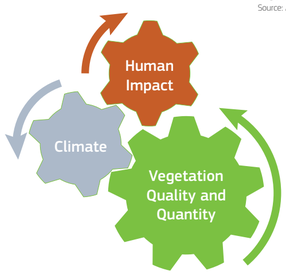
Case studies: Introduction

Case studies on land degradation processes

Angola.
Source: Achim Roeder.



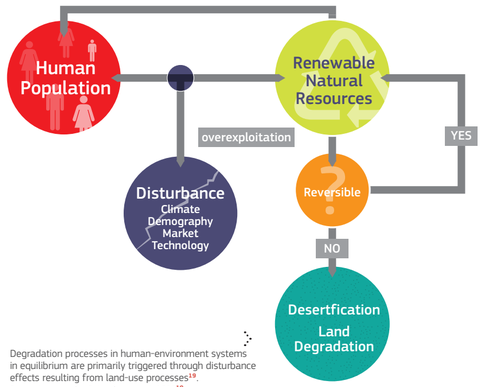
China loesplateau.
Source: Cherlet, M.

Piura, Peru.
Source: Morales, C.

The linkage of natural and human factors has been basis of a number of conceptual frameworks of land degradation[1, 3]. Beyond helping to identify drivers and consequences of land change processes, these frameworks provide the foundation for designing protective measures or alternative land use management concepts, highlight how land use is a key driver of global environmental change, and emphasise the role that human societies have in determining the long-term productivity of land.

Underlying Concepts of Land Degradation

The underlying mechanisms of land degradation processes have been studied in a multitude of case studies, from local to regional scales[4]. Based on an analysis of more than 130 case studies, Geist and Lambin[5] identified four major categories of causal agents: (i) increased aridity; (ii) agricultural impacts (including livestock production and crop production); (iii) wood extraction; and (iv) infrastructure extension, including irrigation, roads, settlements, and extractive industries (e.g., mining, oil, gas). Of the 130 case studies, (i) only 10% were driven by a single cause; (ii) about 30% were attributable to increased aridity and agricultural impacts; and (iii) the remaining cases were combinations of three or all of the causal factors. These results highlight the complexity of land degradation, the necessity for integrative biophysical and socio-economic approaches to study the problem, and why there is no unique analytical framework for addressing land degradation at a global scale.



Degradation processes in human-environment systems in equilibrium are primarily triggered through disturbance effects resulting from land-use processes[19].
Source: Adapted after Puigdefábregas, J., 1998[19]

Even when there are similar causal agents, manifestations of land degradation at the local scale is a function of local biophysical and socio-economic factors. Nevertheless, at a very broad scale, the 'syndrome' approach has been used to model and describe bundles of interactive processes and symptoms of land degradation that appear repeatedly and in many places in typical combinations and patterns[6]. A syndrome of land change thus constitutes the particular combination of specific causal conditions, involving both approximate and underlying factors, and rates of change, i.e., slow and fast causative variables[1]. This implies that, for any given human-environment system, a limited number of causes are essential to predict the general trend in land use.

Five syndromes have been linked to dryland/land degradation processes: the Sahel, Overexploitation, Rural Exodus, Dust Bowl, and Aral Sea[7]. Syndrome analysis relies on a specific semi-qualitative modelling methodology, which brings together elements from complex systems theory, fuzzy logic and expert-judgement evaluations to design maps of the global extension of these syndromes[8, 9]. Similarly, more than 30 high-resolution datasets on land-use intensity, environmental conditions and socio-economic indicators have been used to identify and map twelve archetypes of land systems[10].

Convergence of Evidence

The "convergence of evidence" mapping in this atlas (see page 144) builds on the same principles. The global change issues (GCIs) address the intricate linkage of natural factors (the biophysical GCIs) and human action (socio-economic GCIs) needed to understand land degradation dynamics. Without being based on modelled prior assumptions, it thus illustrates how and where important GCIs currently coincide and exert pressure on land resources, which may in fact lead to land degradation. However, definite conclusions about actual states and processes require contextual knowledge and additional information on local or regional scales.

Hence, global maps describe the disposition of a region towards specific syndromes or archetypes, or they provide suggestive rather than diagnostic conclusions. Only a few studies have demonstrated how conceptual models may be used to produce geographically-explicit assessments of land condition on regional scale[11-13].

Trade-Offs in Land Use Change

While there is agreement that land degradation is intrinsically linked to land use practises[14,15], the approaches how to adequately measure and evaluate their impact on ecosystem level are diverse. The concept of ecosystem goods and services, first used in the late 1960s, was of central importance to the Millennium Ecosystem Assessment and its treatment of desertification and land degradation[2]. Goods and services consist of flows of materials, energy, and information from natural capital stocks, which combine with manufactured and human capital services to produce human welfare[16], while ecosystem functions refer to the habitat, biological or system properties or processes.

