Case study: Monitoring population pressure in low resilience areas

The Sahel, Africa - a complex human-environment system

Background

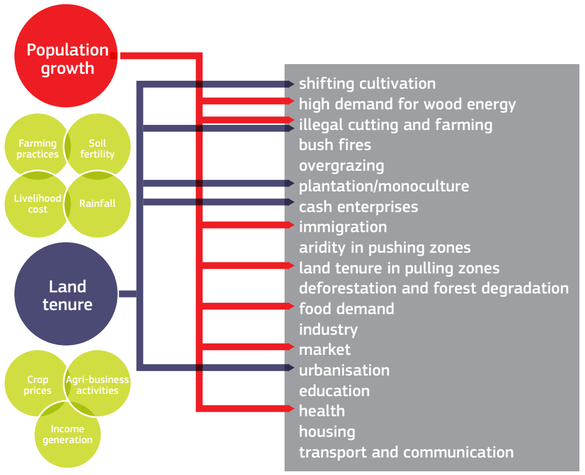
In the past 50 years, anthropogenic influence and climatic variability have caused major environmental changes in the semi-arid Sahelian zone, and the desertification/degradation of arable lands has been of major concern for livelihoods and food security. In the wake of the major droughts in the early 1970s and 1980s, there was a significant increase in scientific efforts to provide an empirically supported understanding of both the climatic and anthropogenic factors involved.

Despite decades of intensive research on human-environmental systems in the Sahel, there is no overall consensus about the severity of land degradation. A range of conflicting observations and interpretations of the environmental conditions in the region and the direction of changes can be found in the literature[1].

Drivers of change

The example from Burkina Faso, shown below, illustrates the main drivers of environmental change[2]. The most important drivers are population growth and land tenure. The most common global change issues (see page 190) over the whole of the Sahel, shown at the bottom of the page, are indeed population change and low income levels.

Examples of causal relationships are displayed using connecting arrows. The interrelationship between drivers and their implications are complex, and all impacts of these drivers have feedbacks on the drivers themselves. Each of the drivers could be considered an opportunity for land restoration and livelihood improvement.

