The Ergodic Principle

The ergodic principle states that the temporal average state of a system equals the average of singles states of an ensemble of the system. Formulated to describe the physics of an ideal gas (Boltzmann, 1871), it is also applied in the growth series concept of whole ecosystems.

Hysteresis

Hysteresis on the other hand is the observable contrary of the ergodic principle, i.e. that the current state of a system strictly depends on the individual temporal development steps – or – that individual history is unequivocally important.

Methods

The Biogeochemistry model Biome-BGC 4.1.2 (Thornton et al, 2002) with dynamic mortality (Pietsch and Hasenauer, 2006) parameterized for the Congo Basin (Gautam, 2012) was used, for long term simulation of forest dynamics. Attractors of model behaviour were reconstructed using Poincaré sections mapped onto themselves (Pietsch and Hasenauer, 2005). Embedding delay was 50 years.

Simulation Results

Attractors of aboveground stem C content reconstructed from 100.000 simulation years exhibited limit cycles. In case of a stable limit cycle the ergodic principle holds and the growth series concept remains valid. In case of instability, with frequent patch level forest dieback events, the ergodic principle does not hold!

Analysis

Artificial climate with known interannual variation in precipitation ranging from 10 % to 40 % (standard deviation) was used to simulate forest establishment on non forest sites (spinup, black triangles). For 37.5% interannual variation in precipitation forest may not establish below 1250 mm mean annual precipitation. Stable limit cycles do not occur below 2800 mm mean annual precipitation.

The same climate was used to simulate the effects of climate change on a stable forest established at 3500mm mean annual precipitation (spindown, open triangles). The pathway of transition from stable limit cycles to 100% forest dieback differs from the spinup and hysteresis is evident! The mean of the transition phase is equal, but the length of the transition phase differs.

REFERENCES


ACKNOWLEDGEMENTS

This research was funded by the Austrian Science Fund (FWF) P-20660-B16, Biodiversa CoForTips and IKI – REDD-PAC.