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The impact of rain events on CO_2 emissions from contrasting land use systems in semi-arid West African savannas

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West Africa's Sudanian savannas are one of Africa's high-potential "bread baskets", where surplus food (e.g. millet, sorghum, cowpea and livestock) is being produced. These ecosystems currently undergo pronounced land use changes and will likely face shorter rainy seasons with more extreme rainfall and droughts in the future. This could have serious impacts on the vegetation and its carbon dioxide (CO_2) exchange with potentially increasing CO_2 emissions accelerating climate warming. Understanding how the CO_2 fluxes in this area respond to land use changes and environmental fluctuations, in particular rain events, is essential to design sustainable land use strategies. However, this understanding is hampered by a limited data availability.

In this study, we monitored net ecosystem exchange (NEE) of CO_2, rainfall and other weather and vegetation parameters during four years (2013-2016) at three savanna sites in southern Burkina Faso and northern Ghana. To this end, a monitoring network of three eddy-covariance stations and nine automatic weather stations was established. The three savannas were characterized by different vegetation due to different land use: i) woody and nearly pristine, ii) a mixture of cropland and grassland and iii) grassland under intensive grazing. Other site characteristics such as climate, soil, or topography chosen were as similar as possible. The impact of rain events on CO_2 exchange for these three contrasting ecosystems was analyzed for single rain events (short-term) and on a yearly time scale (long-term).

We found that the pristine savanna site was a prominent sink of CO_2 (-864 to 605 g CO_2 m-2 y-1) while the two degraded sites were net CO_2 sources (118 to 605 g CO_2 m-2 y-1) with a complex relation with annual rainfall amounts. The NEE responses to single rain events revealed that daytime rain systematically decreased the sink strengths at all sites, which might be associated with decreased light availability. At the degraded sites, additional factors increasing CO_2 losses were rain duration and dry spell length.

The observed patterns of immediate CO_2 flux responses to rainfall at differently used savannas indicate strong internal feedbacks between vegetation and land use changes and raise the question whether the CO_2 sink potentials might be overestimated with possible implications for global CO_2 budgets. Our findings also suggest that carbon sequestration needs to be taken into account when designing sustainable land-use strategies.