Forum Plenary

Session 1: Setting the Stage: Soils, Society and Global Change – Global and Local Perspectives

Soils and the Living Earth

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Introduction

Soils are dynamic and immensely variable resources. Soils can be thought of as an active chemical factory, full of life, but various organic substances and clays are among the products of the factory. These products are important in providing the soils with the properties that make them a natural resource, such as water and nutrient storage and release. Soils are fundamental for the Earth's food chain, and it is often overlooked that a higher number of living species exist underground than above the surface. Furthermore, there is more carbon in soils than in plants and the atmosphere combined. A substantial share of the elevated CO_2 levels in the atmosphere is caused by anthropogenic release of carbon from soils due to their utilization. Therefore, soils play a fundamental role in both biodiversity and global climatic change.

Do soils rejuvenate naturally when damaged? Soil formation can certainly balance losses by erosion to a certain degree. However, huge soil losses in one place may have less effect than a slight soil removal from shallow soils on hard bedrock. Young and often fertile soils characterize active geologic surfaces, such as flood plains, mountains and volcanic regions and they are often resilient to human pressure. More mature soils characterize the plains of the tropics and they are often less fertile than soils of the temperate regions. The fertility of the soil is interlinked with other environmental factors such as climate and vegetation cover – and the effect of man. But the severity of soil losses differs from place to place, making generalizations difficult and often misleading.

When addressing the state of Earth's global soil resources, it is important to understand the main functions of soils and ecosystem services in order to come up with meaningful methods for assessing their state, using transparent methods and well defined concepts. This is not an easy task and there are both successes and failures in attempting to assess the state of soils, locally, nationally as well as globally. The aim of this paper is to provide an insight into threats to soil resources, land degradation processes, and discuss the state of the world resources and limitations to global soil condition assessments.

1. Threats to Soils and Causes of Land Degradation

1.1. Processes – condition – land use – root causes

With an ever increasing population, pressure on soil resources is causing damage to soils at an accelerating rate. There are numerous threats to the welfare of soil resources. These include direct soil losses by erosion, salinization, losses of soil fertility (physical, chemical and biological properties), soil sealing from construction, pollution, losses of vital functions and/or elements of the soils such as water storage capacity and biological function. There are many 'off-site effects' associated with soil erosion and land degradation such as siltation of rivers and lakes, dust pollution, contamination of waters and oceans, increased frequency and severity of both flooding and landslides, loss of biodiversity, and increased CO_2 release to the atmosphere. One important aspect of global change is that thawing of permafrost soils releases huge reserves of CO_2 from the Arctic carbon stock (e.g., Stokstad, 2004).

It can be stated that increasing soil degradation is mainly caused by man-induced pressure on land resources. Expansion of agriculture needed to sustain the growing population is predicted to cause unprecedented ecosystem change and degradation of ecosystem services (e.g., Tilman et al., 2001). It is very important to differentiate between i) degradation processes, ii) the land use causing these problems, and iii) the root causes driving the current land use responsible for the problems. The current user may not be causing the problem, however, may be maintaining poor conditions. The root causes of degrading land use may be economical, poverty, land tenure systems, local and regional politics, subsidy policies, and global trade, to name a few root culprits that drive land use that causes degradation. These root causes need to be addressed to alleviate the effects of land degradation and desertification. The monumental Millennium Ecosystem Assessment (2005) has special sections addressing drivers of ecosystem change, which are identified, classified and their effects studied, using spatial scales (global, sub-global, regional, national and local). Demographic, economic, and socio-political drivers are examples of categories identified for the sub-global scale in the Millennium Ecosystem Assessment (2005). Socio-economic factors were also emphasized in a review of soil erosion science by Boardman (2006). The Desertification Synthesis of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) cites i) social, economic, and policy factors; ii) globalization, and iii) land use patterns and practices as major causes of desertification. They note that "global trade regimes and linked government policies influence food production and consumption patterns significantly and affect directly or indirectly the resilience of dryland ecosystems". Interestingly, they cite land use last in their list. Land degradation processes need to be understood to seek sociological, economic and political solutions. The solutions in the developing countries may often be trade agreements that reduce pressure on marginal lands and reduce poverty. It is also important to note that solutions can be very different between the developing and industrial countries. Several attempts have been made to create helpful models for understanding land use relationships, the DPSIR (Drivers, Pressure, State, Impact, Response) being the most commonly cited model. The European Union – Soil Conservation and Protection in Europe (EU-SCAPE) group developed a simple model, a Sustainability Index Model, that encompasses the relationships between processes and land condition, land use and root causes and is relatively simple to relate to socio-economic drivers (Arnalds, 2005; Imeson et al., 2006).

Natural processes are often stressed as major causes of land degradation, most often climatic fluctuations, spells or events. It is, however, important to bear in mind that most ecosystems are naturally resilient and tolerant to such stresses unless land use has damaged their resilience. Such damage to ecosystem resilience may have occurred in the past, but is not due to current land use.

1.2. The desertification conceptual problem

It is important to understand basic ecological concepts and pathways of land degradation. Understanding of such concepts as resilience and tolerance are often missing in reports and conclusions about desertification. The infamous "marching desert" debate is a good example (see e.g., Force, 1989). The Sahara desert appeared to be expanding > 15 km each year during in the early 1970s, but when the drought ended, vegetation returned naturally (see also Rhodes, 1991). Did the area become more degraded at all? And did the scientific discussion consider earlier degradation and losses of ecosystem resilience and services? The answer is no in at least many cases. This debate is an example of a "one-dimensional" approach (vegetation vs. no vegetation), while both ecological factors and more long-term vision of ecological functions (such as water holding capacity) and degradation processes in the past and future was needed. This "one-dimensional" approach to desertification science resulted in part in the controversial definition of desertification used by the UNCCD. This definition is limited to rainfall conditions ("climate regimes", or "aridity index") rather than what happens to water in ecosystems, or addressing all severe land degradation that affects human livelihood and the effect on sustainability. The Aridity Index merely describes one function related to the ecosystem and is helpful as such, but is only one piece of a larger picture. It is interesting to note that the term 'desert' originally means abandoned land (see e.g., Arnalds 2000). Desert ecosystems are not necessarily formed by desertification and can be relatively rich ecosystems. Humid deserts can be extremely poor as a result of degradation (desertification). These contrasts are well expressed by Icelandic desert ecosystems, which include both humid and dry deserts in terms of rainfall, both natural and as a result of human-induced desertification, but all with similar ecosystem functions. Another example is that severe desertification occurs in many mountainous areas such as Nepal, regardless of climate. The term 'desertification' as it is commonly used, mixes the concepts of ecosystems, (biome, usually vegetated but also often with little vegetation), vegetation cover (barren – dry or not), climate ('arid', but various definitions), processes (multiple degradation processes cause desertification), pressures (drought, land use), and perception (multiple perception such as desolate, abandoned, barren or dry). The key issue should be that all kinds of marginal lands are susceptible to severe land degradation that can lead to reduced productivity of the land and ultimately abandonment, – i.e. desertification.

Figure 1. Which of the two pictures shows a desert? Which one has become desertified? Left: Desert in the western USA, with considerable vegetation cover in an arid region. Right: A desert surface in Iceland, in a cold-temperate humid climate, desertified in the sense of becoming a desolate and unproductive area, where soil water and nutrients are limiting, while unstable surface and erosion processes also contribute to maintaining a barren surface.

Another example of a one-dimensional approach to degradation assessment is using yields as the sole indicator of land condition, as sustainability and other ecological services may be more important for many locations. Fertilizers input can, in fact, mask the long-term effects of degradation by resulting in sufficient yields in spite of severe degradation (Eswaran et al., 2001).

Climate change, land degradation and socio-economic factors are often interlinked, resulting in complex cause-effect relationships (e.g., Dale, 1997). Large scale land degradation is also known to affect climate patterns, which can further intensify pressure on land. There is no doubt that the UNCCD is quite important for the global community and the National Action Plans have great beneficial effects. The UNCCD definition, scientific structure of the Convention (lack of independent panel such as the IPCC for UNFCCC) and other issues are, however, still being debated (e.g., Arnalds, 2000, 2005; Eswaran et al., 2001; Reynolds and Stafford Smith, 2002) and this has a negative effect, both on the Convention and on general efforts to address severe land degradation globally, by restricting the development of a truly global forum for severe land degradation.

2. Assessment – Methodology and Methodological Problems

2.1. Assessing what?

Considering the numerous threats to soil resources and processes of land degradation, it is often difficult to determine which methods are appropriate for assessing the state of soils for any given set of conditions. Site, national and regional differences also make general assessments on the state of the Earth's soils difficult to make. It is therefore obvious that no single method is appropriate for all conditions (see also Lal et al., 1998). Many methods have relied on vegetation cover, which has the benefit of being easily analyzed from aerial photography such as satellite images (see e.g., Bai and Dent, 2006). Soil erosion can be measured at the field plot scale on the ground and models have been developed to calculate erosion quite effectively for agricultural lands. The Universal Soil Loss Equation (USLE) and the Wind Erosion Equation and their derivatives or relatives are the most commonly used. These kinds of models, coupled with landscape analysis, rainfall and other environmental data, have been used to produce erosion risk maps at the regional scale, particularly in Europe (the CORINE project and the EU PESERA; e.g., Grimm et al., 2002). The models put a quantitative estimate to soil losses and the response value is usually tonnes of soil lost from a hectare each year (t/ha/yr). Other methods which are often used for rangeland conditions employ vegetation indices and erosion signatures to assess rangeland condition. These are often based on grading, using 4-6 condition classes or something similar, from excellent to very poor or slight to very severe, to give some examples. It should be noted that it can be disputed where the t/ha/yr response value is the appropriate measure of erosion. Low values (t/ha/yr) can have devastating consequences on shallow soils, but little effect elsewhere. The use or the misuse of USLE has been criticized by many and Boardman (2006) specifically noted that while major erosion is event driven, where there is lack of vegetation cover, the models such as the USLE deal with average conditions. Boardman (1998) has also contested the use of soil erosion rates derived with such models (t/ha/yr response value) for arriving at averages for large areas, as it "distracts attention from the real issue: rates of erosion and associated on-farm and off-farm costs are high in some areas and not in others."

There is a need to differentiate between types of land use when assessing land degradation. It is especially important to differentiate cropland from rangeland and forest when assessing land condition. It is also important to analyze the suitability of cropland for a given production, and not only from the conservation/degradation perspective, but also in light of socio-economic factors, sustainability, environmental costs and societal benefits (Arnalds, 2005).

Productivity is a commonly cited value for assessing land degradation (e.g., % reduction per given time period) and has the benefit of allowing for an estimation of annual losses in revenues (e.g., in $ per year). Lack of productivity can often be masked by direct inputs such as with fertilizers and/or improved technology, which complicate estimates of this kind, and can also give a false sense of security (Eswaran et al., 2001). However, these estimates are extremely important, especially for portraying the damage in terms that many sectors of society can relate to. When applying such methods, it is nevertheless difficult to take other environmental factors into consideration, such as effects on hydrological cycles, flooding, carbon storage, biodiversity, wildlife and aesthetic values.

