# Monitoring Forest Stability

## Background

Degradation of forests has serious implications in terms of biodiversity, productivity and carbon storage. Due to the close canopy that most forests have, applying classical remote sensing based on visible- and near infrared broad band sensors does not give satisfactory results to detect degradation. At the same time, this is the kind of satellite imagery of which we have built up data archives containing over several decades of observations.

## Non Linearity

New developments into ecosystem dynamics and their responses to stress might contain a key to use these archives. Several recent studies have indicated that many ecosystems, including forests, display non-linear dynamics. This means that a forest can show (apparently) very little change when stress conditions increase (e.g., increasing drought), although the inherent conditions do deteriorate (Figure 1). When these conditions pass a critical threshold, a sudden and often irreversible change occurs (Forest collapse). By now it is clear that these apparent stable systems actually do provide information on whether they are likely to tip. This information is hidden in the natural fluctuations that occur in ecosystems. These fluctuations slow down (so called "critical slowing down") when the system is likely to change. There are several relevant statistical indicators that can be derived from time series of these ecosystems to determine the imminent collapse of a forest, and with that it's degradation status.

## Use of Remote Sensing

These fluctuations can be reconstructed and analyzed using satellite time series. This requires that the revisit time is frequent enough, and the sensors capture the correct forest parameters. Normalized Difference Vegetation Index is a usual suspect in this regard (Figure 2). But many other indices could be tested for their appropriateness. Potential remote sensing sources could be NOAA-AVHRR, MODIS, SPOT or MeteoSat data and many others (Figure 3).

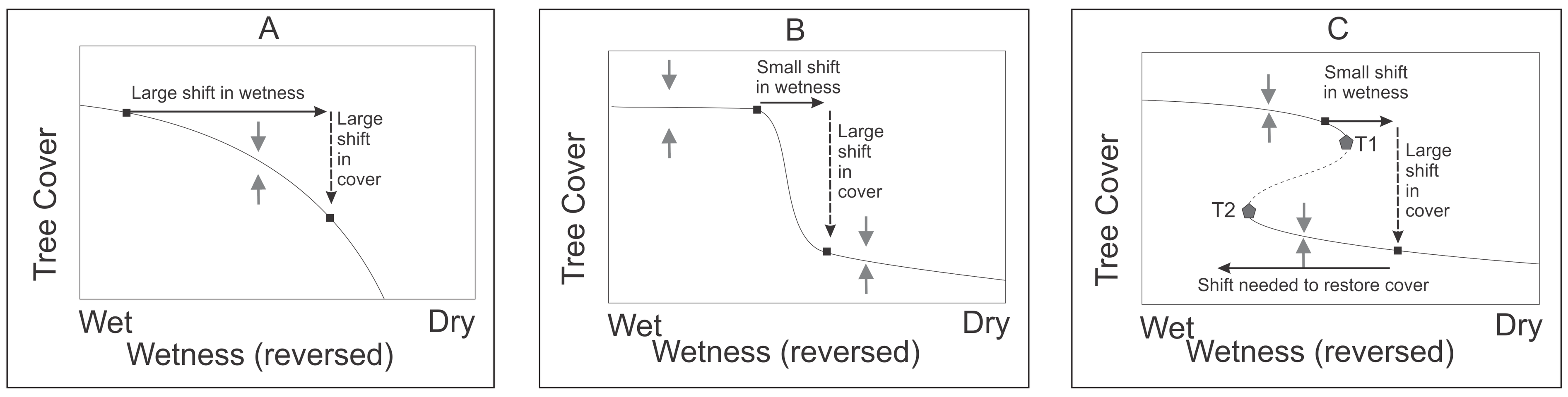


Figure 1: Graphical representation of non-linear dynamics. Note that wetness is reversed (it declines from left to right). Solid lines represent stable equilibria, and dotted lines represent unstable equilibria. The grey arrows indicate the direction the forest system will move to after a small perturbation. In linear systems (A) a large change in wetness can lead to a large change in tree cover. In non-linear systems (B) a small change can lead to a large change in tree cover. However, when the wetness is reversed, tree cover is also reversed. When collapses exists (T1 and T2 in C) a small change in wetness can cause a large change in tree cover, but once the system is changed, a larger reversal in wetness is needed to restore the tree cover, called hysteresis. Besides, a perturbation can also "push" the system over a threshold towards the other equilibrium under certain conditions (indicated with the grey area in C).