Land use practices have not only affected global and regional climate due to the emission of relevant greenhouse gases, but also by altering energy fluxes and water balance[17]. Hence, land use and land change directly impact ecosystem services. Land use and land change and their associated alterations of habitat structure -- as well as release of substances like fertilisers, pesticides, and air pollutants -- impact ecosystems goods and services, amongst them biodiversity, substance flows, water and air quality, soil properties and disease vectors, and ultimately human well-being[18-20].

Management decisions always involve trade-offs among ecosystem services, which must be balanced with respect to societal objectives, i.e. to reduce negative environmental impacts of land use while maintaining economic and social benefits[21, 22]. Although quantifying the levels and values of these services has proven difficult, a scientifically based assessment of these trade-offs is an essential prerequisite for decision-making[18].

Ecosystem stewardship has been proposed as an action-oriented framework to foster the social–ecological sustainability under rapidly changing conditions. Three strategies underlying ecosystem stewardship are: (i) reducing the magnitude of, and exposure and sensitivity to, known stresses; (ii) focusing on proactive policies that shape change; and (iii) avoiding or escaping unsustainable social–ecological traps[22]. All social–ecological systems are vulnerable to change but have the ability to adapt and are resilient, all of which can sustain ecosystem services and human well-being via ecosystem stewardship[22]. Convergence of evidence mapping of GCIs is solution oriented as it provides information on coinciding land stress factors that should be addressed to alleviate stress.

Earth Observation from Space

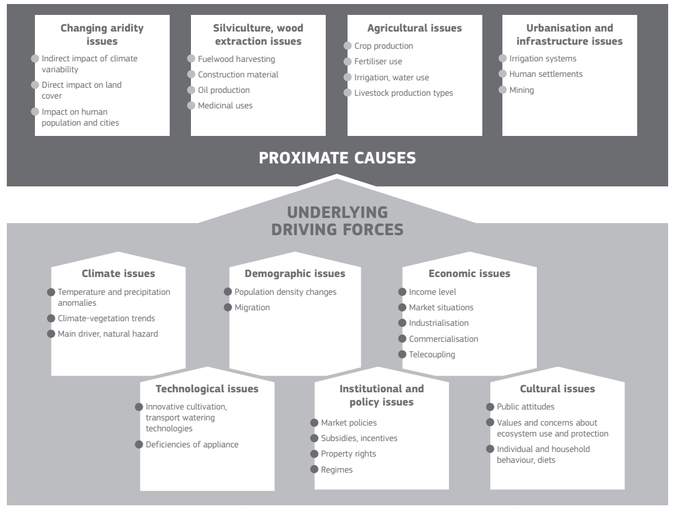
In conceptualising key aspects of land degradation and desertification as pathological processes of multi-annual land-cover dynamics it is almost mandatory to consider time spans on the scale of decades and to decouple changes on the long run from the impact of short-term fluctuations driven by seasonal pulses or single events.

Precise and unbiased information on drivers of land degradation, the extent of affected areas and their characteristics over extended periods of time, are important local aspects that are needed for designing mitigation strategies and for monitoring the efficiency of their implementation. However, access to relevant and continuous data is difficult and often limited. The availability of pertinent Earth observation (EO) data, collected since the 1970s by a multitude of satellite missions, has become increasingly important in compensating for such information gaps. Some of the available satellite data archives cover time spans of more than 30 years and provide open access. Importantly, several of the most relevant satellite missions are already projected into the next decades (e.g. the EU Copernicus EO programme, such that continuity of high-quality Earth observation data is assured. This continuity is an important prerequisite for tracing the high inter-annual variability of ecosystems and for distinguishing between the role of human actions and climate variability.

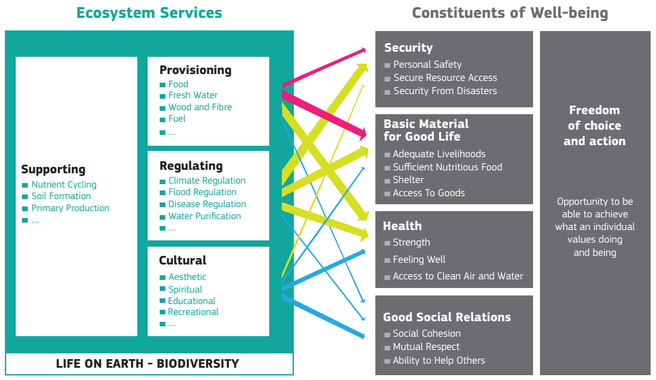
The reliability of EO derived indicators for changing land surface properties relevant to land degradation processes can be substantially improved when integrating remote sensing, ground-based observation and supportive geo-spatial data. Inferring type and magnitude of changes in conditions on-the-ground exclusively from the analysis of satellite datasets might be difficult, as it has been shown with respect to the observed "greening" of the Sahel region of Africa since 1990[23].