2.2. Terms of reference and the time factor

When assessing condition of the land, explicit term(s) of reference is needed. But due to the multi-factorial function of soils and ecosystems, this is difficult to achieve. The time factor is also often overlooked: the present state of land may reflect degradation that occurred a long time ago, measured in decades (e.g., USA,) in centuries (USA, Northern Europe, including Iceland), and millennia (China, Mediterranean, West and Central Asia). In some cases, the land resources can be restored, even long after degradation, but reference to the ecosystem condition tends to be more short-term and areas that were severely degraded a long time ago are often considered in normal conditions.

2.3. Major global assessment efforts

There have been some attempts to review data on global degradation, and important overviews include those published by Eswaran et al. (2001), Lal (1990), and Pimentel et al. (1995). There is also an important review published in the Millennium Ecosystem Assessment, (Dryland Systems, Adeel and Safriel, 2005). There are primarily two major global overviews of land degradation, by Dregne and Chou (1994) and FAO/UNEP/ISRIC (GLASOD, e.g., Oldeman and Lynden, 1997, see also GLADA, 2007). UNEP had previously surveyed desertification problems (UNEP, 1991) globally. The Millennium Ecosystem Assessment attempts to take these and other estimates to come up with more up-to date estimates. These efforts are of immense importance to obtain a global overview of soil degradation. However, they are coarse grained surveys with many limitations. Lal (2004) concluded that the literature on global soil degradation was "replete with gross extrapolations based on scanty data, often outside of eco-regions from which data were obtained." In his review, Boardman (2006) also stressed the need for an update to the scientific approach at the global scale. There is ample room for large improvements in this area of science.

3. State of Soil Resources

What is the state of Earth's soil resources? The world's landmass is about 130 million km^2. A large part of this area is marginal, such as dry, arctic or mountainous areas. Grazing area is considered to be 40-60 million km^2, forests to be 40 million km^2 and about 15 million km^2 to be cultivated. Dryland zones are about 40-60 million km^2, depending on definitions, but are only partly the same as those defined as grazing areas. Published global figures on how much land is affected by degradation vary almost by order of magnitude, or from 10-70% of Earth's drylands. Dregne and Chou (1994) report 70% of dry areas as degraded, a total of about 40 million km^2. Oldeman (1994) reports water erosion as the most extensive degradation process, with a considerably lower extent of degradation (19.7 million km^2 light to extreme, 12.1 million km^2 moderate to extreme). The Global Assessment of Human Induced Soil Degradation (GLASOD) (Oldeman and van Lynden, 1997) cites 11.4 million km^2 degraded within the drylands and 19.6 million km^2 worldwide. They also cite that 1.4 million km^2 has severe and extreme severe degradation. Eswaran and Reich (1998; quoted in Eswaran et al., 2001) estimated that "CCD areas" that have "high to very high desertification" are about 15 million km^2, and all dryland areas affected by water erosion were 23 million km^2 and wind erosion 17 million km^2 (these areas presumably partly overlap). The Millennium Ecosystem Assessment (2005, Chapter 22 on Drylands) reaches different conclusions on the extent of land degradation by stating that 10-20% of the world's drylands suffer from one or more forms of land degradation, but noted many difficulties in reaching their conclusions. The difficulty in obtaining reasonably accurate global estimates of this kind and their limitations should be fully appreciated. The estimates give an indication by order of magnitude, and the results are truly confounding.

The present author has additional reservations to those pointed out by the Millennium Ecosystem Assessment (2005) and Lal (2004) regarding estimates of this kind, especially the terms of reference and time scale. Increased production in a given area compared to what it was some decades ago does not mean that the system is not severely degraded if a longer time scale is used as reference. Many of the areas under consideration are truly quite degraded if centuries or millennia are used for reference, e.g., the Mediterranean and other areas (see above). Furthermore, it is often stated that soil takes thousands of years to form, but perhaps that statement is more valid for the development of certain soil features, such as clayey sub-surface Bt horizons, which in turn only partly explain the fertility of a given soil. A single publication may report much improved production within decades, contradicting its own introduction remarks on non-renewable soil resources. It should also be noted that under many conditions, previous fertility of soil can be attained much earlier than many well-developed soil features (e.g., on loess parent materials and flood plains), and the degraded state can be masked by fertilizer applications.

Productivity loss estimates vary as much as estimates of degradation and soil erosion. The effect of erosion on productivity is very site specific, ranging from 0 to >90% reduction. It is quite difficult to make such estimates on a global scale, unless there are thorough definitions of variables and qualifiers used in such modeling. Among important factors is the time of reference, as was previously mentioned for degradation estimates (year, decade, century, millennia). Rattan Lal and coworkers and several other groups have made notable calculations of productivity losses and costs of erosion for countries and continents, as reviewed by Eswaran et al. (2001). Revenue losses in the US alone are estimated at US$ 44 billion and Eswaran et al. (2001) concluded that on a global scale, the annual losses due to soil erosion are about US$ 400 billion. This is a staggering figure and does at least give an indication of the costs of land degradation in the world. Costs of remediation are not included in these figures, and other environmental costs associated with land degradation, such as increased flooding. Release of CO_2 from soils because of land degradation can also amount to immense costs, considering current carbon trade values. Furthermore, one can hardly put such a numerical figure to the poverty and harm caused by displacement of people and even war caused by degradation of natural resources. It is often cited that more than 1 billion people are at risk because of desertification (presumably limited to UNCCD desertification areas). The risk concept relates to the future. A figure such as one billion people is bound to become much too low an estimate when the population of the Earth has doubled in the not too distant future.

Discussion and Conclusions

Many have pointed out the necessity to clarify conceptual problems associated with desertification research and politics. Reynolds et al. (2003) noted that "there is an urgent need to lessen uncertainties that paralyze action and for new thinking beyond regional and disciplinary concerns". Eswaran et al. (2001) noted that: "Land degradation remains a serious global threat but the science concerning it contains both myths and facts. The debate is perpetuated by confusion, misunderstanding, and misinterpretation of the available information." The very concept of desertification has been questioned by many, as it is used by the UNCCD (see section above). Many have suggested new methodology to cut through the confusion and complexity of desertification science (e.g., Reynolds et al., 2003, Bergkamp, 1995), asking for or suggesting new paradigms (e.g., Reynolds and Stafford Smith, 2002; Geeson et al., 2002; Adeel and Safriel, 2005). It is likely that such a paradigm shift is imminent as there is much research under way that relates to the assessment of degraded lands and restoration. Restoration ecology is currently one of the fasted growing sub-disciplines of the ecological sciences (Young et al., 2005).

In spite of the fundamental importance of the soil resource, it is not adequately cared for in international conventions or law, and rarely in national legislations. The US National Research Council (cited in Doran and Jones, 1996) noted that "Protecting soil quality, like protecting air and water quality, should be a fundamental goal of national environmental policy". Recent developments in many European countries and the EU, with the development of a new Soil Protection Directive, may signify a change. However, because of limitations of the UNCCD, it seems necessary to develop a new UN convention for soils and land degradation.

While it is important to understand the ecology and processes of degradation, it is also vital to understand the socio-economic drivers for the problems and for potential solutions, not merely actions on the ground (see section 1.1. above). Actions on the ground will also have to consider long-term restoration, not short-term economic benefits or merely plant cover (e.g., by using invasive plant species and one-dimensional science approaches, see above). Root causes as drivers of present land use may be traced to subsidies (e.g., in Europe and other industrialized countries). Root causes in developing countries can in part be related to subsidies and trade barriers on agricultural products in industrialized countries, and to global trade in general. These considerations merit much further research on a global scale, and political attention.

It is concluded that much of the land on Earth has degraded soils. Time of reference is a confounding parameter for global assessment methods. Much of this degradation occurred millennia ago (e.g., Mediterranean Europe, Asia, Africa, China), but some of this ecosystem potential can be restored. However, there is severe degradation occurring still today, which is intensified by ever increasing population, which is likely to cause ecosystem damage at a scale never experienced before in human history. Finally, there is an urgent need to develop stronger synergies between sciences and actions on the ground related to climate change mitigation, conservation and restoration of biodiversity, desertification prevention and restoration of degraded lands.

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Global Land Degradation: State, Risks and Prospects under Global Change

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Introduction

Thanks mainly to the United Nations Convention to Combat Desertification (UNCCD), not only desertification (defined as land degradation in the drylands), but also land degradation in the non-drylands has become an issue of mounting interest and concern in both the academic and political arenas. This paper addresses the issue of land degradation's globality with respect to two manifestations of global change, globalization and climate change, and explores how they may jointly put lands at risk of being degraded, while also generating some bright prospects for the inhabitants of drylands.

1. Is Land Degradation Global? The Global Occurrence Criterion

A biophysical phenomenon or process can be described as global if it is either of global occurrence, namely occurring or expected to operate in all or most of the global land, or if it is prevalent only at the local scale, but its effects or outcomes are evident or are expected to have effect at the global scale. Whether land degradation complies with the occurrence criterion, the mammoth project of Global Assessment of Land Degradation (GLASOD) whose results became available in 1990 (GLASOD 1990) could not provide a clear answer. One result is that more than half of global land is degraded, i.e. between 61-65%, and another is that only 15% was degraded in the late 80s of the 20^{th} century. It is the difference in the spatial scale used for assessment that generates these two largely diverging values: the low values represent summation of the land actually degraded in each area unit, whereas the high values are derived from summing up the total area of each map unit within which degradation was detected, irrespective of whether only part or the whole unit's area was degraded. Surely the 15% value stands for tangible degradation, whereas the 65% figure is overly inflated, and the question is what purpose this inflation served.

1.1. Global land degradation and desertification

The launching of the GLASOD project was motivated by the 1968-1974 Sahel drought succeeded by the even more severe one of 1983-1985. The human plight during the latter experienced by around one hundred million people, of which one million starved to death, was then attributed to land degradation brought about by the combination of drought and the overexploitation of land resources by the burgeoning Sahel population. The term “desertification” coined in the early 1930s for describing the “advancement of the Sahara” into North Africa was then revived and applied by the United Nations Environment Programme (UNEP) and later by Agenda 21 to land degradation in the drylands. And, in order to mobilize the international community to “combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa” (United Nations Convention to Combat Desertification) it was necessary to demonstrate, in spite of that full title of the forthcoming UNCCD, that desertification is not only a problem of the Sahel or of Africa in general, but its dimensions are global. GLASOD’s implicit mission was then to highlight this globality of land degradation, with an emphasis on desertification.

1.2. Is desertification global?

The interest in the globality of desertification prompted an extraction of dryland degradation as a subset (41% of the global land) of the GLASOD global land degradation, to be presented in UNEP’s World Atlas of Desertification. Two other assessment projects were launched by smaller teams than that of GLASOD – “Desertification of Arid Lands” (Dregne and Chou, 1992) and “Land-cover – Land-use change – Drylands (LUCC)” (Lepers, 2003). Two sets of value ranges for the spatial extent of global desertification were produced by these three assessments. The first range is that of 4-74% of desertified global land (Table 1, last row). The differences within this very wide range are attributed to differences in mapping scales (as described in the previous section) and depend on whether the huge hyper-arid drylands are included or excluded from the analysis. The second range of values results from attributing the term “desertification” only to the “very severe” degree of land degradation in the drylands, thus implying that the other three degrees of lower severity of degradation used by all three assessments do not really qualify as “desertification”. This set of values yields only 0.1-10% of global lands as already desertified (Table 1, third row from bottom).

