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The distribution of grasslands, savannas and forests in Africa: a new look at the relationships between vegetation, fire and climate at continental scale

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Savannas occupy about a fifth of the global land surface and store approximately 15% of the terrestrial carbon. They also encompass about 85% of the global land area burnt annually. Along an increasing rainfall gradient, they are the intermediate biome between grassland and forest. Undergoing and predicted increasing temperature and CO_2 concentration, modified precipitation regimes, as well as increasing land-use intensity, are expected to induce important shifts in savanna structure and in the distribution of grasslands, savannas and forests. Owing to the large extent and productivity of savanna biomes, these changes could have larger impacts on the global biogeochemical cycle and precipitation than for any other biome, thus influencing the vegetation-climate system.
The dynamics of these biomes has been long studied, and the current theory postulates that while arid savannas are observed because of tree-water limitation, and competition with grasses, in mesic conditions savannas persist because a grass-fire feedback exists, which can maintain them as an alternatively stable state to closed forests. This feedback is reinforced by the different responses of savanna and forest tree type. In this context, despite their relevance, grasses and tree types have been studied mostly in small scale ecological studies, while continental analyses focused on total tree cover only.
Here we analyze a recent MODIS product including explicitly the non-tree vegetation cover, allowing us to illustrate for the first time at continental scale the importance of grass cover and of tree-fire responses in determining the emergence of the different biomes. We analyze the relationships of woody and herbaceous cover with fire return time (all from MODIS satellite observations), rainfall annual average and seasonality (from TRMM satellite measurements), and we include tree phenology information, based on the ESA Global Land Cover map, also used to exclude areas with large anthropogenic land use.
From this analysis we distinctively observe that tropical vegetation dynamics changes along a rainfall gradient more markedly than previously observed, in particular identifying three zones: (i) a dry region, where grasses are dominant and water-limited, and fires are rare; (ii) an intermediate rainfall range, where savanna with grass dominance is the predominant biome, maintained by frequent fires and rainfall seasonality; and (iii) a more humid area, where both savannas and forests can occur, as determined by the grass-fire feedback and the occurrence of different types of trees. The analysis of these important ecological processes can also be applied to the evaluation of Dynamic Global Vegetation Models, that currently have particular difficulties in simulating tropical vegetation.