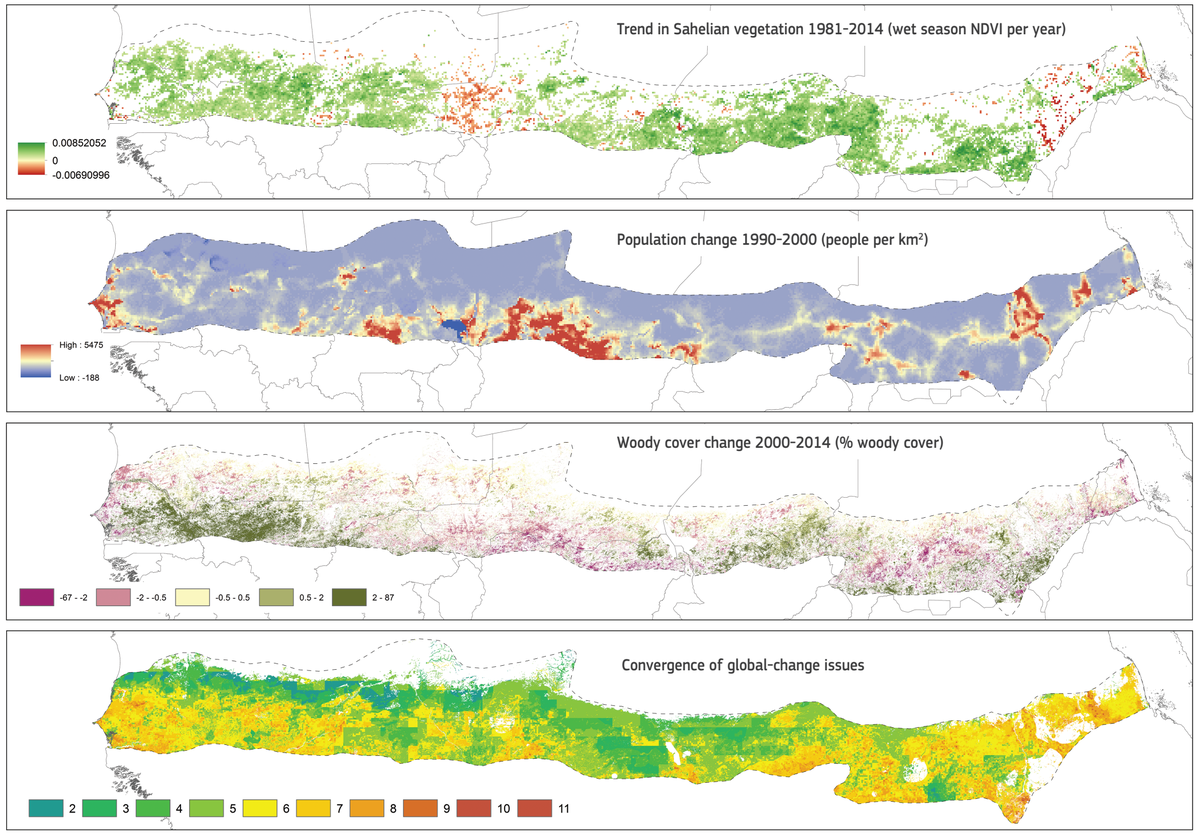


Drivers of land change in Cassou, Southern Burkina Faso.
Source: derived from Ouedraogo, I. et al., 2015[2].

Characterising changes over recent decades

Analyses of Earth-observation (EO) data over the Sahel area show positive trends in rainfall and in vegetation greenness (obtained by using Normalized Difference Vegetation Index (NDVI) time series) over recent decades. This phenomenon occurs over the majority of the Sahel region and is known as the 'regreening' of the Sahel — see top map on the next page[3]. This has been interpreted as an increase in vegetation productivity and contradicts prevailing narratives of a vicious cycle of widespread degradation caused by human overuse as a function of a rapidly increasing population and climate change. The regreening is widely accepted to be driven by an increase in rainfall. However, areas of decreasing NDVI, for example in Niger and Sudan, indicate that the regreening is not uniform across the entire Sahel.

Whereas the increase in NDVI, as observed from EO data, can be confirmed by ground observations of vegetation productivity, long-term assessments of biodiversity at finer spatial scales highlight a negative trend in species diversity[4]. New research also suggests that a considerable part of the observed greening in areas of low population density stems from an increase in woody vegetation rather than the herbaceous vegetation that traditionally supports livestock foraging[5]. Overall it remains unclear whether the observed positive NDVI trends are associated with environmental improvements with positive effects on people's livelihoods[6].



Various aspects of land-change issues in the Sahel region.
Sources:
Based on Brandt, M. et al., 2014[4] and 2015[5];
bottom graph: WAD3-JRC, 2018.

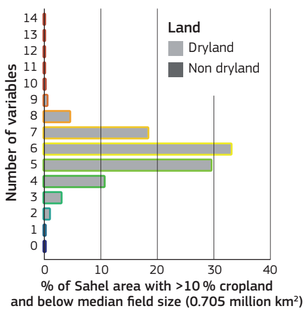
Convergence of evidence

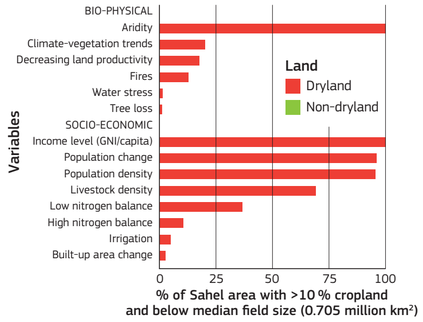
Throughout the Sahel region smallholder cropland is prevalent and cultivation is mostly done on fields smaller than 2 ha.