Thus, depending on needs, stakeholders have been able to choose any of the values within the range of 0.1-74% for addressing the spatial extent of global desertification, depending on whether they wished to support or reject the notion of desertification’s globality. In practice, however, there has been a gradual shift in this usage between 1993, when negotiations on drafting the UNCCD initiated, and 2006 when this Convention terminated a decade of being in force. Namely, at the beginning of this period the figure mostly used was the alarmist one of 70%, whereas towards the end of this period quoting the 10% figure has become more prevalent (e.g. Millennium Ecosystem Assessment, 2005).

Table 1. Assessments of the status of dryland degradation (desertification). Adapted from Safriel (2007).

Assessment	Desertification of Arid Lands (Dregne, 1983, 1992)								Global Assessment of Soil Degradation (GLASOD) 1991								Land-Cover Land-Use Change - Drylands (LUCC) - 2003			
Sources	Dregne 1983				Dregne and Chou 1992				WAD[1]		WAD[2]		GLASOD database[3]				Lepers 2003, Lepers et al 2005			
Dryland zones assessed[4]	HA A SA DSH				HA A SA DSH				HA A SA DSH		HA A SA DSH		HA A SA DS		HA A SA DSH		HA A SA DSH		HA A SA DSH	
Area assessed (1000 sq.km)	47,063 [5]				51,597 [6]				51,692 [7]		61,473 [8]		51,125 [9]		60,902 [9]		51,692 [7,16]		61,473 [8,16]	
% degraded by categories[10]	"Classes" [5]		Land uses[11]		"Classes" [12]		Land uses[13]		"Degrees" [14]		"Degrees" [15]		"Severity" [9]				"Main areas of degraded land" [16]			
	Slight[17]	52	Irrigate	1	Slight	30	Irrigated	0.8	Light	8	Water	8	Low	15	Low	15				
	Moderate	29	Rainfe	5	Moderate	29	Rainfed	4	Moderat	9	Wind	8	Medium	26	Mediu	23				
	Severe	18	Range	65	Severe	39	Range	65	Strong	3	Chemical	2	High	24	High	22				
	Very severe	0.2			Very severe	2			Extreme	0.1	Physical	0.6	Very high	8	Very high	8	Very severely degraded	4	Very severely degraded	10
Total degraded (1000 sq.km)	22,543 [18]		32,718		35,922				10,352		11,370		37,588		41,221		1,959		6,147	
% degraded of assessed area[20]	48		70		70				20		19		74		68		4 [19]		10 [19]	

[1]World Atlas of Desertification (WD), Middleton and Thomas, 1997. Values based on tables in the WAD using GLASOD database and a delineation of the drylands from maps of the dryland zones done commissioned by UNEP to the Climatic Research Unit (CRU) of the University of East Anglia (UEA), using their data sets to derive global Aridity Index values. This dryland types data set was downloaded from the MA core database.
[2]Data from Oldeman 1994, based on GLASOD data base and the global aridity zones delineation by the CRU/UEA (see footnote 1).
[3]Used for the 'Severity' category values, which combine "degrees" of degradation with their spatial extent within mapping units (e.g. map 1.11 p.20 in WAD 1997).
[4]Aridity zones: HA – Hyper-arid; A - Arid; SA – Semi-arid; DSH - Dry sub-humid, following UNEP/WAD classification. Grey zones only are covered by the assessment.
[5]Based on Dregne 1983, Table 6.2, p.174.
[6]Based on Dregne and Chou 1992, Table 1.
[7]Based on WAD, Table 1.1 p. 5 and Table 1.4 p. 18.
[8]Based on WAD, Table 1.1 p. 5.
[9]From GLASOD digitized database downloaded from ISRIC website to the Millennium Ecosystem Assessment (MA) "core data" (e.g. Safriel and Adeel 2005, Fig. 22.9 p. 640)
[10]Terminology for each category used by the different assessments is preserved. The bottom category (bolded figures in a highlighted grey cell) are regarded by the authors of the assessments as a practically irreversible state, which by some it means, in the drylands - "desertification"
[11]Based on Dregne 1983 Table 1.3 p.19; these land uses occupy 41,018,000 km^2 of the assessed "used" dryland, of 47,063 km^2
[12]Based on Dregne and Chou 1992 Table 8.
[13]Based on Dregne and Chou 1992 Tables 3,5,7.
[14]Based on WAD Table 1.4 p.18.
[15]Based on Oldeman 1994, Tables 7.1 - 7.4 pp 108-111. Assessing degradation types (water and wind soil erosion, chemical and physical soil deterioration).
[16]From Lepers, 2003. Degradation is the highest degree (of 3-4 degrees in 5 of the data sets used, or values above a high threshold in all other data bases). Note also that only 62% of the drylands (including the hyper-arid) are covered by data accepted by this assessment, what makes the total assessed global area smaller than presented in the row above.
[17]This class also includes non-degraded areas, mostly occurring in the hyper-arid zone.
[18]'Moderate' to 'very severe', i.e. 'slight' excluded.
[19]Note that this percentage is close to the GLASOD 'high severity' degradation, since in both assessments the mapping scale results in an exaggeration - mapping units defined as degraded are only degraded in part of their area.
[20]These values, though each is a percentage of a different definition of the term 'dryland', are often used to denote 'dryland degradation', or 'desertification'.

2. The Shortcomings of 'Desertification'

Given the high between- and within-study variation in the extent of desertification presented by the different studies, it is evident that when using the spatial extent criterion, the globality of desertification cannot be defended. The root cause of this variation is not just the use of different mapping scales and the choice of different degradation severity criteria by these researchers, but the weakness of the definition of the process they set out to assess. This definition of desertification, spelled out by Article 1 of the UNCCD, can be described as cumbersome, imprecise and loose, leading to such qualifications as "an open concept" (Warren and Olson, 2003). This is exemplified by a 2004 paper published in the journal *Conservation Biology* entitled "Effects of Desertification Caused by *Lithophaga lithophaga* (Mollusca) Fishery on Littoral Fish Assemblages along Rocky Coasts of south-eastern Italy", dealing with the effects of shellfish fisheries on coastal algae. To quote: "The major consequence" of this practice "…is the removal of the biological cover (macroalgae, zoobenthos), which ranges from bare patches to complete desertification", which suggests that "…pressing topics for future research ..." is the "…effects of desertification on fish…" (Paolo et al., 2004). Furthermore, "desertification" was explicitly implicated in being "used as a deliberate strategy to attract attention of funding; 'spin' is another word…". This is exemplified by a proportion of non-dryland developing countries in the UNCCD membership increasing from 20% in 1996 out of 56 countries ratifying the Convention by that year, to 36% in 2003, when the UNCCD had 190 contracting parties. To comply with their commitment to the Convention, many of the 93 dryland ("affected") developing country parties prepared and submitted for donors' support

"National Action Programmes to Combat Desertification" (NAPs). This procedure was also practiced by many of the current 69 non-dryland country parties, in spite of the fact that in having no drylands, by definition these countries can not be affected by desertification, yet they claim to combat it… To conclude, not only the free usage of the term "desertification" contributed to the extreme disparity in values of land degradation in 41% of the global land, but both the loose definition and the inability to assess the extent of the phenomenon might have hampered addressing it effectively.

3. Is Land Degradation Global? The Global Effect Criterion

Faced with the shortcomings of the definition of desertification and with the inability to determine the spatial extent of its occurrence at the global scale, land degradation, though limited only to the drylands and possibly so far affecting (or severely affecting) only a very small proportion of them - most likely 10% (Millennium Ecosystem Assessment, 2005) or even less (see above), can have a "transboundary" effect spanning large parts of the globe, even way away from the drylands themselves. For example, desertification has been implicated for generating dust storms that travel long distances within the drylands, and not only cross the dryland boundaries but are even transoceanic. However, it is estimated that only less than 10% of the global dust storms are due to desertification, and moreover, there might be some tangible benefits to the ecosystems in which this transboundary dryland dust is deposited (Safriel, 2006a). Thus, the physical phenomenon, that of trans-dryland dust storms, do not provide support to the notion of desertification's globality.

But desertification might have social implications of a strong transboundary effect. For example, the migration from developing to industrial countries, such as that out of Africa or of the Near East to Europe, is often attributed to desertification. However, no statistics are available either to demonstrate that the root cause of this migration is desertification, or that a high proportion of these migrants are of a dryland descent. Yet, one can confidently link three relevant observations: all these migrants are from developing countries; most drylands are in developing countries; and, the migration of most migrants is driven by poverty. Therefore, it is safe to assume that a very large proportion of global migration is driven by poverty in the drylands. Thus, it is living in the drylands, and not necessarily desertification, that generates poverty as well as drives migration. In other words, in a globalized world, local poverty, i.e. poverty in dryland areas, has global effects and should be of global concern.

4. The Expressions and Sources of Dryland Poverty

There is no hard evidence of how much poverty there is in drylands. This is because like desertification, poverty is loosely defined, and its statistics are usually available at the country scale in which drylands are aggregated with non-drylands. An attempt of the Millennium Ecosystem Assessment (MA) to compare the Gross Domestic Product (GDP) of people aggregated by ecosystems rather than by countries revealed that, at least in Asia, the GDP per capita is lower in drylands than in the other five ecosystems, which, when combined, cover the Asian land surface (Fig. 1). It is thus likely that dryland peoples are on average less affluent than people of other ecosystems, but the fact that drylands also exhibit the highest infant mortality rate compared to that of other ecosystems (Fig. 1) may point to a severe relative disadvantage of dryland livelihoods.

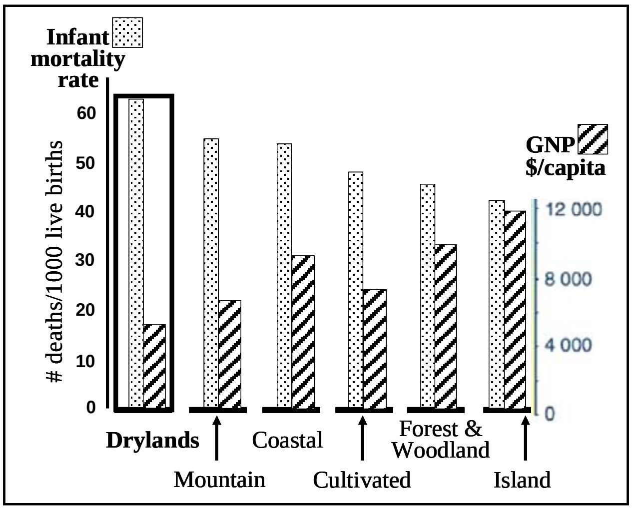

Figure 1. Poverty indicators in Asia (after Millennium Ecosystem Assessment, 2005).

