Chapter 23
The Economics of Land and Soil Degradation-Toward an Assessment of the Costs of Inaction

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Abstract Recarbonization of the biosphere is a desirable objective in view of climate change and greenhouse gas (GHG) emission problems. Yet it is confronted with at least two challenges. First, there are increased trade-offs between biomass uses in the emerging bio-economy (e.g., food-fuel competition). This impacts the role of soils for carbon (C) sequestration. These trade-offs are to be reconciled by accelerated knowledge and innovation intensive approaches in a “Green Growth” strategy. Secondly, the degradation of the earth’s lands and soils is increasingly recognized as a global problem as extent and impacts are increasingly affecting and affected by environmental and social vulnerability as well as climate change. Both of these challenges cannot be met without a comprehensive assessment of the land and soil degradation issue. A review of the state of the art on the quantification and mapping of degradation, its effects and driving forces, and its economic valuation is provided here. Further, a framework for a global assessment of costs of Action versus Inaction against degradation is proposed.

Keywords Land and soil degradation • Economic valuation • State of knowledge • Methodology

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Abbreviations

C	carbon
CO_2	carbon dioxide
the CAVI approach	costs induced by continued degradation
BöR	German Bio-economy Council
GLADA	Global Land Degradation Assessment
GLADIS	Global Land Degradation Information System
GHG	greenhouse gas
LSD	land and soil degradation
LADA	Land Degradation Assessment in the Drylands
MAC	marginal abatement cost curve
MA	Millennium Ecosystem Assessment
NPP	net primary production
NDVI	Normalized Difference Vegetation Index
RUE	rainfall use efficiency
RESTREND	residual trend analysis
SOC	soil organic carbon
SOM	soil organic matter
SA	South Asia
SSA	Sub-Saharan Africa
SLWM	sustainable land and water management
TEEB	The Economics of Ecosystems and Biodiversity
UNCCD	United Nations Convention to Combat Desertification

23.1 Introduction

The bio-economy is defined as the cross-sectoral element of the economy which produces, processes or uses any type of biological resources, as well as the services related to this element (BöR 2011). The bio-economy, thus, covers very different types of activities, spanning from the traditional production of raw biological material (e.g., traditional forestry or agriculture) to frontier industries in the field of biotechnology. The existence of the bio-economy is a fact. Human development has been based on the use of biological resources from the beginning, and humankind has continuously developed and benefited from innovations in the way that it can consume these biological resources (BöR 2011).

As the demand for biological resources increases – due to factors such as population growth, changes in consumption behavior, the globalization of the world economy, the development of new bio-based products, or the need to find substitutes to decrease the world's dependence on inorganic raw materials and fossil fuels in the energy, construction and industrial sectors – competition over the same biological resources will intensify. Further, the value chains of the different sectors of the (bio-) economy become increasingly intertwined and complex.

An example of this trend is the intensification of the link between agricultural and energy markets (von Braun 2008). Fuel prices drive food prices not only as input factors but also because of the competition between biofuels and food products over land resources and other inputs. This, compounded with a growing world consumption of food and a reduction in the growth rate of agricultural production, recently resulted in increased volatility of food prices, with devastating effects for the poorest (von Braun 2008).

As value chains for biomass are generally becoming longer and competition over biological intensifies, it is crucial that biomass-use efficiency along the value chains increases. Priorities must be set in the use of biomass. The German Bio-economy Council (BöR) notes that the material use of biomass creates higher values than its use in the energy sector (BöR 2011). Thus, the argument of the BöR is that value chains must be organized so that biomass can be used first in the material chain, and then in the energy chain. These priorities should also include by-products. For example, by-products of the agricultural production are increasingly used for and developed into feed, fertilizer and energy value chains (e.g., grain – oil mills, sugar – bio-ethanol). Even higher value product chains will be available for these by-products in the future as biotechnology will enable to break down and extract specific substances from biological material.

In several instances, the increase in competition over biological resources across the sectors of the bio-economy is aggravated by the fact that stocks are already being depleted at alarming rates. Such is the case for productive land and soils around the world. Arable land per capita worldwide decreased from 0.45 ha in 1950, to 0.35 ha in 1970 and 0.22 ha in 2000, and is projected to decrease to 0.15 ha by 2050 (Lal and Stewart 2010), with alarming trends between 1970 and 2005 in Sub-Saharan Africa (SSA) and South Asia (SA) (from 0.50 to 0.25 ha and 0.28–0.14 ha, respectively, Nkonya et al. 2011). As the competition over land resources intensifies, land prices are set to rise worldwide. The phenomenon of "land grabs", i.e., the (trans)national commercial acquisition of large tracks of land, has strongly increased in recent years and is further evidence of the increased competition over land resources.

Land degradation, in its most recent and inclusive definition, refers to the change in productivity and change in the provision of ecosystem services and the human benefits derived from them (Nkonya et al. 2011). This definition is very inclusive and covers issues such as desertification (i.e., land degradation in the drylands), soil degradation, as well as the degradation of what is produced from the soil (i.e., decrease in biomass production and cover, for example due to deforestation or other land cover changes, or decreased capacity of soil to sustain biomass growth). Soil degradation in this chapter is defined as a decrease in soil quality, e.g., a decrease in the amount of soil nutrients and in the concentration of soil micro-organisms, that is associated with a decrease in the ability of the soil to sustain agricultural production in particular, or to sustain other terrestrial ecosystem services and benefits. The role of soil micro-organisms for soil organic carbon (SOC) sequestration is one of the scientific frontiers, with scientists studying the impact of increased temperatures on their activity, amongst other things (Reichelt 2009).