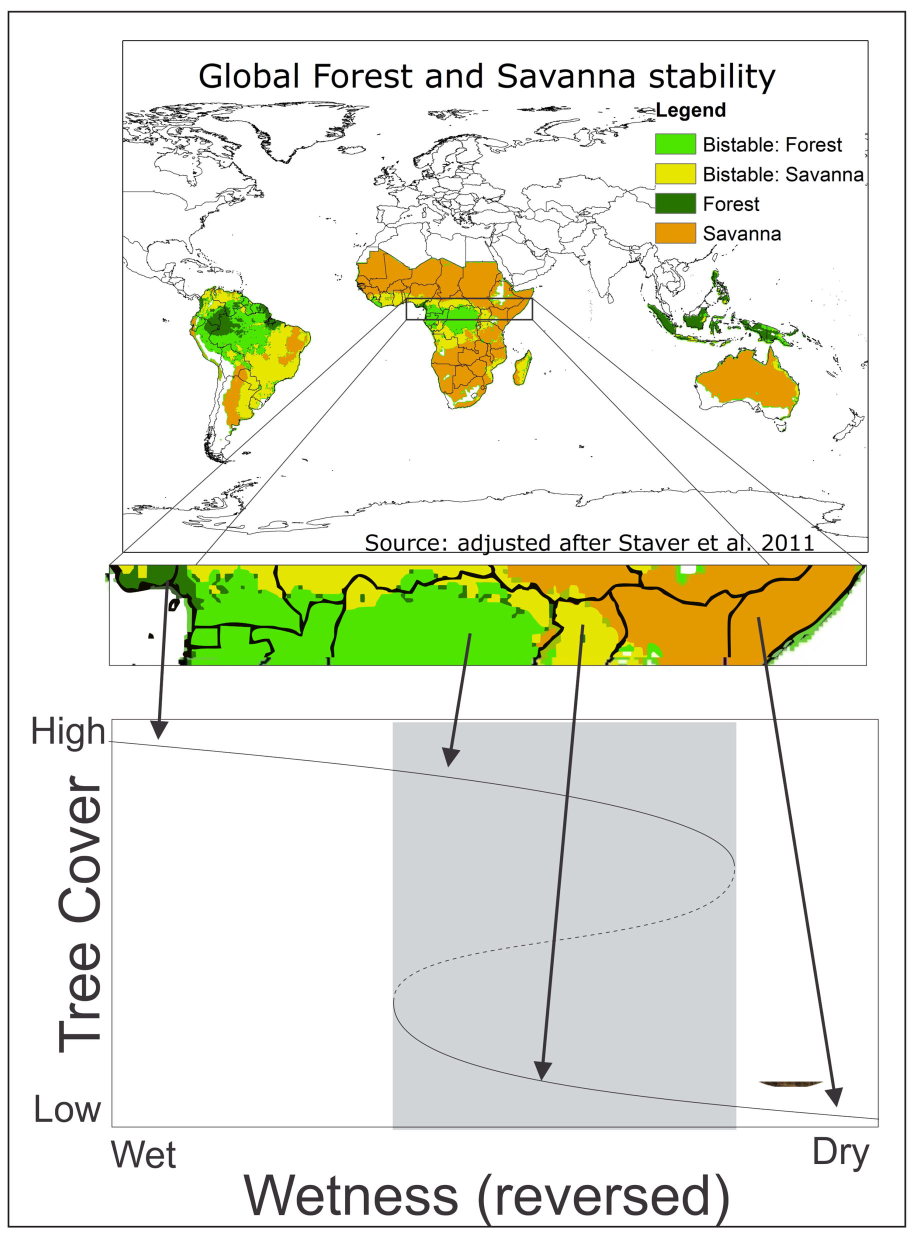


Fig. 4: Tipping points in the savanna-forest system. The arrows point to examples of locations and their probable location along the wetness gradient.