Another product of the MA is an assessment of the average net primary production of the global ecosystems, and not surprisingly, it shows that drylands have the lowest value in the provision of this essential ecosystem service (Fig. 2). But what is surprising is the MA finding that the human population growth rate (during the last decade of the 20th century) was highest in the drylands (Fig. 2). Thus, this combination of the highest growth rate of the dryland population attempting to generate livelihood from the globally lowest natural, inherent land productivity can in itself breed poverty, with no need to invoke desertification. By the same token, this combination of high population growth and low land productivity can pose desertification risk, yet poverty can emerge even prior to the materialization of this risk.

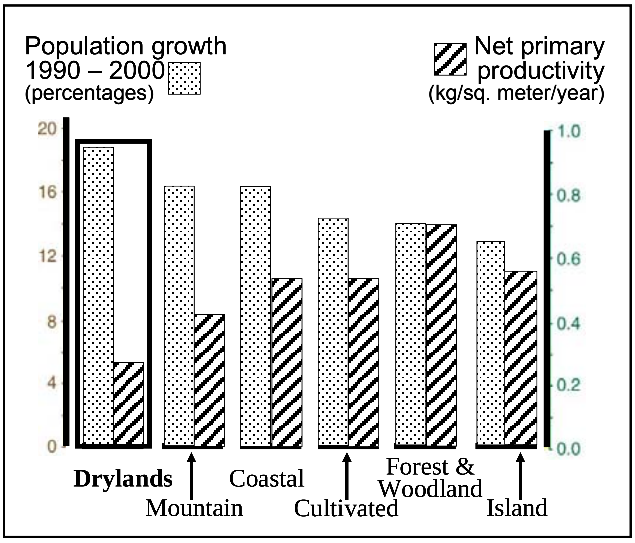

Figure 2. Land productivity and human population growth in ecosystems covering most of the global land area (polar ecosystems excluded). Source: Safriel, 2007.

To conclude, though migration has recently become a problem of a global scale and its link to poverty is undisputable, and though poverty is tightly linked to dryland livelihoods, hard data for attributing either migration and/or poverty to desertification is not available. Therefore, desertification fails to comply with the transboundary impact criterion of globality. Yet, another source of a transboundary impact of desertification may exist, one which is linked to the phenomenon of human-induced global climate change.

5. Climate Change and Desertification

One of the local impacts of human-induced global climate change is the projected increased evaporation (and transpiration) and reduced precipitation in the drylands (Meehl and Stocker, 2007). These combined would lead to reduced soil moisture and hence water availability for primary productivity. This reduced productivity in the drylands is likely to exacerbate global warming, in different ways (Fig. 3). First, the global carbon sink, i.e. the function of photosynthesis in fixing atmospheric carbon, will be impaired by the reduced soil moisture, which is in drylands the limiting resource of productivity. This would also reduce the global carbon reserve in two tracks. First, the overall plant biomass (including the above- and below-ground vegetation cover) which is the live carbon reserve will be reduced. Also, the transport of carbon from the live parts of plants to the soil, in the form of litter to be transformed to soil organic matter, will be reduced. Thus, altogether the rate of increase of the global carbon reserve will be slowed down. In addition to this, the reduction of vegetation cover due to reduced water availability would lead to intensified soil erosion, which in drylands is one of the major expressions of desertification. Most significantly in this context, the carbon stored in drylands soils is likely to be oxidized once soil is eroded and its stored organic compounds exposed to air and water.

Soil erosion thus results in overall increased carbon dioxide emissions from the drylands to the global atmosphere, which intensifies the global warming that further impacts drylands. Similarly, since soil organic matter increases the soil's water holding capacity, the overall loss of soil organic carbon caused by desertification (whether human-induced or climate change-induced or both), causes further reduction of soil moisture in the drylands. To conclude, two positive feedback loops are involved in the desertification-climate change linkages, whereby these two processes intensify their mutual exacerbation (Fig. 3).

The currently evident desertification expressed in soil erosion, irrespective of whether its spatial extent is small or large, or whether or not it has been exacerbated by climate change, already contributed and is contributing to an increase in carbon emissions to the global atmosphere. Similarly, the processes that have led and are leading to soil erosion in the drylands, i.e., reducing vegetation cover due to overgrazing and to transformation of rangelands to croplands, already reduced and are further reducing the sink function as well as the carbon reserve stored in the drylands, which also contributes to global warming and climate change. However, the proportional contribution of drylands to the increased atmospheric concentration of atmospheric carbon dioxide has so far been small (only about 4% of the total global emissions from all sources combined originate in the drylands) (Millennium Ecosystem Assessment, 2005). Yet this amount is expected to increase (Safriel and Adeel, 2005), depending on global emissions and desertification trends. To conclude, whether resulting from the misuse of land by drylands people, or being exacerbated by global climate change, desertification contributes or has the potential to contribute to global climate change. Although the magnitude of the projected contribution is not yet quantified, it attributes a degree of globality to land degradation in the drylands.

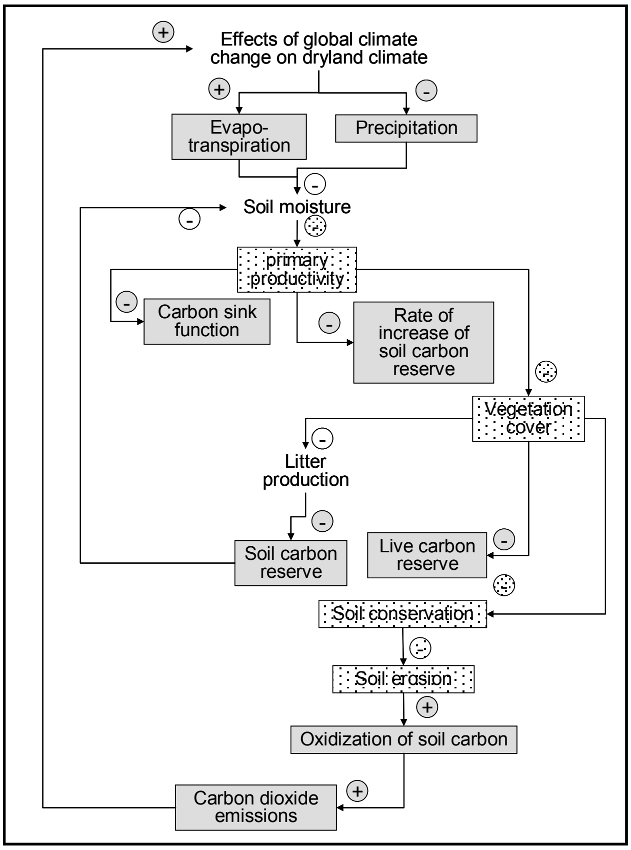

Figure 3. Effects of global climate change on desertification (dotted rectangles) and effects of desertification on global climate change (grey rectangles). Arrows with minus signs stand for reduced rates or quantities, and arrows with plus signs stand for an increase in effect.

6. Global Climate Change and Drylands Opportunities

The UNCCD process has promoted ideas, tools and instruments for addressing, or "combating" desertification, which mostly addresses avoiding degradation of land while aspiring to promote further development of the drylands, mostly through increasing land productivity. Similarly, through the United Nations Framework Convention on Climate Change (UNFCCC) mechanisms to both mitigate climate change and adapt to its effects have been proposed, and these are also expected to assist in avoiding the exacerbation of desertification and in promoting increased drylands' biological productivity. However, by 2050 the projected persistent growth of the global human population is expected to make humanity short of 4.5 million km^2 of good cultivable land for providing its nutritional needs (Safriel and Adeel, 2008). This would bring added pressure on agriculturally marginal lands, those of naturally low productivity, mainly found in the drylands. The mounting pressure may prove to be beyond the ability of handling, by all measures, "combating desertification" through increasing land productivity. Thus, even if the current extent of desertification is relatively small and means to avoid it while promoting land productivity improves, an eventual widespread desertification and poverty are inevitable, since land productivity is not limitless. It is therefore timely to explore alternative livelihoods in the rural dryland areas, ones that reduce pressure on land resources yet promote the human well-being of the growing population. And in this context, paradoxically, the projections of global climate change offer some bright prospects for drylands people. These prospects of alternative livelihoods are in sharp contrast to those of the ominous vicious circle of the desertification-climate change nexus portrayed in Figure 3, in which all dryland livelihoods are based on land productivity.

7. Carbon Sequestration as a Dryland Alternative Livelihood

Following the publication of the Fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report in late 2007, the recognition of the prevalence of the climate change syndrome and the awareness of the need to mitigate it and to adapt to its impacts have become widespread, and the quest for solution is expected to intensify. In this context, it may be instructive to draw attention to the inherent drylands' potential and relative advantage over other areas in promoting the mitigation of climate change at the global scale. The first relevant attribute of drylands is in their potential for mitigation through increasing carbon sinks and reserves. Arresting desertification, restoring the sink function of degraded drylands and even promoting the sink function of the vast non-degraded drylands, for example, through dryland afforestation (Safriel, 2004; Safriel, 2006b; ICARDA, 2007) can have a significant contribution to the global mitigation effort. More importantly to drylands people, promoting the drylands sink can generate a new source of income, under the Clean Development Mechanism (CDM), and other carbon trading mechanisms under the outgoing Kyoto Protocol and the currently negotiated new international legal instruments under the UNFCCC. Note that the sink function is carried out by plants; hence, its promotion as a drylands livelihood still depends on biological productivity. But drylands afforestation for carbon sequestration is not as exploitative and degrading as the traditional pastoral and farming dryland livelihoods.

8. Drylands' Renewable Energy Options

The second relevant attribute of drylands is their potential for mitigation by reducing global carbon emissions, and this is through the development of alternative, renewable energy sources. In two tracks of renewable energy development drylands not only have high potential, but also a relatively competitive advantage. The first depends on biological productivity, but one that is totally detached from the land and its soil – biofuel produced from aquaculture of unicellular algae. Desert aquaculture is an emerging drylands livelihood, mostly practiced in drylands of industrial countries (Safriel and Adeel, 2005), but also in developing ones (Adeel and Safriel, 2008). It has been demonstrated that the water demand of agricultural crops cultivated in drylands is higher than that of aquaculture products cultivated in drylands (Safriel and Adeel, 2005). Furthermore, not only is dryland aquaculture economic on land use and does not degrade it, but also the economic returns of aquaculture products may be higher when cultivated in drylands than when cultivated in non-drylands. Finally, though most aquatic organism cultivated in drylands are fish and crustaceans, algae of high commercial value are cultivated too (Warren, 2006). Much research and development is still required for production of biofuels based on unicellular algae, but this avenue should not be neglected.

Most prospects are of course in harnessing the highly abundant, year-round solar radiation available in drylands as a source of renewable energy. It has been calculated that 4% of the global desert area can provide the whole current global annual energy demand (Safriel, 2004), or that an area of 320 km^2 of the Sahara Desert can provide all the annual energy demand of Europe (Warren, 2006), provided that such areas are supported with installations already equipped with available technologies. Here too, research and development is still required for improving means of electricity storage and transportation, compatible with conditions prevailing in dryland environments. Moreover, research is needed into the cultural, social, economic and political issues that need to be resolved to guarantee that dryland rural communities receive their fair share of the accrued income, as well as that they are rewarded for their contribution to the mitigation of global climate change.