The recarbonization of the biosphere is understood in this chapter as the process of drawing carbon (C) back out of the atmosphere and sequestering it on land, either in the vegetation cover or in soil. The assimilation of atmospheric carbon dioxide (CO_2) in plants is a result of the photosynthesis process. The capture of atmospheric CO_2 in soils is the result of several processes, both "natural" and "man-made". The natural process is the result of decomposition of dead plant biomass, which in turn enriches the soil with SOC and is an important source of nutrient for plant growth. Thus soils naturally store C. The combined total of C stored in soils worldwide is several times higher than that stored in biomass or in the atmosphere (Blaustein 2010). In that respect, soils hold the potential to contribute to the decrease in atmospheric CO_2 concentration if managed wisely, but also to aggravate atmospheric CO_2 levels if managed unwisely. As expressed by Lal (2004), SOC is an important resource in itself, the main component of soil organic matter (SOM), a major source of nutrient, and SOC levels ought to be restored as a mean to improve the productivity of soil and land resources. Careful management of the C cycle in agriculture may increase soil productivity and have the added benefit of decreasing atmospheric CO_2 concentrations. The conversion of grass lands into crop land has for example a negative impact on the atmospheric CO_2 balance, as grasslands trap much C into their root system, are less disturbed by management practices (i.e. tillage) and receive less fertilizer than croplands. The conversion of forests into crop land releases also C into the atmosphere due to enhanced oxidation of C-rich soil organic matter (SOM). Similarly, tillage farming practices or the burning of agricultural residues release SOC through oxidation. Man-made processes of C sequestration also exist and are currently developed, as alternative and supplementary solutions to reductions in greenhouse gas (GHG) emissions. They include the injection of CO_2 into the oceans or into underground geological formations, as well as trapping C in the form of various carbonated minerals.

Land and soil degradation are caused by two types of processes, i.e., processes which are typically man-made, and natural processes over which humans have little or no control. Their effects, however, can in many cases be mitigated by human interventions. Causes of land and soil degradation are reviewed in more detail in a later section. The emphasis at this stage of the paper is on the existence of a link between land and soil degradation (LSD) and human actions. These actions, or lack thereof, are the enactments of choices made by land users (defined broadly, from farmers to national institutions), individually or collectively. These choices are usually the results of decision-making based on the information at the disposal of the land users and on the set of rules administering land use and management. These conditions which frame the decision-making process are referred to as "institutions" and are broadly defined as "the rules of the game" under which actors form their decisions. Similarly to other cases of depletive natural resource uses, it is then assumed that land use decisions leading to LSD are the consequences of a rational decision from a single land user's perspective given the set of institutions.

If the degradation of land and soil resources is sub-optimal from a societal point of view (i.e., not the single user's view but society as whole including future land users), it is likely that the land user's decisions are ignoring impacts of his/her decisions on other (potentially future) members of the society. Economists refer to this as the externalities caused by the present exploitation of the land resources. A typical externality mentioned in this context is the siltation of water ways caused by the erosion of agricultural land. The externality can also be imposed on land users of the future. The current land user is depleting the productive capacity of the land in a way that is rational from his/her perspective, but not from an intergenerational one. In this sense, land and soil quality are public goods from a societal and multigenerational perspective, and there are no incentives for the current land user to conserve the productive capacity of the land for the future. Institutional arrangements, such as national laws or market interactions, can influence and modify the incentive structures affecting land use and management. The role of policy makers is then to ensure that these structures deliver the socially desirable set of land use decisions, including soil and land conservation actions. From an economic standpoint, it is crucial that these actions meet the requirements of effectiveness and cost efficiency, in order to guarantee their economic sustainability. The recarbonization of the soils is one solution envisioned to the issues of soil degradation and climate change. Thus, it is important that recarbonization is evaluated along other options, technical as well as institutional (i.e., influencing the way land users form their decisions, such as policies aiming at decreasing CO_2 emissions), according to the criteria of effectiveness (i.e., what results can be achieved in terms of soil improvement and climate control) and efficiency (i.e., at what costs can these achievements be attained).

23.2 Land and Soil Degradation in Economics

A change in LSD matters because of its impacts on the benefits that people derive from the use of the land, soils and services they can provide. Many of these benefits are not directly observable or quantifiable through market interactions, as markets for many environmental goods and services do not exist. Hence, as a first step for the evaluation of LSD it is important to catalogue and evaluate all the ecosystem services that un-degraded lands and soils provide. All types of terrestrial ecosystems (and their services and the benefits they provide to humans) should be covered in a comprehensive global economic assessment of LSD. This includes anthropogenic ecosystems – i.e., ecosystems which are heavily influenced by people (Ellis and Ramankutty 2008) such as agro-ecosystems, planted forests, rangelands, urbanized zones. Meanwhile, a vast majority of the literature investigating the impacts of LSD, its costs and mitigation deals with agro-ecosystems. Yet, agro-ecosystems (defined as spatially and functionally coherent units of agricultural activity) are strongly linked to other ecosystems, for instance through the provision of ecosystem functions such as supporting and regulating services (e.g., climate regulation, water purification).

UNCCD (1996) defines land as “the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system". As such, land provides ecosystem services categorized in the Millennium Ecosystem Assessment (MA 2005) as supporting services (e.g., soil development, primary production, nutrient cycling), provisioning services (e.g., the delivery of food, fibre, forage, fuelwood, biochemicals, fresh water), regulating services (e.g., water regulation, pollination/seeds, climate regulation) and cultural services (e.g., recreation, landscapes, heritage, aesthetic).

Whilst MA (2005) was instrumental in illustrating the importance of ecosystem services to human well-being, the concept of ecosystem services is not always perfectly suitable for framing the economic valuation of land resources. This point is clear in Balmford et al. (2008), i.e., what economists seek to value are the benefits people derive from the ecosystem services, not the services themselves. The concept of ecosystem services as proposed in the MA (2005) lends itself to a problem of double-counting. Although the separation between a service and the actual benefits people draw from it is not necessarily straightforward, clearly the valuation of nutrient cycling as a supporting ecosystem service and of food production as a provisioning service illustrates the double-counting issue. At this point in time, not enough is known about the relationships among the various types of services and between the different services and benefits for an economic valuation of LSD to focus solely on the benefits derived from terrestrial ecosystems. Focusing on the measurement of benefits whenever possible, and keeping in mind the issue of double-counting when falling back on literature estimates of the value of services when needed, is ,thus, crucial under current knowledge. Yet, the challenges posed by the dynamic interactions between LSD and the opportunity costs of land use change, altering the nature of ecosystems and of the benefits and services they provide, demand a global coverage of the latter. Unfortunately and despite considerable advances in the economic valuation of ecosystem services in recent years, there are still many gaps in this field in terms of the coverage of specific ecosystem services and gaps in the geographical coverage of such valuation.

23.3 The Relationship Between Climate Change and Land and Soil Degradation

Climate change and LSD are related through the interactions between the land surface, the soils and the atmosphere. These interactions involve multiple processes, with impact flows running from the land to the atmosphere and vice versa. The feedback effects between climate change and land degradation are not yet fully understood.