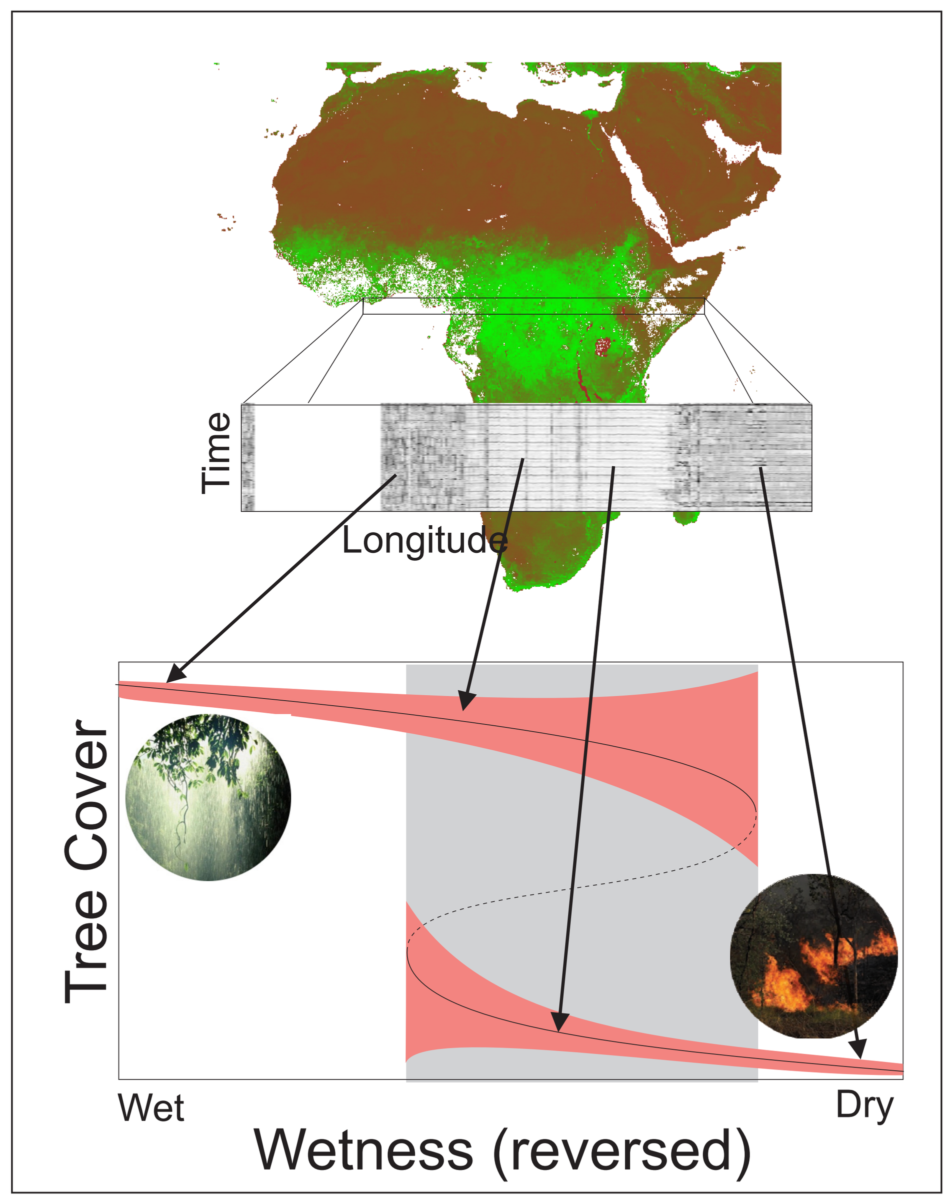


Fig. 5: Autocorrelation at-lag-1 as a potential early warning indicator along a transect across Africa. The map of the continent shows a 10 day maximum NDVI image from SPOT vegetation in 2012. Green values indicate high values and brown indicates low values of NDVI. The white areas are missing data due to clouds. The bar in the middle represents a time series over the transect of autocorrelation at-lag-1 for NDVI values of the last 13 years. White colours indicate high autocorrelation, black colours indicate low autocorrelation. Close to tipping points, autocorrelation is expected to rise, indicated by the red area around the equilibrium in the lower graph, and the increased "whiteness" in the time series data.