9. Traditional vs. Alternative Dryland Livelihoods

The climate change-induced and other alternative dryland livelihoods are not equally implementable and beneficial in all drylands. It is necessary to recognize that 'drylands' is not a uniform ecosystem but represent a series of ecosystems positioned along an aridity gradient. The position of an ecosystem along this gradient determines the relative advantage of alternative vs. traditional livelihood and the appropriate mix of the two to be practiced. Paradoxically, the economic advantage and relative benefit of alternative livelihoods increases with increased aridity. For example, both aquaculture and solar energy production are more advantageous in desert drylands than in non-desert drylands, due to lower competition on water and land resources in the former than in the latter. Drylands afforestation as a carbon sequestration project, on the other hand, is more advantageous at the boundary between desert and non-desert drylands rather than in the drylands at the two extreme ends of the aridity gradient (i.e. in the hyper-arid and the dry sub-humid drylands). It can therefore be recommended that the climate change-induced alternative livelihoods will gradually replace livelihoods depending on exploitative land productivity as aridity increases. Thus, most efforts in sustainably improving land productivity should prevail in the dry sub-humid drylands, but should cease to be practiced in hyper-arid drylands. Solar energy development, on the other hand, is best practiced in the latter, but also arid areas where aquaculture can flourish. In arid areas, on the other hand, both traditional and alternative livelihoods can coexist (Fig. 4). Furthermore, the alternative ones can provide a backup to the traditional ones. This is because of dependence on biological productivity whereby the latter are highly vulnerable to the climatic and market variations, to which the alternative ones are more resistant.

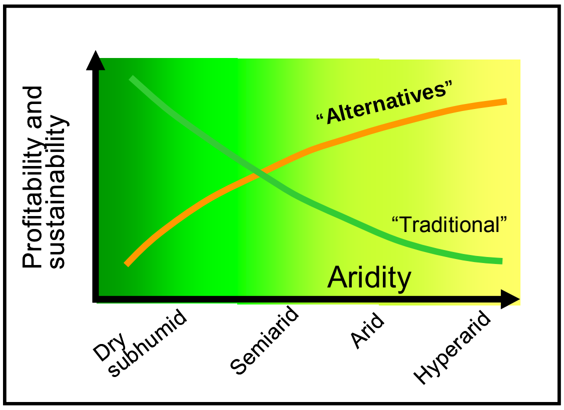

Figure 4. Positioning the mix of traditional and alternative dryland livelihoods along the drylands' aridity gradient.

Conclusion

Regarding the state of current global land degradation, its spatial extent is not yet determined. It has a potential, which might already be partly materialized, to breed poverty in drylands, mainly due to the combination of low natural productivity and high human population growth. The risk of land degradation, especially in drylands, is high and increasing. Both expressions of global change, globalization and climate change, constitute risks and prospects, or pose challenges and opportunities to drylands' inhabitants. As for globalization, the potential linkages between land degradation, poverty and migration are of mounting concern, and the globally dwindling amounts of good cultivable land while population growth continues is likely to generate severe degradation in drylands as well as in other marginal lands. As for climate change, it exacerbates desertification, and may also be exacerbated by desertification. But the need to mitigate it creates new economic opportunities in drylands. Their natural attributes make them highly suitable for developing livelihoods based on solar energy production as well as biofuels based on the culture of aquatic microalgae. Also, mobilizing land productivity for carbon sequestration may become a viable economic option for drylands people. Nevertheless, the prescribed mix of traditional and alternative dryland livelihoods should be tailored to the degree of aridity which characterizes each of the different dryland ecosystems.

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The Global, Social and Ethical Context of Sustainable Land Management

Maryam Niamir-Fuller, United Nations Development Programme[1]

Introduction

Land degradation is a global problem. There is a growing recognition that combating land degradation through sustainable land management is not merely a matter of getting the technology right – it is also imperative that we get the ethics, incentives and policies right

While land degradation is being effectively combated in some parts of the world, this by no means is universal, and along with the prospects of negative impacts from climate change, the situation is expected to worsen in the future. The Millennium Development Goals (MDGs) – the first worldwide attempt to chart a common course with clear deliverables for sustainable development – cannot be achieved if land degradation trends continue. The majority of developing countries with serious land degradation problems are not achieving their goals under MDG 1 (reducing poverty by half by 2015). According to recent estimates, while many regions have been able to reduce the poverty rate, it remains a major problem in sub-Saharan Africa, which is also a region greatly affected by land degradation.

Poor land management by past and present generations has resulted in loss of ecosystem services on a grand scale. The Millennium Ecosystem Assessment (MA) (2005) has helped us to use global statistics more realistically, though the rate of global land degradation is still unclear. But both the MA and the speakers at this Forum have reaffirmed that land degradation occurs in every country around the world, and therefore is of global concern.

1. Socio-economic Conditions

Population increase, a North-South divide in terms of income, energy use and consumerism, and globalization and migration are factors that affect equity and equal access to a minimum standard of human well-being, and affect sustainable land management efforts.

1.1. Population increase and its consequences for the land

The population of the world is increasing; currently, it stands at 6.68 billion people, and is projected to grow to 8 billion people by 2020. The human footprint continues to have a huge impact on natural resources. But we often forget to look beyond the rural landscape. Cities, roads and airports now cover 2% of land area, or 2.6 million km^2. While the global rate of urbanization is now at 48% and increasing, this is no panacea for our rural landscapes: it merely increases the pressure on rural areas to provide more consumerables, such as wood for furniture and paper, or food for feeding the hungry in the cities.

With this increasing population, the competition for land is growing. Croplands and pastures now cover about 40% of the world‘s land area. The Millennium Ecosystem Assessment reported that expansion of cropland into forests and pastures is the single most contributing factor to land degradation. But these croplands themselves are vulnerable to degradation, especially with increasing fragmentation of holdings, declining nutrient load and water holding capacity. The current land degradation rate, if not reversed, will lead to 50% loss in crop yields in the next 40 years, seriously undermining food security, and fuelling a vicious cycle of more cropland expansion into natural areas and competition for land. If these trends continue, we will soon be talking about “nutrient credits” in addition to the water and carbon credits of today.

1.2. Biofuels: a blessing or a curse?

The current demand for biofuels, coming primarily from the commercial transport sector, has already created serious environmental damage where it has been unsustainably produced. While in some countries, such as Brazil, fuel from sugar cane has been sustainably produced in the past decades, the current high demand is raising the spectre of massive land conversion in the *cerrado* (adding to the land conversions for soya beans), in tropical coasts and peatlands through palm plantations, and large-scale conversion of rangelands and other drylands to jatropha. Biofuels can have positive or negative effects on food security, soil and water quality, rural employment and global climate change. This depends on many factors, such as: i) ecological conditions and environmental policies at the local and national levels (protection of virgin lands, certification, etc.); and ii) land ownership, access to finance, and involvement of farmers in the production, processing, use and trade of biofuels.

1.3. The widening income gap

The gap in per capita income between the richest and the poorest countries has widened. While the income gap was 30:1 in 1960, in 2000 it had increased to 80:1. According to the World Bank (WB), 950 million people live under US$ 1/day, which is classified as the threshold for extreme poverty (this figure is equivalent to 17.7% of the developing world). When the differences in the cost of living are taken into account, a WB study shows that if a family of three in India, living on US$ 1/day, were to consume at international standards, then their cost of living in India would be US$ 120/day. Globally, 20% of

[1]Currently with the United Nations Environment Programme.

the world's people in the highest-income countries account for 86% of total private consumption expenditures – the poorest 20% only accounting for a minuscule 1.3% (UNDP Human Development Report, 1998). Specifically:

- the world's richest fifth consume 45% of all meat and fish, while the world's poorest fifth consume only 5%;
- the world's richest fifth consume 58% of total energy, while the world's poorest fifth consume less than 4% of total energy; and
- the world's richest fifth consume 84% of all paper, while the world's poorest fifth consume 1.1% of all paper.

Excluding South Africa, whose economy and power consumption dwarf other nations', Africa's remaining 700 million citizens have access to roughly as much electricity as do the 38 million citizens of Poland. Much of this electricity goes to industry: a single aluminum smelter near Mozambique's capital, Maputo, gobbles four times as much power as the rest of Mozambique, and fewer than one in four sub-Saharan Africans are hooked up to national electricity grids.

1.4. Environmental migration

Extreme poverty and increasing income differentials, combined with environmental degradation in both rural and urban areas, is fuelling the highest rates of environmentally induced-migration ever seen. It is not easy to arrive at definitive estimates of people that have been displaced due to "slow" environmental factors (as opposed to environmental disasters), as the interaction between the environment, other push-pull factors and migration makes this a complex process. Global and regional statistics on environmental migrants is lacking and largely anecdotal. For example, in 1994, the Almeria Statement indicated that 135 million people could be at risk of being displaced as a consequence of severe desertification. Oxford University has used the figure of 150 million by 2050, estimating the number of people displaced by climate change in China alone at 30 million (Lambert, 2002) More recently, Christian Aid (Christian Aid report, 2007) has brought attention by estimating that 1 billion people will be displaced globally by 2050 due to environmental degradation. Even the smallest of these estimates exceeds the number of refugees displaced by war.

The main question is: with such massive mobility, how can the ethic of land care remain internalized, practiced, and protected? It is recognized that some mobility is inevitable, and even a necessity (e.g. urbanization, labour mobility and remittances, movement to adapt to climate change, reducing human footprint on ecologically sensitive areas, etc.). However, forced migration, and especially that forced by environmental degradation, can displace people off the land, reduce their incentives to take care of the land, and increase incentives to exploit ecosystem services for short-term gain.

As Daily and Walker said, with the increase in globalization and multi-lateral corporations, the power of governments to influence the management of natural resources has diminished (Daily and Walker, 2000). In many cases, it has been reduced to a role of managing conflicts between corporate and business interests and local traditions. At the same time, there is a growing movement for localization, manifested through increasing decentralization of government decision-making, the Slow Food movement and other "local is good" advocates, and scientific recognition of the value and power of traditional systems of natural resource management. All of these forces affect decisions taken on land use and land care, but very rarely do they work with each other.

2. Enabling Environment, Policies and Markets

Weakening environmental governance and land tenure insecurity are major impediments to sustainable land management. Relatively limited public funding for sustainable development has fuelled a growing desire for harnessing the power of markets. And yet, the markets themselves have never been good at ensuring equitable distribution or protecting the rights of the poor.

2.1. Linking markets with sustainability

According to Transparency International, of the 163 countries they surveyed in 2005, only 12 have significantly improved their overall corruption rating since 2000. Corruption surrounding the extraction of natural resources, particularly forest resources, has brought local environmental governance to its knees. Corruption in the forestry sector is widespread in many countries due to: strong international demand for consumer products; weak environmental ministries that do not have enough strength or budget to adequately control forest industry and production; powerful economic groups that benefit from illegal logging; and strict legislation (permit procedures, field level monitoring, enforcement), causing high costs for producers who need to access the market and facilitate government documentation (Brown & Wells, 2004). There is a need to reform the regulatory framework for the industry and reduce transaction costs while targeting institutional corruption through strengthening of land rights, simplification of administrative procedures, access to information and greater transparency, awareness in consumer markets, and the promotion of sustainable forest management that will be more prone to exclude free riders from the market place. The European Union's decision to move towards 100% purchase of certified timber by 2010 is a major step forward that should be emulated worldwide.