Climate change impacts land degradation because of its longer-term trends and because of its impacts on the occurrence of extreme events and increased climate variability. Climate change trends include the increase in temperature and change of rainfall patterns. These are two determinants in the creation and evolution of soils, notably through their impact on the distribution of vegetation. Further, climate variability, a predicted consequence of climate change, holds the potential for some of the most severe human impacts. For instance, the occurrence and severity of droughts has been related to actual declines in economic activity. In SSA in particular, climate variability will affect growing periods and yields, and is expected to intensify land degradation and affect the ability of land management practices to maintain land and water resources in the future (Pender et al. 2009). However, it must also be noted that climate change is not only a negative influence on land degradation. For example, agro-climatic conditions are expected to improve in some areas.

Simultaneously, land and soil degradation impacts on climate change through the direct effects of degradation processes on the land surface, which then affects for instance atmospheric circulation patterns, as well as through the effects of LSD on land use, land use changes in turn affecting the climate.

In those complex interrelationships between climate change and LSD, sustainable land and water management (SLWM) can play a crucial mitigating role. Notably, research has shown the links between soil C sequestration and its impact on climate change and food security (Lal 2004). Soil C sequestration transfers atmospheric CO_2 into the soils, hence mitigating its climate change impacts. Increasing soil C stocks in turn has a positive impact on crop productivity, at least past a certain minimum threshold (World Bank 2010). Thus, SLWM practices that sequester large amounts of soil C can provide a win-win-win solution to the issues of climate change, land degradation and some of its human dimensions, such as food security (Lal 2006). Examples of such practices, which aim at the recarbonization of the biosphere, include no-till farming, cover crops, manuring and agroforestry (Lal 2004).

The extent of the win-win-win situations mentioned above and the conditions under which they can be realized are areas where more systematic research is required. As climate change and variability will impact different regions in different ways, so too will their consequences vary in terms of LSD in general. Further, the linkages between land and climate systems hold important keys to the valuation of the costs of LSD and of land conservation or restoration.

23.4 Why Is a Global Assessment of Land and Soil Degradation Necessary?

LSD is a widespread environmental issue affecting all climatic zones. Desertification is a term often used to describe LSD in arid, semi-arid and dry sub humid areas (as illustrated by the definition of the UNCCD) while studies focusing on the observation of land degradation as a loss of vegetation cover clearly identify that land degradation is very important in humid areas which account for almost 80% of the world's total degraded land area (Bai et al. 2008). Naturally, the results of studies on the extent of land degradation are dependent on the definition of LSD that they use and on the indicators of degradation they rely on. One clear fact remains nonetheless, i.e., although the type of degradation and/or the processes through which degradation takes place can be highly local specific, the issue of LSD is global in terms of its extent. LSD is also a global issue in terms of its impacts on human well-being. It affects land users (e.g., farmers), the consumers of land products (e.g., food), the users of other ecosystem services which are affected by land degradation (referring to the notion of externalities mentioned earlier, e.g., the users of sedimentated water ways), as well as consumers and producers of goods which are affected by land degradation through market mechanisms (e.g., producers and consumers of goods using land products as inputs, such as bread, or competing with land products for inputs such as labor, water, capital). All these elements of the general issue of LSD, and the fact that land quality is a global public good, point towards the need for a global assessment of the costs of LSD.

The economic assessment of environmental and climatic problems has received increased international attention in recent years. For example, the Stern Review on the Economics of Climate Change was released for the British government in October 2006 (Stern 2006). The Economics of Ecosystems and Biodiversity (TEEB) initiative was launched as a consequence of the G8+5 Environmental Ministers meeting in Potsdam, Germany, in March 2007, and has since produced several publications aimed at emphasizing the value of ecosystems and biodiversity as well as on ways how they can be managed. We propose to follow a framework similar to that put forward by those reports, i.e., an economic evaluation of the costs of action (i.e., the costs of mitigating land degradation) versus the costs of inaction (i.e., the costs induced by continued degradation) – the CAVI approach.

The Stern Review (2006) demonstrated the appeal of the CAVI approach lying in the immediate comparability of the results which matter to policy and decision-makers. It allows to answer the following question: what is the discounted value of the economic impact of letting land degradation taking place, which carries no immediate costs but future costs in terms of decreased terrestrial ecosystem services and benefits, compared to the discounted economic impacts of undertaking actions against land degradation now carrying immediate costs in terms of actions and future benefits in terms of sustained (relative to the inaction scenario) terrestrial ecosystem services and benefits? Implementing the CAVI approach is not an easy task. For the assessment to be unbiased, a wide range of effects and outcomes must be integrated in the analysis. They should include direct and indirect effects of LSD on the biosphere and their direct and indirect economic outcomes across the value chain of terrestrial ecosystem services and benefits and all their links to human well-being.

Land use decisions affect terrestrial ecosystem services and the stream of benefits they provide and, thus, impacting human well-being. The costs and benefits of these impacts can take several forms:

- On- and off-site costs and benefits, i.e., occurring either at the location where land degradation takes place (e.g., increased fertilizer used to compensate for depleted soil nutrients), or in other locations – the idea of externality (e.g., sediments resulting from erosion are carried in water ways, with potential costs – maintenance of dams, or benefits – increased fertility for downstream agricultural land).

- Indirect costs and benefits, which refer to the socio-economic impacts of LSD which go beyond the socio-economic group in which they are created, e.g., the food security impacts beyond the land-users, or the economy-wide effects of increased input prices for non-agricultural sectors due to the increase in agricultural prices and increased demand for inputs in agriculture. Indirect costs and benefits could be broadly defined as externalities, but giving them a specific name and differentiating them from the other externalities described above should highlight their importance and how little is known about them. They are a crucial component of a global assessment of the human dimensions of LSD.
- Current and future costs and benefits, i.e., LSD economic impacts felt instantly, during the life-cycle of the current land users, or in future generations – the time dimension is particularly important as certain forms of LSD are slow processes and/or processes whose consequences might not be fully observable for the current land users.

All categories need to be considered in order to cover not only private costs and benefits (i.e., those of the land user), but (more crucially) social costs and benefits. Thus, reflecting the overall impacts of LSD on human-well-being from the society's (and the planner's) perspective.

The CAVI approach and its implementation in the case of LSD is discussed in a later section.

23.5 The Causes of Land and Soil Degradation

In order to assess land degradation, it is important to identify its driving forces. They are generally classified as proximate or underlying causes of land degradation. The former can be split into biophysical causes and in unsustainable land management practices. The latter are those causes which indirectly affect the proximate causes, for instance the reasons why unsustainable land management occurs. Examples of the two categories are presented below.