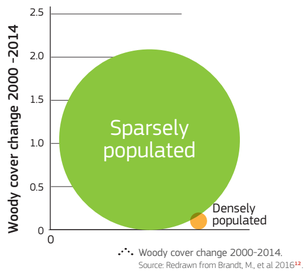
Maps on the following pages show the coincident global change issues (GCIs) in the Sahel region and the graphs show the occurrence of GCIs within the smallholder cropland (see page 144 and after).

Over the larger part of the smallholder cropland (82%), all in dryland, five to seven GCIs coincide. All these smallholder communities are characterised by low per capita income. In 90% of this area, population change is high as are population densities. Being mostly small subsistence based farms, livestock densities are also high in 70% of the area. 30% of this smallholder cropland is nutrient deficient and only 5% is irrigated. Drought conditions have impacted on 20% of the area, and land productivity has seen a persistent decline in 18% of the area. This is probably lower than expected, but is still slightly higher than the average of 14% of global cropland (see pages 148 and 152). Places where six or seven GCIs coincide and a decline in land productivity is observed may be of concern.

Landscape of Sahel.
Source: Daniel Tiveau/CIFOR. Flickr.com





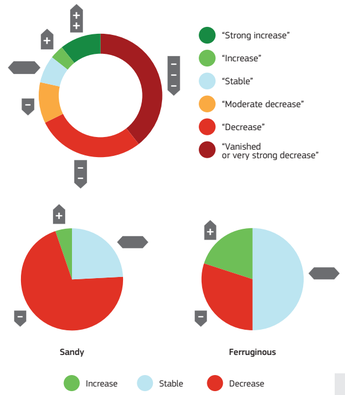


Woody cover change 2000-2014.
Source: Redrawn from Brandt, M., et al. 2016[13].

Greening in sparsely population is linked with increase in the Woody vegetation. Kite arial photograph in the Fakara region of Niger.
Source: Gérard Bruno and Delfosse Philippe, ICRISAT.

Loss in biodiversity

Local population perception suggests a general loss in woody species diversity in Mali.

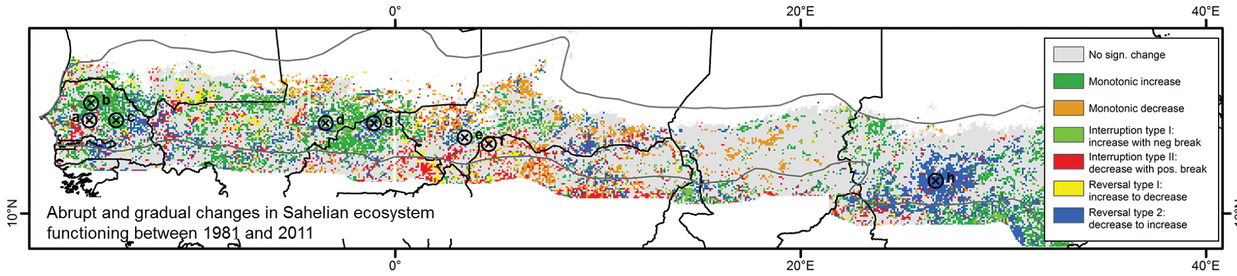


Botanic inventories 1983 and 2013 confirm a loss in woody species, especially in sandy areas in Senegal[5].
Source:
Top graph: based on Brandt, M. et al., 2014[4].
Bottom graphs: based on Brandt, M. et al., 2015[5].

Case study: Monitoring population pressure in low resilience areas (cont'd)

The Sahel, Africa - a complex human-environment system (cont'd)

Human- and climate-induced desertification in the Sahel has been a major concern during recent decades. Conflicting findings are found in the literature as regards whether or not desertification has been a general feature of the Sahel. Partly, this relates to differences and inconsistencies in the definition of concepts and to disciplinary, strategic, methodological and sampling differences[10]. It is therefore of great importance to monitor land dynamics in a transparent way by combining long-term information from EO data of different levels of spatial detail with ground observations. Currently, EO time series show a positive trend in vegetation greenness across the Sahel without indications of widespread desertification. However, an improved understanding of the changes in ecosystem composition and functioning behind this greening is needed. Recent studies suggest that the trend can at least partially be attributed to the expansion of agricultural areas, a considerable proportion of which is irrigated[13]. How much of the increasing productivity is sustainable, or will be absorbed by rapid population growth, is difficult to decide. However, it is clear that the pressure on available land, but also on protected areas will continue to increase. Currently, the relationships between changes in ecosystem services (including livestock forage, fuelwood and biodiversity) and livelihoods/land use remain unclear in the Sahel, making conclusions on the environmental and societal benefit premature.