2.2. The dependence on land

Land is a key component in today's interconnected poverty and environmental challenges. It is the primary means by which many in the world earn a living, invest, accumulate, and transfer wealth between generations. We now know that secure tenure and secure access to natural resources allow rural communities to invest in the future, and organize and gain strength in their negotiations during contractual agreements, be it with the government or the private sector. But land is also at the source of much political volatility, as competition in access to land and resources has often led to tensions locally, regionally or internationally. The unstable peace situation in Côte d'Ivoire, for example, is a consequence of a politically motivated eviction of rural workers of foreign origin from lands they had been using for generations. In Sudan, a history of successive conflicts erupting in rural areas in the wake of droughts and famine pitted pastoralist herders against sedentary farmers. In the Sudanese government's absence of reaction and the lack of systems to handle disputes, the population armed itself, which initiated decades of civil war (Flint and de Waals, 2005).

2.3. Funding for environmental services

Public funding for development has only recently seen a modest upward trend. Official Development Assistance (ODA) from the Organisation for Economic Co-Operation and Development's (OECD) Development Assistance Committee (DAC) to developing countries rose to a record high of US$ 106 billion in 2005 (OECD DAC, 2005). This represents 0.33% of DAC's combined Gross National Income (GNI), not quite as high as the 0.7% target established by the UN General Assembly, and still about US$ 20-50 billion short of the ODA levels needed just to meet the MDGs. The share of ODA's GNI allocated to environmental issues, such as energy access and water, has actually dropped. Estimates are that only about US$ 2-6 billion will be available annually from 2010 onwards for environmental issues (including sustainable land management). Other sources of finance need to be explored to address pressing environmental priorities.

Payment for environmental services (PES) schemes in various forms are being developed. Though the greatest potential in PES systems is in the fisheries sector, the expected amount from cap and trade markets, such as carbon finance, are estimated at US$ 14 billion annually post-2012, and this could raise resources several times greater than what is available through ODA, and influence global investment decision-making. However, as can be seen in the deliberations of Working Group 3 of this important Forum, there are several key barriers to the compliance markets that prevent the market from investing in projects that provide benefits to both global warming and sustainable land management, among them: the high upfront costs and perceived risks involved; difficulties of accessing upfront financing; access to information on technical options; proven but not mature technologies; and, the issue of ownership of carbon credits.

The majority of Clean Development Mechanism (CDM) projects, as defined in Article 12 of the Kyoto Protocol, are located in China, Brazil and India, and the current investment in carbon sequestration from Afforestation/Reforestation projects in the CDM is only 0.2% of the market. In the majority of low income developing countries, the greater part of the carbon flux is from the agriculture and land use sectors, not from the industry and energy sectors.

Lal (2001) has estimated that the dryland carbon reserve is being depleted at the rate of 0.23-0.29 billion tonnes carbon per year due to land degradation. If this amount of carbon were to be sequestered through land restoration techniques, at the current market rate of US$ 5 per tonne of CO_2e, it would mean an annual investment return of US$ 4.2 – 5.3 billion per year.

Voluntary markets have seen this potential for carbon sequestration and are now "picking up steam", as the Katoomba Group has assessed (Hamilton et al., 2007). Forestry projects make up 36% of the volume of voluntary markets, or about US$ 32 million per year, with a substantial amount being traded in South America and Africa. However, the prices paid for verified emission reductions (VER) in the voluntary carbon markets can be very volatile (e.g. ranging from US$ 3/tCO_2e, to US$ 45/tCO_2e), and the voluntary markets are affected by the same barriers as the compliance markets when it comes to benefiting poor countries. The current debate on developing a post-2012 Kyoto regime is an important part of the global policy debate, to which the International Forum in Iceland is expected to contribute.

There is a growing trend of treating environmental services (especially regulatory and production services) as marketable commodities through different PES schemes. Biodiversity credits, certification schemes, water credits and carbon credits are already in the mainstream. Some are talking about pollination services (especially with the recent disastrous reduction of the bee population in North America). Such schemes have the potential to mobilize billions of dollars from the private sector for environmental protection. However, some are questioning the ethics of treating such common and global goods as commodities. The key ethical issues that need to be considered are: Who owns the credits? Who benefits from the credits? Can ownership of carbon emission reductions (CER) be separated from ownership of land? Is there a risk that governments will "nationalize" CERs as they have land, water or other natural resources? How do we ensure "fair trade" when it comes to these environmental markets? Will the private sector take advantage of the lack of knowledge of local communities and purchase land at rock bottom prices? Such questions need to be considered before we can move forward in an equitable way.

Conclusion

In conclusion, land stewardship is a time-honoured concept common to all races and ethnic groups. However, the ethical use of land and its resources cannot survive alone on a concept, and indeed, in many places it is already lost. Policies, incentives and mechanisms for sustainability need to support both a "horizontal" equity (the now) and an inter-generational equity (a sustainable future). Horizontal equity requires that we fix problems generating from: inadequate or conflicting land and natural resource tenure/access; poor governance and decision-making; and, population growth and displacement. There are quite a few good practices and successes to draw from. But perhaps our biggest challenge today is how to scale up these good practices for the future, and to ensure access by all to increased well-being and healthy soils and ecosystem services. Ethical policies and sustainable financing (including the ethical use of the carbon markets) are key challenges that we hope to move forward through our dialogues and actions of this Forum.

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Land Degradation/Desertification, Society and Global Climate Change in Latin America

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Introduction

Global climate change and desertification – the land degradation of drylands due to factors including climate variations and human activities – are among the most serious environmental challenges facing the world today. Both processes entail dramatic situations of economic losses, poverty and migration. This paper provides an update on drylands and desertification status in Latin America. We introduce the issues related to climate change and desertification in the Central Andes Region and in some selected Sustainable Land Management and Desertification Combat Experiences. The processes that are affecting the Andes Mountains and the settlements in their areas of influence, likely to be extrapolated to other drylands in the world, can be used to identify good and bad environmental practices and the lessons learnt from previous experiences.

1. The Future Facing a Changing Scenario: Synergies between Desertification and Global Climate Change

According to the latest Intergovernmental Panel on Climate Change (IPCC) report, the mean temperature of the Earth has risen 0.74°C (0.56 - 0.92 °C) since the beginning of the 20th century (IPCC, 2007). Desertification affects the ecological and economic productivity of more than 30% of the world's drylands (6150 M ha), entailing dramatic situations of poverty and migration. Data from the United Nations Environment Programme (UNEP) (1990) show that 6 M ha/year are lost to desertification processes, representing a financial loss of US$ 42 billion/year in the early 1990s. An economic assessment of the impact of climate change, recently presented by Sir Nicholas Stern (2006), estimates that the impact of global warming at the end of the 21st century could cost as much as 20% of the world's gross domestic product (GDP). According to Stern (2006): "All countries will be affected by climate change, but the poorest countries will suffer earliest and most. Deeper international cooperation will be required in many areas, most notably in creating price signals and markets for carbon, spurring technology research, development and deployment, and promoting adaptation, particularly for developing countries".

Spatial and temporal variations of the Palmer Drought Severity Index (PDSI), a good proxy of both surface moisture conditions and streamflows, reveals that the global very dry areas, defined as PDSI $<$-3.0, have more than doubled since the 1970s, with a large jump in the early 1980s due to an ENSO (El Niño Southern Oscillation)-induced precipitation decrease and a subsequent expansion primarily due to surface warming, while global very wet areas (PDSI$>$3.0) declined slightly during the 1980s (Dai et al., 2004). Together, global land areas in either very dry or very wet conditions have increased from 20% to 38% since 1972, with surface warming as the primary cause after the mid-1980s. These results provide observational evidence for the increasing risk of droughts as anthropogenic global warming progresses produce both increased temperatures and increased drying (Dai et al., 2004). These general concepts and processes become much more evident at the regional and local level where the effects and synergies are starting to be visible. The challenge is to analyze how society and the economy will prevent and adapt to these changes.

2. The Situation in Latin America

Contrary to the widespread perception of Latin America as the green subcontinent, with rainforests and woodlands from the Caribbean to the southern tip of South America, drylands – affected by different levels of desertification - comprise 25% of the total land area. Data from the year 2000 indicate that these dryland areas are inhabited by 519 million people, which represents 28% of the total population. Thirty-five percent of this population lives in conditions of poverty, and 16% live in extreme poverty. Unlike other continents, such as Africa for instance, Latin America is urban (75% of the population lives in urban areas) and its deserts are, in the most complete sense of the word, uninhabited areas or areas with very low population density, except for points of population concentration in coastal urban areas such as Lima, Peru.

Desertification in Latin America, as elsewhere in the world, is a combination of natural risks – critical in drylands – and the human pressure that overloads and affects the biological and economic productivity of drylands ecosystems. Outstanding among natural phenomena are the effects of sustained and recurrent droughts; dust storms; pronounced climate oscillations in the semi-arid and dry sub-humid areas; El Niño-Southern Oscillation phenomena affecting land uses in coastal and inner areas; and, reduced snow precipitation in the mountains affecting water supply for settlements in the Andes foothills.

These natural risks should be linked to the human pressure derived from the socio-economic and political situation of the countries in the region: massive deforestation of rainforests and woodlands from the tropical Amazonia to the cold rainforests of Patagonia, including the sub-tropical dry woodlands; accelerated loss of biodiversity; overgrazing and decline of productivity in savannas, grasslands and shrublands; growing rural-urban migration, desertion of productive lands and increased levels of rural, urban and sub-urban poverty; salinization/alkalinization and water table logging in irrigated lands; affected quality and quantity of surface and ground water resources; degradation of soils with high agricultural capacity; unplanned extraction of non-renewable resources (mining, oil); quick loss of traditional knowledge and values; non-desired land use changes; accelerated and unplanned urbanization; foreign debts jeopardizing processes of local development and growth; loss of infrastructure (silting of dams, dredging of harbours, destruction of roads and railroads, bridges, etc.); lack of hierarchies in environmental policies at the national level, among them the combat of desertification; strong processes of poverty and migration; soil loss and salinization; misuse of water resources; and, loss of biodiversity. According to UNEP (1990), desertification reaches alarming figures in South American drylands: 305.81 M ha, over a total of 420.67 M ha of agricultural lands, are degraded (72.7%). Grasslands (390.90 M ha) are the most affected: 297.75 M ha (76% of their total area). In rain-fed lands (21.35 M ha), 6.64 M ha are degraded (31%). In irrigated lands (8.42 M ha), 1.42 M ha are degraded (17%). It is estimated that direct measures to combat desertification to recover a total affected area of 8,415,000 ha in the irrigated drylands of South America would amount to a global cost ranging between US$ 2,024,000 and US$ 5,211,000.