23.5.1 Proximate Causes

The **biophysical proximate causes** of land degradation include topography (e.g., slope, exposure to sea water flux in costal zones, exposure to volcanic activity), land cover, climatic conditions (in particular extreme and variable weather patterns, such as heavy rainfalls, storms, cyclones, wild fires), soil erodibility, pests, and diseases.

The relationship between climate (change) and land degradation is particularly interesting and complex. In some cases, the impacts of climate are of sufficient intensity to induce ecological land degradation without human interference. Examples include dry and hot climate and natural bush fires, or monsoon rain and erosion. However, very often human activities trigger or exacerbate ecological land degradation (Barrow 1991). In an era of climate change, such human-induced triggers of or contributions to ecological land degradation might increase. The dynamics of the climate change – land degradation, through the interactions of the land (surface and below surface) with the atmosphere, involve multiple, simultaneous and changing processes and feed-back effects between the two systems. Not all interactions are fully understood yet.

Amongst **unsustainable land management practices**, the most frequently cited examples include land clearing, overgrazing, cultivation on steep slopes, bush burning, pollution of land and water sources and soil nutrient.

23.5.2 Underlying Causes

Institutions (including policies and incentive structures for land users) and other socio-economic factors affect the proximate causes of land degradation. In particular, they largely determine why the unsustainable management of land resources takes place. Underlying causes of LSD are particular relevant to study in a global assessment of the costs of action versus inaction against LSD, as they are the most directly influenced by land management (and other) policies. Some of the most commonly cited examples of underlying causes are presented below. As many examples show, the impact of the underlying cause on LSD is often ambiguous and context specific. Such complex interactions point towards the need for tailored and well-researched policy interventions against LSD. Such interventions require more research efforts for a better understanding of the key economic drivers of land management decisions and of the trade-offs that land users face between economic and ecological goals. These issues are likely to become more complex as the bio-economy grows.

National level policies can have a strong influence on land management practices, for instance through regulation or incentive structures. This influence can be direct, i.e., the policy directly targets land management (e.g., the payment for ecosystem services scheme to conserve forest and biodiversity in Costa Rica, Pagiola 2008). This influence can also be indirect, for example a policy targeting poverty reduction can indirectly impact on land management (e.g., a reform of land tenure systems). Indirect impacts can be positive or negative with regard to LSD. For example, agricultural policies, farm or input subsidies in particular, naturally have an enormous influence on land management. Subsidies have contributed to higher adoption of fertilizer use in several developing countries (Heffer and Prud'homme 2009), a mostly positive result from the LSD perspective. Yet subsidies can also contribute to environmental pollution through the excessive application of fertilizer (Mulvaney et al. 2009).

Over the past four decades, **international policies** and initiatives have increasingly been oriented towards sustainable development (Sanwal 2004), with strong impacts downstream the whole way to community-level land management. Examples of general initiatives include the Rio Summit of 1992, the Millennium Summit of 2000, the 2002 Johannesburg Summit on Sustainable Development. The Millennium

Ecosystem Assessment (MA) and TEEB illustrate global research efforts. An international initiative that directly addresses land degradation is the United Nations Convention to Combat Desertification (UNCCD) which went into effect 1996. The Asian Green Revolution was initiated as an international strategy aimed at increasing agricultural productivity to meet the increasing demand for food and had strong local impacts in terms of LSD, contributing to a reduction in the conversion of land to agricultural production (Borlaug 2000; Hazell 2010).

On the other hand, international policies can also have negative (indirect) impacts on LSD. International trade agreements are often mentioned in this respect. For example, some argue trade liberalization, coupled with financial and macroeconomic national policies and as well as growing world demand impacts the Brazilian agriculture, especially soybean production in the Brazilian Center-West – a Savanna area called Cerrado and a notoriously fragile ecosystem with naturally low levels of nutrients, supporting an important biodiversity (Mayrand et al. 2005). Erosion is a major issue with estimates of 6 kg of soil erosion for each kilo of crop produced (Mayrand et al. 2005). A double impact due to intensification and expansion can be observed with further indirect impacts through the marginalization of small farmers. The latter can often take the form of exclusion of the small farmers from "1st choice" input markets, including good land, capital, machinery, fertilizers, trapping them into the 2nd class food production chain relying on unsustainable and suboptimal production techniques and levels (yields below the production possibility frontier and agriculture extension on deforested land). Then land degradation further increases the level of marginalization closing the LSD – poverty trap.

Market access for agricultural producers can impact on LSD either positively or negatively, through complex incentives based on agricultural output and input markets. For example, good market access can lead to higher producer prices and cheaper agricultural inputs prices for the land users. Both can serve as incentives for investment in land management (Pender et al. 2006). On the other hand, easy market access can provide alternative livelihood opportunities. This can increase the opportunity cost of labour in agriculture and, thus, provide negative incentives to invest in labour intensive land management practices (Scherr and Hazell 1994). The application of other land and soil-preserving inputs such as manure can also be affected by (lack of) market access, for instance, through interactions with alternative fuel sources such as coal. Many other interactions between agricultural inputs, their substitutes and complements, through market transactions partly determine the adoption of sustainable land management practices and the level of LSD.

Boserup (1965) showed how agriculture can intensify under high **population density**. In support of this theory, empirical studies have illustrated the positive relationship between population density and land improvement (Bai et al. 2008; Tiffen et al. 1994; von Braun et al. 1991). However, evidence of the opposite also exists (Grepperud 1996). Indeed, the link between a decrease in per capita cropland availability (Katyal and Vlek 2000) and increasing food demand per capita worldwide (due to higher income levels) on one hand, and increasing global levels of LSD (e.g., conversion of forests into cropland, expansion of agriculture into more fragile land, unsustainable nutrient outflows) on the other hand, is intuitive. The differences between evidence found in various studies can be explained among other things by a wide range of conditioning factors, such as agricultural marketing, whose impacts have been discussed above, and by the scale of the analysis.