Abrupt and gradual changes in Sahelian ecosystem functioning between 1981 and 2011.
Based on: Horion, S. et al., 2016[7].

The mapping and understanding of environmental change is a difficult endeavour in the highly complex human-environment system of the Sahel. More than any place else in the world, local drivers of changes (e.g. shifting cultivation, fires, soil erosion, misuse of natural resources) are superimposed upon global drivers (e.g. climate change, drought), which in turn may lead to gradual and/or abrupt change in ecosystem functioning. All these result, when looking at the entire Sahel, in a patchwork of diverse change scenarios.

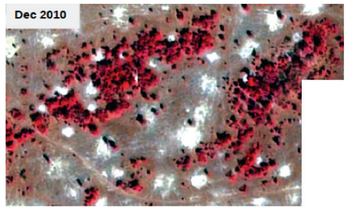
A map of ecosystem-change types that highlights the possible occurrence of an abrupt change in ecosystem functioning (method based on [7]) shows categories of change in the functioning of the Sahel's ecosystem. The map shows changes and abrupt shifts in ecosystem functioning using rain-use efficiency (RUE, i.e. the ratio between the above ground biomass and total rainfall). The map captures a number of details regarding the environmental changes that have occurred over the period from 1981 to 2011, ranging from monotonic change (positive or negative) over interrupted trends (two periods of similar trends separated by an abrupt shift) to reverse trends in ecosystem functioning (two periods of distinct different trends separated by an abrupt shift).

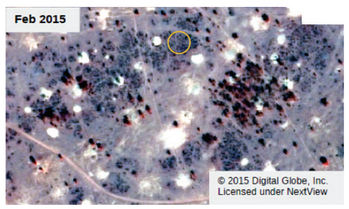
The diverse nature of the changes in the Sahelian ecosystems is illustrated by photo pairs, high-resolution satellite images, interview results and a drought diagram. The approximate location of the illustrated cases is reported on the Sahel scale change map.

Changes in vegetation composition

Drought-induced tree and shrub dying

Several years of low rainfall have caused a recent mass dying of shrubs in Senegal.

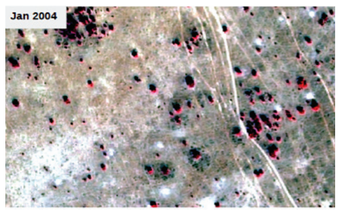


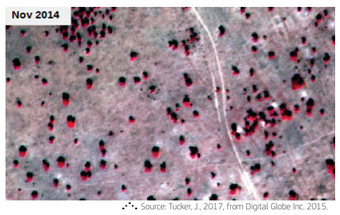


Source: Tucker, J., 2017, from Digital Globe Inc. 2015.
(for location, see yellow circle above)

Spreading of robust species

Balanites aegyptiaca and *Combretum glutinosum* spread in the sparsely populated rangelands of Senegal.

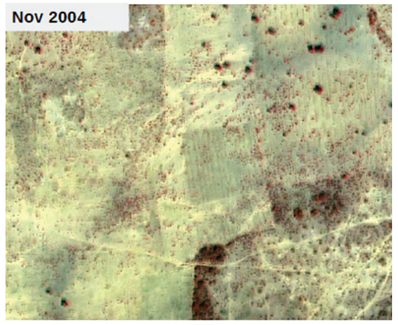


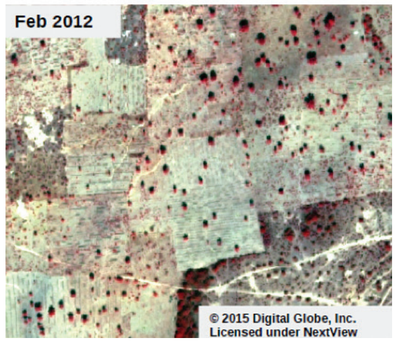


Source: Tucker, J., 2017, from Digital Globe Inc. 2015.