There is clear evidence that South America is experiencing unprecedented climate change. For example, a major retreat of ice bodies during the 20th century has been documented along the Andes, from the tropics in Venezuela and Colombia to the southern tip of the continent in the sub-Antarctic domain (Francou et al., 2005; Ramirez et al., 2001; Leiva et al., 1989; Villalba et al., 2005; Masiokas et al., 2007). The observed general glacier retreat in the warming tropical Andes has increased significantly in recent decades (Francou et al., 2005). Small-sized glaciers are particularly vulnerable in warmer climates, with many of them having already disappeared in several parts of the world during the last century. In many localities across the Andes, reduction in glacier area has been associated with negative trends in snow precipitation and in the Andes rivers run-off. Although in recent decades some basins in the tropical Andes have experienced an increase in run-off as a consequence of glacier retreat, in the long term there will be a reduction in water supply as the glaciers shrink beyond critical limits (Jansson et al., 2003). Recent glacier recession has also been documented throughout the Patagonian Andes. Temperature records in north Patagonia show significant warming, which has been concurrent with negative trends in regional precipitation and streamflows. These climatic variations are largely responsible for the widespread glacier recession documented for northern Patagonia. The south Patagonian region has warmed significantly during the 20th century and also experienced a concurrent, widespread glacier mass loss. On the contrary, the increase in the humidity levels of air masses coming from Amazonia and the sub-tropical Atlantic provokes the arrival of major precipitation events during the summer on the plains east of the Andes. In many cases, these incoming wet air masses are associated with more extreme storms, many of them accompanied by severe hail. These contrasting trends between reduced precipitation in the Andes and abundant rainfalls in the plains are consistent with an increase in humidity proceeding from the Atlantic in the sub-tropical region, and with a decrease in the Pacific contribution to approximately 20°S through to the southern extreme of the continent. Taking advantage of the good performance of the General Circulation Models (Labraga and Lopez, 1997; Labraga, 2005) to reproduce the atmosphere's dynamics associated with the seasonal changes in precipitation in South America, it is interesting to examine different simulation results considering possible future changes across the continent. Figures 1 and 2 present the changes in temperature and precipitation for summer (December to February) and winter (June to August) months projected for the period 2080-2099 in comparison to those from 1980-1999 over Central and South America from the MMD-A1B simulations averaged over 21 models (IPCC, 2007).

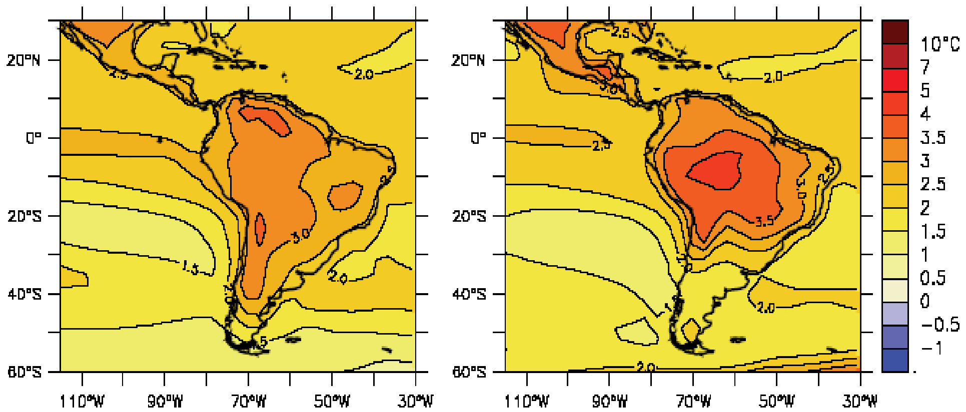

Figure 1. Changes in the summer (December to February, left) and winter (June to August, right) mean surface temperatures (°C) in South America for the interval 2080-2099 in comparison to1980-1999 from the MMD-A1B simulations (from Christensen et al., 2007).

In general, the simulations indicate a similar seasonal increase in temperature in tropical regions, but a larger increase in summer than winter in mid- and high-latitudes in South America (Figure 1). The expected increment of the summer temperatures for the period 2080-2099 is above 3 ºC over the Andes and the plains in the central sector of the continent north of 40ºS. These changes will cause an increment in the regional evapo-transpiration values, alter the proportion of liquid and solid precipitation and the seasonal distribution of the rivers' flow, with an earlier occurrence of peaks of run-off.

The climatic simulations for the period 2080-2099 indicate that the summer precipitation in the subtropical plains will increase between 15-20% (Figure 2). This increment contrasts with a decrease of the same magnitude or even larger in the Central and Patagonia sectors of the Andes Cordillera. There are no expected changes in the winter precipitation in the flat regions, but in the Central Andes of Argentina and Chile there will be a substantial reduction of 20-30% (IPCC 2007; Figure 2). It is important to note that the results of these climatic simulations for the interval 2080-2099 are clearly consistent with the trends recorded in precipitation during the 20th century.

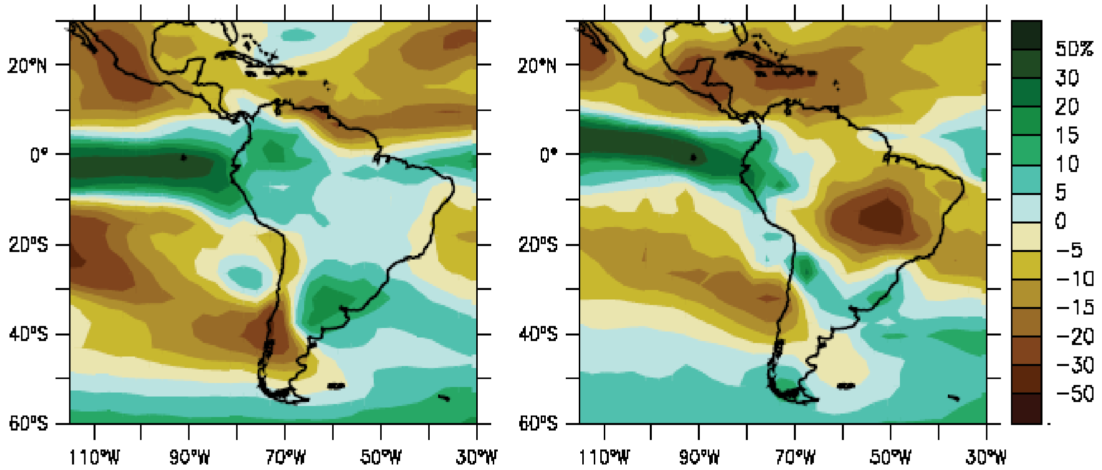

Figure 2. Changes (%) in summer (December to February, left) and winter (June to August, right) precipitation in South America for the interval 2080-2099 in comparison to 1980-1999 from the MMD-A1B simulations (from Christensen et al., 2007).

3. Desertification and Climate Change in the Southern Cone: the Central Andes Region

A transect running at 32ºS, from Valparaíso on the Chilean coast to the Desaguadero river, in Mendoza, Argentina, shows that both sides of the dry Andes face a similar problem: an increasing demand for water resources to sustain urban, agricultural and industrial development (Figure 3). In central Chile, the Metropolitan, V, and VI Regions contain ca. 8.4 million people (55% of Chile's population). About 48% of the annual discharge of the Maipo River (the main water source for Santiago) is withdrawn to meet these needs. Central Chile also accounts for about 45% of the total irrigated area of the country. On the eastern Argentinean side of the central Andes, the rivers serve a population of ca. 2.2 million people in the provinces of San Juan and Mendoza. With less than 200 mm of precipitation per year, agriculture must rely on irrigation. Hydro power plants fed by the Cordilleran rivers generated 62% and 86% of the total domestic energy generation in Mendoza and San Juan, respectively. Special mention is made of the situation of the vast eastern fluvial aeolian plains lying along the Argentinean eastern slope that constitute storage units of water resources, both ground and surface water. In favoured sectors, the beneficial action of rivers has resulted in a Mesopotamian model on the wide alluvial fans. These are the "oases", where the combined offer of water and soils has allowed for the creation of irrigated crop areas and the settlement of cities that articulate their irrigated space of influence in a viticulture agricultural model. These oases and cities, whose main representation is Mendoza - where 97% of the population is concentrated in 3% of the territory – decrease in magnitude from north to south. These are the places where systematized irrigation and joint use of ground and surface water resources are practiced, and where dams for water distribution are built. But these are also the places where water use is more inefficient and land is more highly degraded. And beyond the isolated patches - like green islands – of the oases lies the non irrigated desert, with its immense range of different environments linked by dryness. The desert, which we call "our invisible space" (Montaña et al., 2005), has been neglected by politicians and decision-makers.

These are practically uninhabited drylands – less than half an inhabitant per square kilometre – subjected to accelerated processes of desertification due to abusive use of resources. The irrational management of resources brings about increasingly critical situations: expansion of saline areas and exodus of rural people; decreased carrying capacity of the grazing lands due to their loss of productivity; and the consequent concentration of the rural populations in cities under poorer living conditions.

Our deserts show contrasting activities. On the one hand, subsistence pastoral activities (extensive goat breeding only for meat production) have a strong impact on the fields due to overgrazing. On the other hand, the oil and mining industries extract the richness from the substrate without improving the local territory, many times polluting the water resources. People living there are mainly affected by the lack of water, in both amount and quality. The desert stores water at great depths (in many cases with arsenic), which makes this resource inaccessible to its few inhabitants who have to manage with rudimentary wells and reservoirs. One of the major desertification processes was the logging of the native woodland. At a depth of between 5 and 15 m, the water table feeds the dry open mesquite woodland (*Prosopis spp*.), which deserves particular attention because of its importance to the population. Today, it has practically disappeared. Studies conducted on environmental history show the decline of the woodland in the desert. It was cut down and used to build the viticulture and wine-growing oasis. In a 35-year period, from 1901 to 1935, during the railroad expansion, 992,748 metric tonnes of forestry products were cut down, a total of 198,550 deforested hectares (Abraham & Prieto, 2000). This wood from the desert has been used in the oases as vineyard poles and props. Such studies are important when desert development policies are defined.

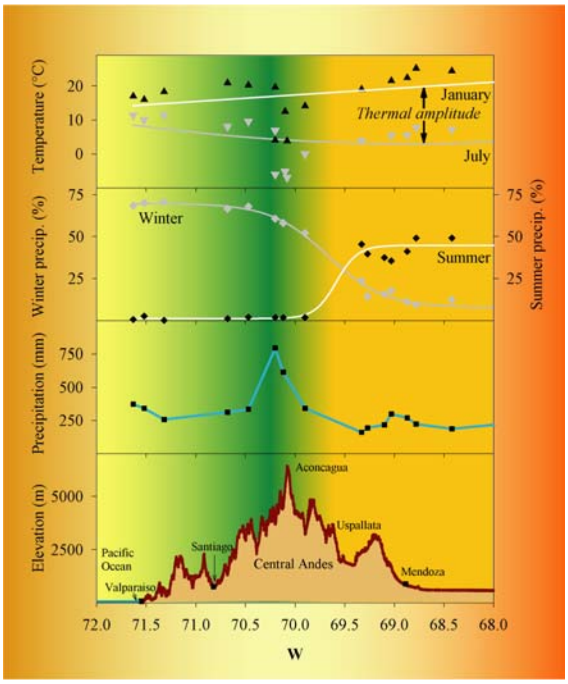

Figure 3. Transect across the Central Andes at approximately 32◦S, showing changes in mean January and July temperatures (upper), in seasonal (summer and winter) precipitation distribution (middle), and in total annual precipitation (lower) associated with topography (bottom). Locations of the meteorological stations are indicated by triangles (▲) in (upper), diamonds (♦) in (middle), and squares (■) in (lower). Meteorological stations in the latitudinal band between 31◦30'S and 32◦30'S have been included in this transect.