Secure **land** (user) **rights** are intuitively important to incentivize land users to invest in soil and water conservation measures. The reason is that such measures typically have high up-front costs and delayed benefits. Indeed, several studies have illustrated the positive impact of land titles on land management in different countries (Deininger and Chamorro 2004; Lopez 1997; Alston et al. 1995). However, Brasselle et al. (2002) showed that the literature on the topic provides rather inconclusive evidence on the sign of the impacts. Land titling efforts in particular (i.e., efforts to establish safer land right systems) have often failed to improve land management, to increase agricultural productivity, or to reduce poverty (Place and Hazell 1993; Deininger 2003) and decreased rangeland productivity through the permanent settlement of nomadic populations (Thomas and Middleton 1994). Further, in some cases insecure land rights can act as an incentive for increased investment in land improving strategies as the land user applies them to enhance his/her tenure security (Besley 1995; Place and Otsuka 2002; Brasselle et al. 2002). From these examples, it is evident that the impacts of land tenure policies are often context-dependent. This calls for local-specific policies to improve land management, reduce poverty, and achieve other objectives. In particular, the gender implications of land tenure systems are important to consider. For instance, if women cannot own land, they often cannot have access to agricultural inputs either leading them to adopt unsustainable land management practices.

The literature on the links between **poverty** and LSD reveals two diverging paradigms. In the first one, the idea that poverty leads to LSD which leads to yet more poverty is central, forming a vicious circle (Way 2006; Cleaver and Schreiber 1994; Scherr 2000). The reasons why the vicious circle is formed vary among authors, but a commonly cited cause is the lack of investment capability or "investment poverty" (Reardon and Vosti 1995), preventing poor farmers to invest in land conservation measures for lack of labour and/or capital means. As Safriel and Adeel (2005) pointed out, "*poverty is not only a result but also a cause of degradation*". Poverty is also often associated with the isolation of farmers on marginal, low productivity land (Rockström et al. 2003). In the second paradigm, different authors argue that the key factor is the strong dependence of the livelihood of poor farmers on the state of their land. This gives them equally strong incentives to utilize their limited labour and capital resources to maintain their soils and mitigate LSD, provided that the conditions under which they operate (i.e., legal system, market access) allows them to allocate their resources efficiently (de Janvry et al. 1991). As an illustration, Nkonya et al. (2008) found a negative relationship between soil erosion and livestock endowment. Thus, in the case of poverty and LSD, arises again a situation where the sign of the impact of the underlying cause on LSD cannot be generally determined and needs to be investigated on a case by case basis, along with many confounding factors. Other underlying causes of LSD listed in Nkonya et al. (2011) include infrastructure development, access to agricultural extension services, and local institutions.

23.6 The Extent of Land and Soil Degradation: What Is Known?

Although we have chosen the terminology of LSD in this paper, the definitions of land and its degradation widely cited in the literature include the state of soils as part of the "inputs" in the production land ecosystem goods and services (UNCCD 1996, Part 1, Article 1e, FAO 1979). The reason for choosing this terminology comes from our perception that the recent global studies of land degradation have shifted the focus away from the need to understand the processes which govern the productivity of soils and how these are affected and by what, when a decrease in the productivity of the soils is observed. Rather, most recent studies focus on the results of a decrease in soil productivity as these are more readily observable. For example changes in vegetation cover (type and/or intensity) can indicate land (and soil) degradation and are "easily" observed globally and across time via satellite imaging and remote sensing technologies. It should not be forgotten that indicators of changes of vegetation cover (a visible outcome) are proxies of land and soil degradation (a less visible process).

A commonly used index of vegetation cover is the Normalized Difference Vegetation Index (NDVI). It is computed based on the reflection of red and near-infrared light by the vegetation surface. Taking into account factors such as climate, soils, terrain and land use, deviations from the norm can be interpreted as land degradation or improvement. However, increases in the value of the NDVI can hide actual land degradation, for example, because of atmospheric CO_2 fertilization (Vlek et al. 2010). Further, it cannot differentiate between types of vegetation and cannot identify land use change. The NDVI, thus, seems to provide crucial information when coupled with additional local-level data and information and ground-truthing. Yet it remains the most used indicator of LSD at the global scale due to its availability and easy computation. There are other global indicators of land degradation or improvement which are computed from satellite imagery (e.g., net primary production, NPP; rainfall use efficiency, RUE; or residual trend analysis, RESTREND). Yet they are related to the NDVI and thus suffer from the same drawbacks. As a result, the few global assessments of land degradation have simultaneously been recognized as important achievements and criticized for their inaccuracy.

From a human perspective, global land degradation particularly matters because the availability of "good" or fertile land at the global scale can be considered as a public good. Nonetheless, not all land degradation is equally "humanly" concerning in the short to medium term. What policy makers need to take action against LSD are to be based upon assessments of where it occurs and impact human the most. Such areas can conceptually be viewed as areas where the cost of inaction against LSD is the highest, or areas where the net benefits of action against LSD is the highest. For example, areas with high population density, a high incidence of poverty and a strong reliance on the land resources in the livelihood strategies of the poor are clear priorities for action. Thus, global assessments of land degradation should aim to combine ecological indicators with socio-economic indicators. The Land Degradation Assessment in the Drylands (LADA), the Global Land Degradation Assessment (GLADA), the Global Land Degradation Information System (GLADIS) and Vlek et al. (2010) have all made advances in this direction. Population density is the most commonly applied information related to human impacts with relationship to land degradation. Vlek et al. (2010) added land use information in their analysis whereas GLADIS further offers the possibility to combine NDVI maps with information on agricultural and forest values and production trends, accessibility, tourism, human development index. The results of numerous studies are discussed in a review of global assessments of land degradation provided in Nkonya et al. (2011). They highlighted the shortcomings in the current state of knowledge about the global state of land and soil resources and their human impacts, as well as in methodological issues (choice of indicators of degradation and confounding factors). For the purpose of the discussion here, it is important to keep in mind that although the NDVI and related indicators currently provide the only empirical tools for global assessments of LSD, they have clear shortcomings. In particular, their ground-truthing reveals many (and large) errors, their relationship with actual LSD is still debated (see for example, Vlek et al. 2010), and their application and treatment in parallel with socio-economic indicators and models is still hampered by a lack of compatibility in data format and nature. Further, a comprehensive methodology to overcome these issues, such as that outlined in Nkonya et al. (2011), has not yet been applied. It will require concerted efforts by many parties to produce a global and integrated assessment of LSD. As a positive sign for the future, several independent research groups and other stakeholder groups have come together around the issue of LSD and are already making contacts in that respect. Simultaneously, the economic perspective on land degradation is increasingly recognized as a federative perspective to gather knowledge and energy around the global LSD issue.