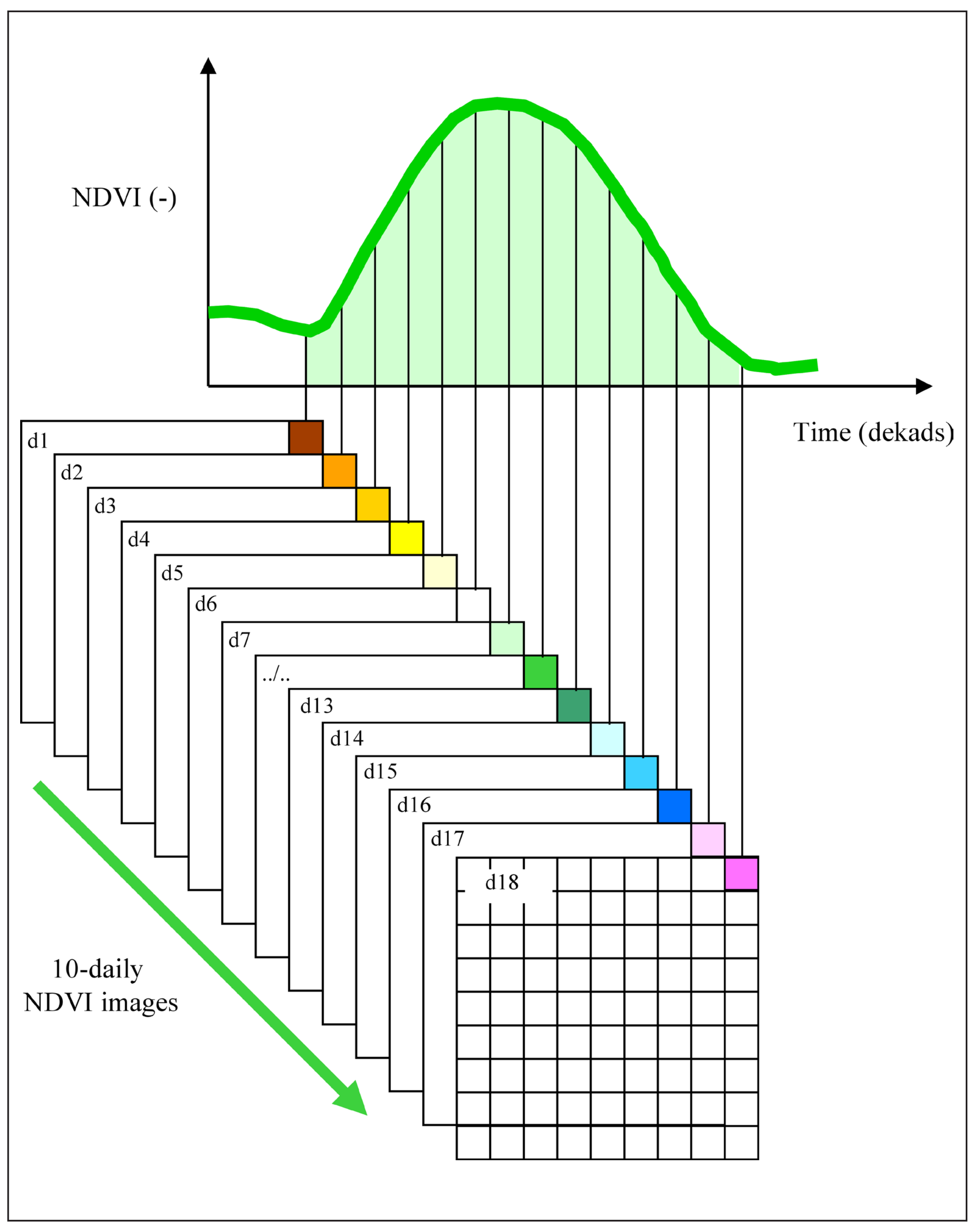


Fig. 2: Time series of NDVI might be suitable to detect forest degradation.

