Plant diversity may affect climate–vegetation interaction

In a new study, published in *Nature Geoscience*, Prof. Dr. Martin Claussen, director of the department "The Land in the Earth System" at the Max Planck Institute for Meteorology (MPI-M), and researchers of his team analysed to what extent plant diversity influences the stability of climate–vegetation interaction.

Terrestrial biosphere and climate affect each other. Plants need sunlight and rain, the vegetation in turn changes heat fluxes between soil and atmosphere as well as evaporation and water storage in the soil. This interaction can be so strong that abrupt regime shifts in ecosystem and climate may occur, as exemplified by the vegetation and desert in northern Africa. Approximately 15 years ago, Martin Claussen, Victor Brovkin and former colleagues concluded from theoretical considerations that the Sahara, much greener several thousand years ago than it is today, must have expanded to its present size within just a few hundred years. While some geological records seem to support this hypothesis, the only vegetation record from the Sahara, recovered by Stefan Kroepelin from pollen findings in the sediment of Lake Yoa in the northeast of the Republic of Chad, seems to tell a different story; there were no abrupt changes in vegetation and rainfall, but only a gradual trend towards a drier climate, accompanied by strong centennial fluctuations in the vegetation cover.

Various attempts to reconcile theory and data have been unsatisfying so far. Now, a new idea seems to shed light on the problem. In their study, Martin Claussen, Sebastian Bathiany, Victor Brovkin and Thomas Kleinen from MPI-M have explored the idea that plant diversity affects the dynamics of climate-vegetation interaction. On the one hand, some plant types in their model are sensitive to changes in precipitation, leading to an unstable "vegetation-climate" system i.e. abrupt changes in vegetation cover and precipitation may occur if only these plants are prevalent. On the other hand, other plant types that are more drought-resistant and more resilient to minor changes in precipitation are considered in their model. If both plant types interact with the climate simultaneously, then plant diversity tends to attenuate the instability of the interaction between climate and vegetation. The system shows strong fluctuations, as can be seen from Kroepelin's data, but abrupt changes do not occur anymore.

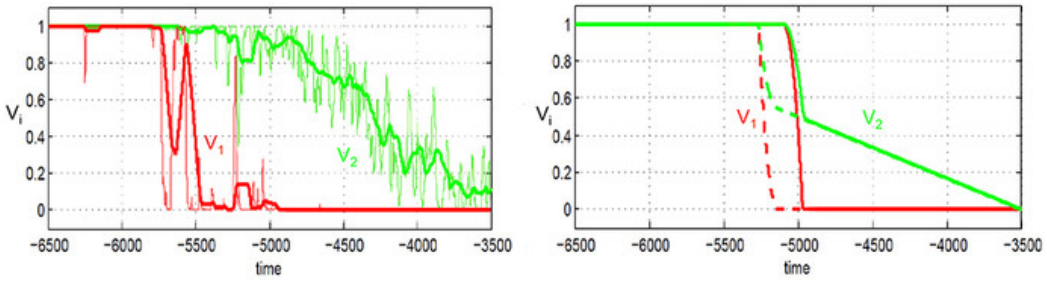

Figure: Transient dynamics of a mixture of sensitive and insensitive plant types interacting with climate. Red lines depict a plant type which exhibits a high sensitivity to changes in precipitation such that abrupt changes in areal coverage may occur, if this plant type interacts with climate alone. Green lines show a plant type which is rather insensitive to changes in precipitations. This plant would not reveal any abrupt change when interacting with climate alone. However when both plant types together interact with climate, then abrupt changes do not occur. Instead the areal coverage of each plant type show strong fluctucations. Thin lines show annual mean values, thick lines, a 100-year running mean.

Interestingly enough, the "vegetation-climate" system also stabilizes if sensitive plant types, distinguishing themselves only by different thresholds are mixed in the model. Some plant types are sensitive to minor changes in precipitation in humid climate while others can survive on a limited amount of water, but react rapidly with the onset of aridity. However, this system is only seemingly stable and may hide instability: If some plant types were removed or introduced, an abrupt shift in vegetation cover and precipitation may occur as a surprise.

The present study provides a possible explanation for Kroepelin´s reconstructed shifts in vegetation and climate in northern Africa several thousand years ago and focusses on the tropical ecosystems in semi-arid climate. The principle that plant diversity can affect the stability of climate-vegetation interaction may generally apply.

Paper:

Claussen, M., S. Bathiany, V. Brovkin, and T. Kleinen (2013) Simulated climate-vegetation interaction in semi-arid regions affected by plant diversity. Nature Geoscience, doi: 10.1038/ngeo1962.

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