Figure 23.1 below is a map showing the evolution of the average NDVI between the baseline period 1982–1986 and the end period 2002–2006. The average is computed based on the sum of bi-weekly observations collected throughout the two periods, at pixel level and resolution of 8 × 8 km. Areas of land improvement are colored in blue, areas of land degradation in red. In Nkonya et al. (2011), this map is presented in combination with different socio-economic indictors. The results presented in that report and their discussion exemplify the complexity of the relationship between socio-economic indicators and land degradation.

23.7 Land and Soil Degradation: The Costs of Action Versus Inaction Approach

Nkonya et al. (2011) presented a methodology for the cost of action versus inaction approach in the case of land degradation. The main points of their arguments are presented here. Degradation affects the economic value of land because this value is based on the capacity of the land to provide services. These services include

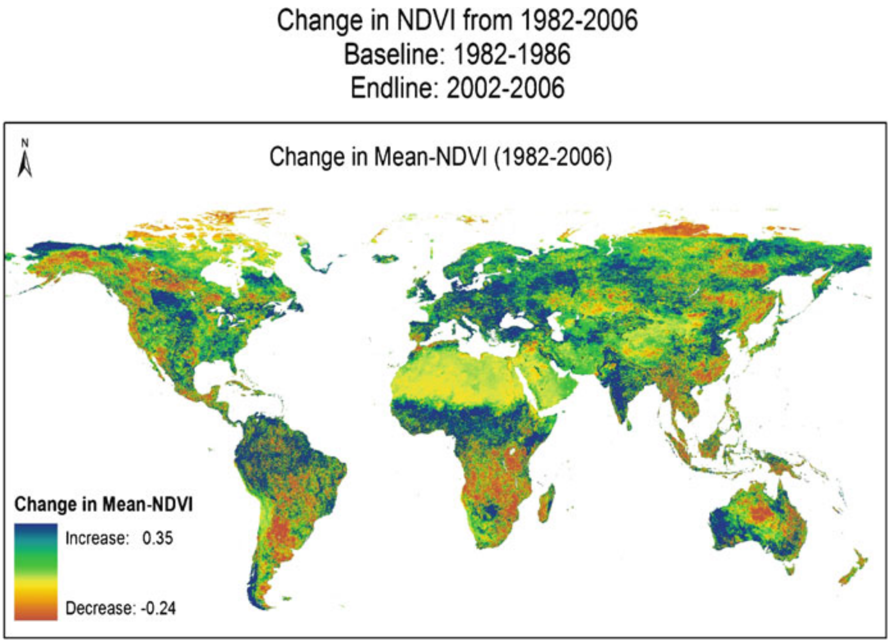

Fig. 23.1 The evolution of vegetation cover worldwide between 1982 and 2006 (Cartography: V. Graw, ZEF, University of Bonn, April 2011, Data: Global Inventory Modeling and Mapping Studies (GIMMS))

physical output (e.g., food and resource production) and other services impacting on human well-being (e.g., recreational parks, water filtration, flood control). Ethical, philosophical, and cultural considerations that give ecosystems a value, irrespective of their benefits to humans, are undeniably important but are not part of this assessment. It can be assumed that they would increase the incentives to take actions to protect land resources. No studies provide an economic valuation of the impacts of LSD on ecosystem services in general. Rather, they focus on specific types of ecosystem services and on selected benefits that human draw from these services. The most commonly investigated are the so-called provisioning services (MA 2005), and the particular benefits are food or feed production. Nkonya et al. (2011) give an account of the type of ecosystem benefits and geographical cover of many LSD studies. Clearly, more work is needed to get to a comprehensive global and integrated assessment of LSD. The important message is that all impacts of LSD must be represented in a global assessment. That includes the impacts on:

- the environment;
- the economy, through market interactions between land ecosystem "products", their inputs, and other up- and down-stream goods and services;
- humans, i.e., land users and their dependents as well as society as a whole.

The impact of environmental factors on human well-being is not straightforward. Economists are still debating what a good measure of well-being might be, and how this is linked to economic performance beyond measures of gross domestic product (Stiglitz et al. 2009). Surely, LSD has an impact on the amount of agricultural production and on its price (captured in the GDP measure), but its impact on human well-being extend beyond this. So it is not only the variety of ecosystem services and benefits impacted by LSD that must be extended for a global assessment, but also the ways in which these are valued, taking into account all economic, social and environmental costs and benefits.

Following influential reports on the valuation of the impacts of climate change (Stern 2006) and of biodiversity loss (TEEB 2010) on human well-being, an economic assessment the costs of action (i.e., costs of mitigating land degradation) versus the costs of inaction (i.e., costs induced by continued degradation) against land degradation must be undertaken to guide policy makers and inform all stakeholders of the LSD debate and the public in general. This approach aims to answer the following questions:

- What is it worth taking action against LSD (benchmarked against the costs of inaction)?
- Where and when should action take place to yield the most beneficial impact from society's point of view? To answer this question, one should assess and compare:
  - Where the costs of action are the lowest,
  - Where the costs of inaction are the highest,
  - Where the impact on human well-being is the highest.

Since land degradation is a process that occurs over time, intertemporal considerations will characterize land users' decisions. This means that the benefits derived from land use (and the value of the land) need to be maximized over time and that land users are assumed to continuously choose between land-degrading and land-conserving practices. In many cases, it turns out that the costs of prevention of LSD are much smaller than the costs of rehabilitation (Schwilch et al. 2009), favoring early action.

From an economic perspective, the current profits of adopting land-degrading practices are continuously compared against the future benefits deriving from the adoption of land-conservation practices. A rational land user will let degradation take place until the benefits from adopting a conservation practice equal the costs of letting additional degradation occur. Each land user determines his own optimal 'private' rate of land degradation. This optimal 'private' rate of land degradation depends mainly on the costs and benefits that the land user directly experiences – such as yield declines due to degradation. Typically, productivity losses are referred to as on-site costs (i.e., taking place on the land user's area of land). Hence, those ecosystem services that result in lower production levels are considered in his decisions but those that do not become measurable in terms of lost production are neglected.

In fact, many of the costs related to land degradation do not directly impact an individual land user. As a consequence, the private rate of degradation is likely to exceed the optimal rate of degradation from society's viewpoint. From a society's point of view, all costs and benefits (including externalities) that occur due to ongoing land degradation need to be considered to result in the optimal 'social' rate of land degradation. To achieve this, a global assessment must go beyond the consideration of on-site and direct costs that land users experience in terms of lower yields for instance. It must also account for changes in the value of the benefits derived from all ecosystem services that may be affected on and off-site, (e.g. off-site costs caused by the sedimentation of waterways), as well as for all indirect effects (e.g. economy wide impacts through market interactions, threats to food security and the social impacts of food insecurity, poverty and other outcomes affecting the society).