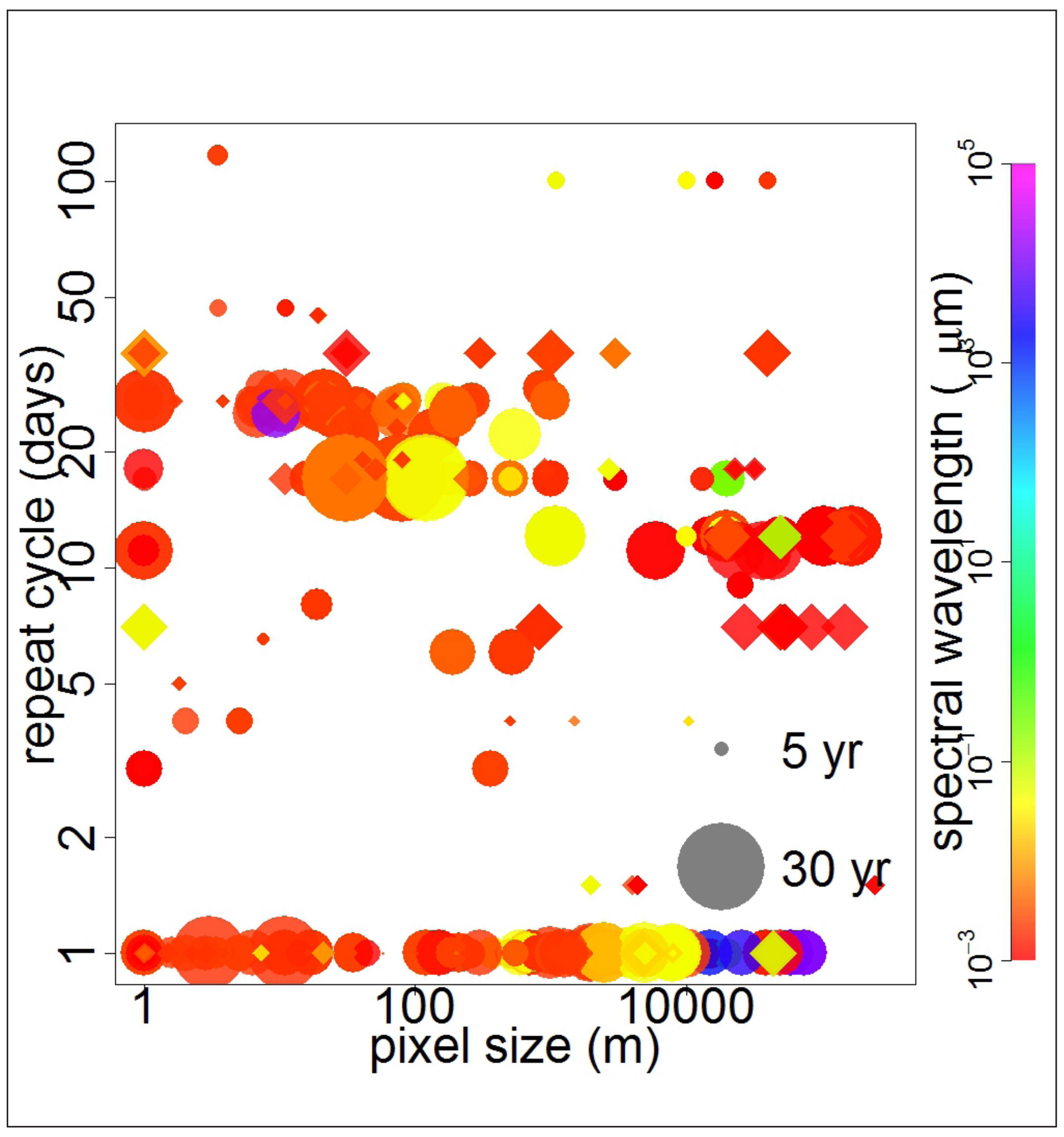


Fig. 3: Overview of the spatial and temporal domain of currently active (circles) and ended (squares) satellite borne sensors, their time of service (size) and the electromagnetic frequency they cover (colour).

## Possible topics

* Compare various stability indicators across landscapes (Figure 4)
* Sensitivity of these indicators over time
* Case studies in Kalimantan (Indonesia), Pleistocene savanna remnants (Gabon), Collapsed forests in Western Australia or other relevant cases that a student can come with.

## Requirements

* Programming skills in R or IDL
* Statistical aptitude
* Knowledge of vegetation indices
* Affinity with plant ecology
* Good RS and GIS skills


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