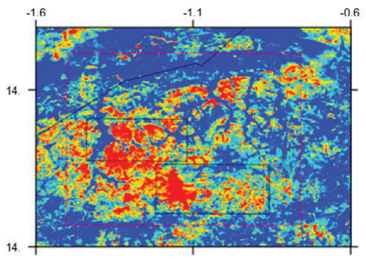
Agroforesty

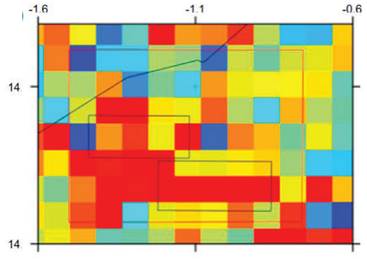
The increasing amount of woody cover in agricultural fields in northern Nigeria reflects the protective management of parkland trees by farmers[8].





Source: Tucker, J., 2017, from Digital Globe Inc. 2015.





Importance of spatial scale in land degradation monitoring

Comparison of trend analysis results derived from medium resolution (250m left) and low resolution (8km right) products in northern Burkina Faso. The 25m resolution product reveals that land degradation was limited to plateau areas (in red), whereas valley areas show improved conditions (in blue), thereby providing additional insights into mechanisms and drivers of change.
Source: Rasmussen, K., 2014[10]

Land degradation

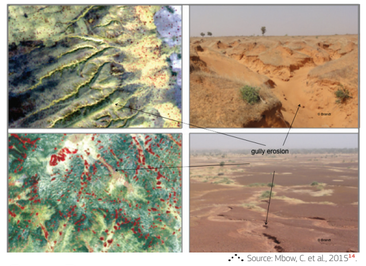
Livestock caused soil degradation in Senegal's pastoral zone

Source: Tappan, G. and Brandt, M.

Land and soil degradation

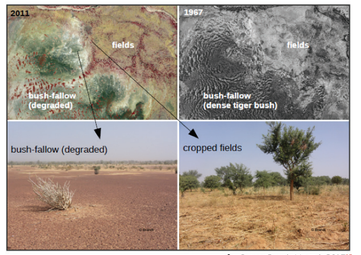
Extensive removal of trees in Mali's rangelands, causing soil erosion (Case A). Whereas trees in farmer's fields are protected (Case B), the surrounding rangeland is highly degraded, and dense tiger bush from 1967 is transformed into stony desert in 2011[9].

Case A



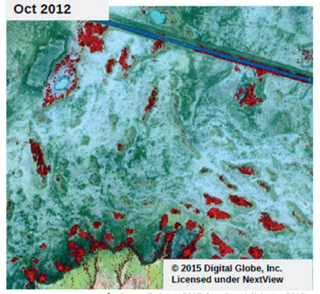
Source: Mbow, C. et al., 2015[14].

Case B



Source: Brandt, M. et al., 2017[15].

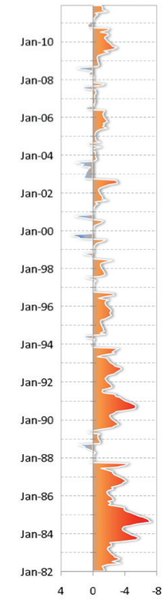
Overuse of woody resources leads to soil degradation[8]



Source: Tucker, J., 2017, from Digital Globe Inc. 2015.

History of drought

There has been an alleviation of the drought constraint in Sudan since the 1980s and early 1990s. However, recurrent droughts remain a threat for the environment and the population, notably due to the unstable political situation[11].



Drought indicator.
Source: Van der Schrier, 2013[11].

Affected population (in billions).
Source: Emdat, 2016[12].