Institutional factors can prevent individual land users to reach a socially optimal decision in terms of land management. For example, imperfect or unenforced land rights, distorted and volatile market prices, lack of information about future damages related to degradation, and imperfect or missing credit markets, are among the factors that prevent land users from investing in potentially profitable soil conservation measures. Anything that creates uncertainty about the future benefits of conservation measures reduces farmers' incentives to adopt them. A global and integrated economic assessment of land degradation must account for all factors that influence the costs of action, including the institutional factors that partly determine the costs of soil and water conservation measures, as well as the costs involved in changing the institutional structures and incentives governing land management.

23.8 Implementing the CAVI Approach in the Case of Land and Soil Degradation

This approach can be made operational by comparing marginal costs and benefits (i.e., costs and benefits of a very small change in the level of degradation) related to degradation. For the application of this method it is paramount that information about the marginal social cost related to continued degradation (marginal costs of non-action) and the marginal social cost related to conservation (cost of action) can be gathered. Below we provide a generic example of how this can be carried out in the case of agriculture.

First, to construct the marginal cost curves production functions that link the extent of degradation to the maximum agricultural output associated with a technology (non-conserving or conserving) must be developed. This allows capturing the on-site productivity loss as the most direct impact of LSD on farmers. Besides direct costs and benefits of land degradation, off-site costs and benefits as well as indirect effects need to be taken into account as well. In order to come up with a socially optimal level of degradation, a mix of economic methods has to be identified to address the various on- and off-site, direct and indirect costs and benefits (Nkonya et al. 2011).

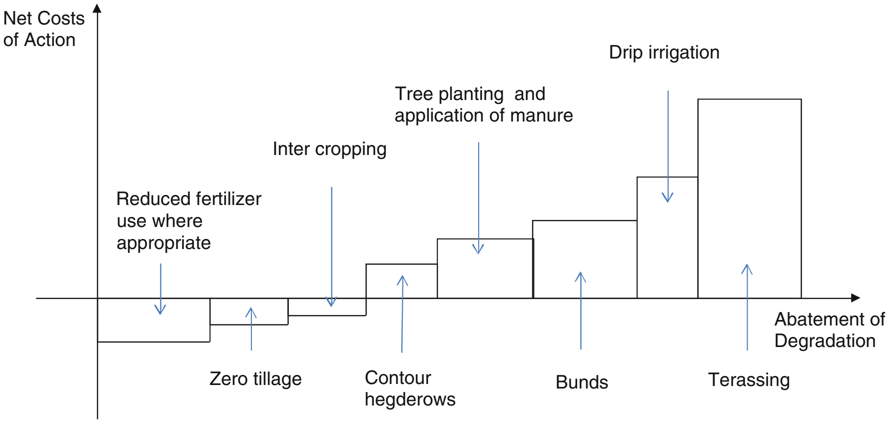

Fig. 23.2 Marginal abatement cost curve, a stylized example (Nkonya et al. 2011)

As time plays a vital role and the impact of land degradation may aggravate over time, time considerations must be incorporated as well. Costs and benefits that arise over time have to be discounted in order to be comparable. We support the use of a low discount factor as in Stern (2006) for a global, intergenerational issue such as LSD. Due to the current lack of knowledge on the long-term impacts of agricultural practices on degradation rates (and potential price fluctuations), uncertainty has to be incorporated in the analysis as well.

The marginal cost of Action curve (often referred to as marginal abatement cost curve (MAC)) consists of various measures (soil and water conservation techniques, institutions, policies) and their cost to abate degradation by one unit. On the MAC, each point along the curve shows the cost of a combination of action(s) to abate degradation by one additional (called marginal) unit, given the existing level of degradation. Marginal changes refer in this case to changes in LSD caused by a single (combination of) measure(s). The rising MAC curve (positive slope) indicates that as a higher level of abatement is achieved, the cost of the next unit of abatement increases: the MAC is an increasing function of the level of abatement.

In practice the MAC curve is difficult to observe or estimate. One way to approximate it based on conservation measures is illustrated in Fig. 23.2 below. Such a construction of the MAC curve is only an approximation of the real MAC curve. Nonetheless, similar techniques have been successfully applied in other contexts of natural resource conservation to guide policy choices (McKinsey and Company 2009 for the case of water). As (combinations of) abatement strategies are applied (independently to each other but within a given study region), their impacts on specific processes of degradation (e.g., levels of soil nutrient, water retention, or erosion) are measured, controlling for other factors affecting degradation (weather/climate, slope, working practices of the farmers). Given the number of "units" of degradation which are abated by these measures and given their total cost, an average cost of abatement over the range of abated degradation is computed, albeit in abstraction of how much abatement had already been achieved before the implementation of this specific (combination of) strategy. The horizontal aggregation of average costs over given (small) ranges of degradation abatement can be viewed as an approximation to the MAC curve.

In this example, strategies with negative costs are included. These illustrate cases where correcting current production practices strategies simultaneously decrease land degradation and production costs for a given level of output. A typical case of such win-win situation is when fertilizers have been over-used, leading to strongly decreasing marginal returns in yields per unit of fertilizer and causing degradation issues such as salinity and other chemical degradation. The most expensive conservation strategies to the right are typically labor and/or equipment intensive.

The marginal cost of inaction curve represents the continued impact of non-conserving/land mining agricultural (and other land use) practices on costs. In extreme cases, it can come to land being abandoned by the farmer (at least its original or most profitable land use is abandoned), in which case the cost of inaction is equal to the value of the fore-gone production, net of the costs of conservation measures. A crucial feature of the costs of inaction is that they will tend to rise with time and with increasing levels of land degradation. The short term strategy of delaying action can initially pay-off, as the early costs of inaction are lower than the up-front costs of action. However, past a certain threshold, one can expect that the cost of delayed abatement rises sharply above the cost of earlier action. For example, this can happen if delayed action makes it more difficult to restore already lost productivity and mitigate continued negative off-site effects: action now is cheaper than action later. This effect is compounded by the fact that delayed action increases the price of productive land, as non-degraded land has become scarcer.

