and vegetation cover (grassland and tiger bush thickets) are found to be the main factors explaining this increase, with the drainage network development contributing to a lesser extent. These synergistic processes explain the Sahelian paradox in the absence of land use change and could play a role in other Sahelian watersheds where runoff increase has been also observed.