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Simulation of water and nitrogen cycle in natural savannah and rainfed agriculture in Burkina Faso, West Africa

E. Lehmann (1), R. Grote (1) and H. Kunstman (1)

(1) Institute for Meteorology and Climate Research Atmospheric Environmental Research (IMK-IFU), Garmisch-Partenkirchen, Germany

Tropical savannahs cover an area of 17 x 10^6 km^2 worldwide. The properties of this system are highly dynamic and influence the regional as well as the global climate. However, these dynamics of physical properties, carbon-, nitrogen-, and water exchange with the atmosphere are still not very well understood.

Models are suitable tools to represent these vegetation dynamics and have been implemented as parts in regional climate and air chemistry as well as hydrological simulations. These implementations are mostly originating from vegetations systems in the temperate regions and are often not very well adapted to tropical landscapes such as savannah. One reason is that they generally do not consider the drought dependent leaf area dynamics or the differentiation of rooting depth which is decisive for the complex interactions between grasses and trees. They also do not account for nitrogen emissions into the atmosphere that effects regional air quality. The progress in these issues is hampered by the difficult access and an often low data quality.

In this study, models for different biosphere processes have been adjusted to the vegetation dynamics in the savannah. These sub-models are combined by the modular biosphere simulation environment (MOBILE) that can itself be coupled to regional models. First, MOBILE has been complemented by a 1-dimensional physically-based water balance model originating from the Oregon State University (OSU) model (Chen and Dudhia, 2001). This enables a computation of the soil moisture dynamics, runoff generation and the full surface energy balance. This model has been modified using a sophisticated allocation mechanism (Grote and Pretzsch 2002) to represent seasonal leaf area dynamics of savannah trees and grasses as well as consider species specific rooting depth for water uptake. Secondly, the DNDC model that describes soil carbon- and nitrogen balance has also been implemented into the framework (Li et al., 2000; Stange et al., 2000). It is now closely linked to the modified OSU water balance module and can be used to calculate nitrogen and methane emissions in dependence on soil physical and chemical dynamics.

To overcome knowledge gaps in parameterization of the soil- (e.g. saturated soil water potential, porosity, wilting point, hydraulic conductivity) and the vegetation-model (e.g. interception capacity, stomata resistance, rooting depth), computationally efficient multi-objective parameter estimation techniques (simulated annealing) have been applied. This particularly useful technique enables successful simulations of both biological (gas emission) and hydrological observations (heat flux, soil moisture and temperature) with limited site information available. The combined model is evaluated against measured gas emission and heat fluxes during the rainy seasons 2005 and 2006 (carried out within the African Monsoon Multidisciplinary Analysis, AMMA).

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