Such analytical framework should be undertaken in several representative areas, thus bringing the site specificities of LSD into its global economic assessment. So far, valuation studies of the costs and benefits of land degradation/land improvement have focused on agro-ecosystems and their provisioning services. The framework needs to be developed, in combination with knowledge built in projects such as TEEB, to cover more terrestrial ecosystem services and their benefits. The approach should be as comprehensive as current science and knowledge allows, including all the services affected directly or indirectly by LSD. This can be achieved similarly to the analysis of agro-ecosystem services, relying on representative case studies. The case studies have to be representative of different ecologies, livelihoods and institutional settings. Thus, and in order to have statistically valid results, the case studies need to be drawn from a global sampling frame. As a second component of the global coverage of the land degradation issues, a global assessment must go beyond case studies and incorporate the transboundary dimensions of land degradation. These dimensions can be punctual (e.g., erosion in country A causing sedimentation of dams in country B) or at larger scale (e.g., land degradation in a specific area having impacts on global climate or on at larger scale food prices). Such transboundary effects of LSD must first be observed, recorded and then accounted for through integrated (i.e., geographically and sector-wise connected) and dynamic (i.e., accounting for the time dimension) modeling approaches.

23.9 The Institutional Set Up for a Global Integrated Assessment of Land and Soil Degradation

Clearly, the realization of a global assessment of the costs of action versus inaction of LSD requires much cooperation across regions – to gather the representative case studies – and disciplines – to better integrate the natural science aspects of LSD and its indicators with its human impacts. Lal (2010) also points to the need for soil scientists to cooperate with several other disciplines in order to globally address LSD issues. Such a concerted effort cannot materialize and gain global credibility without the appropriate institutional set-up including review processes. The key lessons learnt from previous large scale environmental assessments (Stern 2006; TEEB 2010, Intergovernmental Panel on Climate Change) is that scientific evidence and results must be developed independently and without intervention of policy stakeholders. Further, the scientific work must be submitted to strict peer review processes. Only if these two conditions are fulfilled can the scientific evidence on and assessment of the global costs of LSD gain global acceptance. However, the process needs to lead to policy-results, and thus should not take place without consultation with the policy stakeholders of the LSD issues. Continued dialogue between the scientific sphere and the policy sphere is required to ensure that the science-based evidence becomes policy-relevant. Nkonya et al. (2011) proposed an institutional set-up fulfilling these three conditions of independence, quality and relevance. It is given in the diagram below (Fig. 23.3).

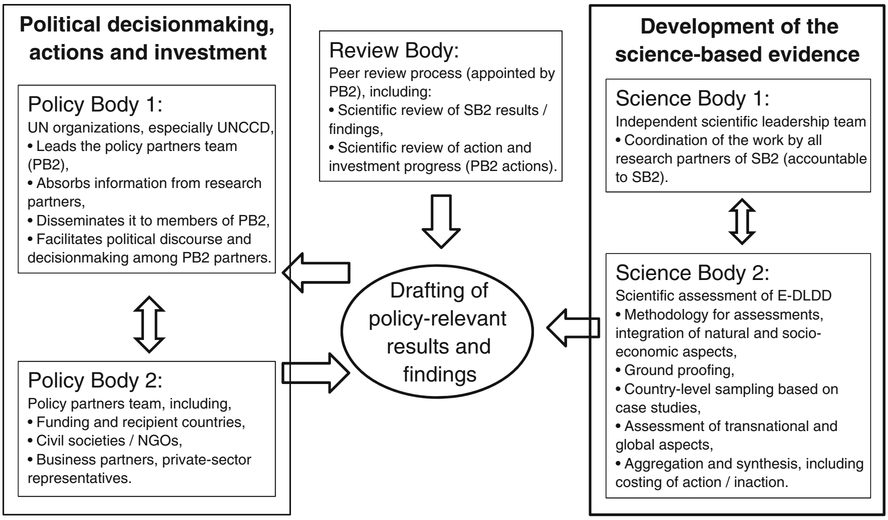

Fig. 23.3 Institutional set-up for a global assessment of LSD in a cost of action versus inaction framework (Nkonya et al. 2011)

23.10 Harmonizing Land and Soil Management in a Growing Bio-economy

Based on the global economic assessment proposed for LSD, a general framework for policy action (including science policy) for land and soil management can be laid down. Crucially, as we have discussed throughout this paper, this assessment must be time dependent. As such, it must make reference to the global trends of the bio-economy, broadly characterized by an increased competition over biological resources, and land in particular. Priority setting among sectors and value chains of the bio-economy is required, but needs to be based on objective, science-based and economic evidence. In this context, the interactions between climate change and LSD depicted earlier need to be factored in. Solutions to the LSD issue presenting potential win-wins, such as the recarbonization of the biosphere, should play a prominent role in resolving the issue of LSD under the likely scenario of the development of the bio-economy. Nonetheless, all solutions need to be appraised objectively in terms of their opportunity costs as well as their benefits. In the current world context of fast growth in demand for food and biomass, slow growth in agricultural and generally biomass production, fast growth of output prices (e.g., food) and resources prices (e.g., land, water) and increased undernutrition, the recarbonization of the biosphere (through improved land management practices) has the potential to drive up the price of biomass and food, thus increasing the human costs of LSD. Solutions to such contra-productive effects take time to implement such as enhanced agricultural (and generally biomass) productivity and/or changes in consumption behavior.

23.11 Conclusion

The main messages of this paper can be summarized as follows:

- Preventing the degradation of or restoring the land and soil resources is essential to ensure the sustainable production of increasing amounts of biomass;
- The recarbonization of the biosphere is one strategy with great potential to restore/conserve soil resources under these circumstances, with added benefits in terms of climate change mitigation;
- Nonetheless, the economics of recarbonizing the biosphere, and more generally of LSD and its mitigation, must be clarified in order to take the step of policy implementation;
- Awareness of the importance of the LSD issue and of the importance of soil and land resources in the climate change debate have risen in recent time and time is now ripe for an global and integrated assessment of land and soil degradation, based on the concept of the costs of action versus inaction;
- The LSD issue is a global issue and thus needs global action and mechanisms to guide such action;

- The mechanisms and institutional arrangements for the implementation of the global integrated assessment of LSD must follow best practices exemplified (or not) in other global economic assessments of nature's resources.

Acknowledgments This chapter partly draws on a recent study on the economics of land degradation by ZEF and IFPRI (Nkonya et.al. 2011) of which von Braun and Gerber are co-authors. The authors are also grateful to two anonymous reviewers, whose comments helped to improve this chapter.

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