Selected Cases

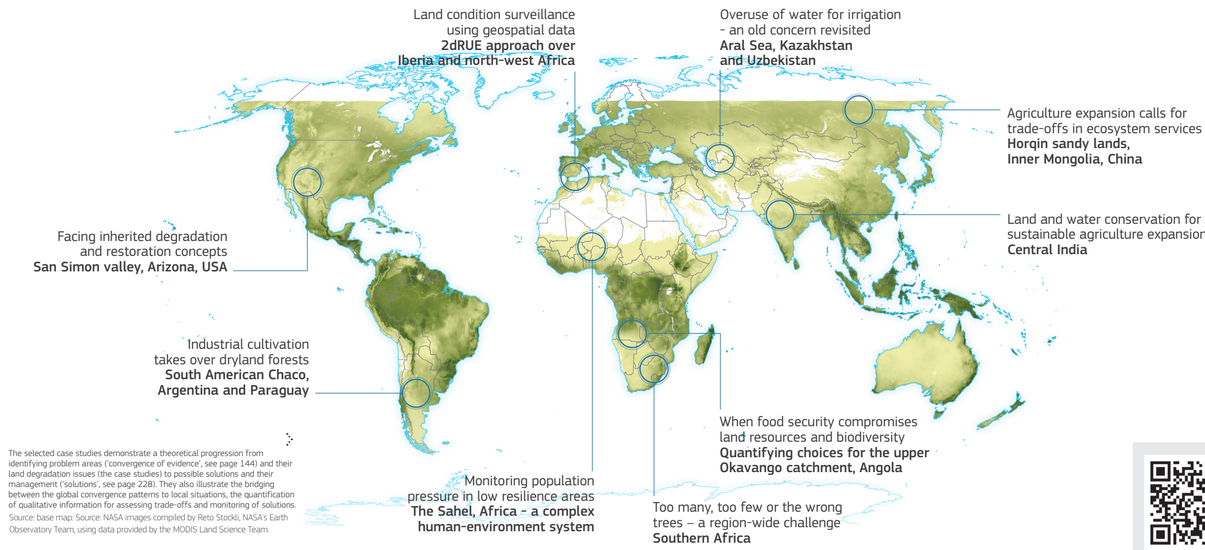
The case studies presented here demonstrate that human interaction and inadequate management of scarce resources especially in drylands are central components of the land degradation problem. Furthermore, they provide guidance into how best to harness the competence of humans to successfully mitigate the consequences and design pathways towards a more sustainable future (see page 228 on Solutions). While illustrating how these complex interactions play out in specific settings, case studies are also intended to suggest how difficult and often misleading it is to infer the type and magnitude of changes in conditions on the ground from the diagnostic analysis of global datasets alone. For example, considerable efforts have been spent to drawing general conclusions about the observed "greening" of the Sahel region of Africa since 1990. Increases in greenness, however, could be interpreted as positive in one setting (i.e, recovery of productive rangeland vegetation), but negative in another (i.e., invasion of undesirable plants into degrading rangelands). Although, the convergence of evidence approach copes with such possible differing situations and suggests areas of concern for further analysis, the case studies illustrate the viable need for local analysis to derive conclusions at a scale that is adapted to interventions and solutions. They also illustrate the essential and possible links with wider scale information to design sustainable land management strategies.



Causes of desertification. Six broad clusters of underlying driving forces (fundamental social or biophysical processes) underpin the proximate causes of desertification, which are immediate human or biophysical actions with a direct impact on land cover[1].
Source: Adapted from: Geist, H. and Lambin, E., 2004.



Consequences of ecosystem change for human well-being.
Source: Millennium ecosystem assessment, 2005[10]



The selected case studies demonstrate a theoretical progression from identifying problem areas ('convergence of evidence', see page 144) and their land degradation issues (the case studies) to possible solutions and their management ('solutions', see page 228). They also illustrate the bridging between the global convergence patterns to local situations, the quantification of qualitative information for assessing trade-offs and monitoring of solutions.
Source: base map: Source: NASA images compiled by Reto Stockli, NASA's Earth Observatory Team, using data provided by the MODIS Land Science Team.