Another important desertification process was the use of water in high and medium river watersheds for irrigating the oasis, which resulted in the drying of wetlands in the desert. Several important wetlands (one of them a Ramsar site: "Lagunas de Guanacache") stretched along the margins of the low basin, supporting great biodiversity. The use of the water of rivers for irrigation has stopped their course, and now they are mere sand rivers that no longer carry water, with the logical outcome of wetlands drying. In addition, actions for land recovery and control are scarce and insufficient. The main processes, deforestation, overgrazing, expansion of the agricultural border, urbanization, salinization and water table rise in the oases, land desertion and poverty, continue to bring serious consequences to land degradation.

But, facing the possibility of climate changes at a global scale, the major problem that confronts the region is the uncertainty about climate behaviour in the long/medium term. Scientists warn that 70 years from now the current amount of rain in the sub-tropical plains at middle latitudes of South America might significantly increase, whereas a drastic decrease of snow precipitation will take place at the same latitudes in the Andes Cordillera. Summers will be rainier in the regional plains. In response to global warming and hence, to a more dynamic atmosphere, summer precipitation will be linked to convective storms, with heavy rain and severe hail. Convective storms will affect crops and human settlements, also augmenting the possibility of floods and mudflows in the mountain and piedmont zones. Simultaneously with these changes in the plain, snow precipitation will diminish in the Cordillera during the winter (Table 1). In the present day, the mean Cordilleran precipitation is 250 mm and according to scientists' projection, by the end of the century it will be substantially reduced.

Table 1. Impacts of climate change on ecosystem services across the Central Andes.

ECOSYSTEM COMPONENT	ECOSYSTEM SERVICES	IMPACT OF CLIMATE CHANGE	IMPLICATIONS
Glaciers and snow fields	Provide freshwater to downstream ecosystems	Reduction in annual streamflow	Irrigation in the Central Andes Hydropower generation in the Central Andes and North Patagonia
		Timing of snowmelt	Irrigation in the Central Andes Hydropower generation in the Central Andes and North Patagonia
	Enhance recreation opportunities & aesthetic values of landscape	Reduction in winter recreational opportunities	Visitor satisfaction
		Loss of landscape icons	Tourism revenues related to water-based recreation across the Andes
		Summer streamflow	Increasing "summer drought" in Northern Patagonia Salmon production in Northern Coastal Patagonia

How will the local societies and economies cope with these environmental changes? The water from snowmelt will diminish while summer precipitation will augment, posing deep changes in the management of natural resources. A higher efficiency will have to be achieved in the use of water proceeding from the Cordillera, as it will tend to diminish with time. The unfavourable effects from future increases in summer precipitation will have to be mitigated. These changes could lead to a change in the regional productive activities and, possibly, to a change in the traditional culture of water management in many regions in South America. If we add the generalized desertification processes in practically every ecosystem to this changing climatic scenario, vulnerability increases even more. In a changing world where humid places will be subject to progressive dryness, and the other way around, the map of desertification is likely to change, and so the need will arise for those who already know about the changes that desertification processes entail to transfer their experiences and knowledge to all those unaware of the consequences of land degradation. It is vital to link the experience generated by the United Nations Convention to Combat Desertification (UNCCD) in relation to concrete and practical measures to prevent and combat desertification with the important scientific findings of the other environmental conventions. Thus, the lessons learnt from experiences on sustainable land management become valuable. An instance of a procedure towards an integrated assessment of desertification was developed to launch a case study of Sustainable Land Management and Desertification Combat in the dry central Andes of South America (Abraham et al., 2006).

As a basic conceptual framework, soil was assumed as an environmental issue, as a nexus for the multiple interactions between the natural and social systems that go beyond sector dimensions which are exclusively related to biophysical aspects. This means that soil must be regarded as a *complex problem*. Understanding the environmental problem of soil as an environmental issue requires a theoretical-methodological treatment in transdisciplinary terms that would contain the uncertainty levels typical of complex systems, surpassing simple approaches of reality referred to classificatory structures of thematic variables (land, water, vegetation, demography, etc). How can we deal with the complexity of such an issue? This degree of complexity can only be tackled through the use of Integrated Assessment (IA) and a participatory approach to be able to obtain a Sustainable Land Management Procedure, which means, in practice, linking the generation of knowledge with intervention actions. IA is known (Freitas, 2000) as the intersection between a vertical integration of actors and interests and a horizontal integration of disciplines and sources of knowledge and allows to confront the multiple dimensions of the environment by encompassing natural and social sciences to provide integrated scenarios, likely to simultaneously consider economic, social, ecological and political issues.

4. Sustainable Land Management, Local Level Monitoring, and the Participatory Approach. Case Study within a Case Study?

The Lavalle desert in Mendoza, Argentina is an area with natural, environmental and cultural conditions highly representative of drylands of the Monte desert that stretches for over 614,000 km^2 and other countries in Latin America. This case study has been conceived in the framework of a "research-action" methodology. It includes basic surveys and the obtaining of desertification benchmarks and indicators to the implementation of a "Demonstrative Production and Services Unit" and the "Desert Observatory" to monitor the impact and response of the project (Pastor et al., 2005). The latter is underway at "La Asunción" locality in the core of the Lavalle desert, with the active participation of local actors, mainly the local government and the indigenous communities (Huarpes) in synergy with the scientific/technological sector. While the holistic approach to sustainable land management and desertification prevention is a major improvement compared to the sector approaches of the past, it is a major nightmare for anyone wanting to assess the impact of a sustainable land management programme. In a way, it is on theoretical grounds that we assume that knowledge management, capacity-building, creation of an enabling environmental policy, in addition to on-the-ground interventions, is much better than the traditional technical assistance.

The context of action is the Lavalle desert (10,197 km^2), with a population of 3,213 inhabitants, a disperse population that does not exceed 0.33 inhabitants/km^2. This is the desert where some of the Argentina aridity poles are located (mean annual rainfall is 80 mm at "El Retamo" locality). The main economical activity is a subsistence production system based on goat breeding for meat and manure. The current production system is characterized by high territoriality and individualism, low profitability and negative impact on the ecosystem productivity. Only goat meat is produced, with a survival rate of only 30% of kid goats, because of the winter parturition, when the forage supply is minimal in these desertified lands. Leather is not used, milk is not produced, and the goats are actually only used as a device to produce manure, which is the most looked-for product, and this leads to overstocking, overgrazing and worsening of sanitary conditions. The use of goat livestock at the family scale entails excessive number of goats, extensive grazing techniques, serious problems in land tenure and property, problems in herd sanitation (brucellosis, tuberculosis), and scarce drinking water contaminated with arsenic (HACRE, or Hidroarsenicismo Crónico Regional Enémico).

After more than twenty years of non-stop work on research and transfer in relation to the development of the drylands in Mendoza, the north-western region of Argentina, the Laboratorio de Desertificacion y Ordenamiento Territorial of IADIZA (LaDyOT/IADIZA) began in 2003 to develop and implement the project "Strategies for local development and combat of desertification and poverty in indigenous local communities of the Argentinean Monte desert" through a partnership with the Municipality of the town of Lavalle and the indigenous Huarpe Community of La Asunción, with the financial support of the Argentine-German Technical Cooperation Agency (GTZ), the Federal Investment Council (CFI) and other institutions such as the Inter-American Development Bank (IADB), Land Degradation Assessment in Drylands – Food and Agricultural Organization of the United Nations (LADA-FAO), and the National Secretary of Science and Technology in the framework of the National Action Programme (NAP) for Argentina. This work addresses as its main goals: to combat land degradation and develop a rural/local/sustainable development model that combines the best options for combating desertification among all participants:\; to take the challenge of incorporating deserts in economic and production circuits, according to the motto "living with the desert" rather than combating it; and, to show that the cooperation of scientists, non-governmental and governmental organizations, local governments and communities is possible within a research-action proposal, based on the acknowledgement of the potential existing in the desert, going beyond both compensation- and assistance-based approaches. It is framed within a rural territorial development conception, with the purpose of integrating a rural desert land into dynamic territories in a competitive and sustainable way. We started a process of intervention based on the intensive use of endogenous resources that proposes to generate more sustainable development strategies in rural indigenous communities of the Mendoza desert, to improve the status of the ecosystem through an integrated management of natural and cultural resources, and to promote improvement of the socio-economic conditions of the inhabitants of drylands. Among the objectives, we can highlight the will to have an incidence on current production practices by incorporating conservation concepts and experiences in herd management, preservation and validation of the natural and cultural heritage, reforestation and revegetation of degraded lands, animal and human health, social organization, irrigation efficiency, waste recycling, use of water resources and non-conventional energies, production of organic manure, tourist and cultural services, and fundamentally, obtaining healthy food products.

The work methodology for desertification assessment (Abraham et al., 2006) is based on the design of a participatory procedure where, starting from the identification and prioritization of problems and objectives, we obtain and evaluate desertification indicators and, on the grounds of the shared knowledge of the system and of the desertification processes affecting it, all actors together design the impact hypothesis and the intervention actions. All this will be incorporated into an Integrated System for Desertification Assessment and Monitoring, located *in situ*, at the “Desert Observatory”. Thus, we designed a system based on partnership-building among small producers, where each contributes as many parous goats as possible. These goats are housed at the UPYS (Pilot Unit of Production and Services): a sort of “hotel for goats”, designed to keep them most of the year in order to produce milk, milk by-products, kid goats, sanitation, food supplements, information, basic and applied research and eco-tourism products. The outputs we expect to achieve are: a desert-adapted production system for healthy food (pastures, composting and vermiculture); a laboratory for primary sanitary control of goat herds; a reforestation nursery; an observatory of processes to measure desertification and land recovery; and, an interpretation center for education, transfer and tourism. The numbers are clear and speak for themselves of the direct impact that is being generated in the framework of the recovery of degraded lands and the economy of the production unit “puesto”: only 28 goats incorporated into the UPYS system yield the same profit as the system generated by 200 goats in the current mode of exploitation. Therefore, only 56 goats included in the system are needed to double the family’s monthly income, versus more than 400 in the current mode of work. That is to say that, besides decreasing the pressure of overstocking rate on the fields, their recovery and improvement is being promoted through a reduction of stocking rate and through reforestation and revegetation with native species.

Thus, a highly significant change is being fostered by positioning the producer above the poverty line, a change that is, moreover, easily perceived by the population, and that entails high commitment of adherence to the Project, within a feedback process. This means that, at a local scale, the progress of desertification processes is being reversed and poverty indices are effectively being diminished.

5. Linking Local to National/Regional/Global Levels: Different Scenarios, Depending on the Development Styles Adopted

Integrated Assessment is a good tool at the local level but, rising in scale, the challenge is to relate local progress to progress at national, regional and global scale. In this sense it is essential to discuss and agree on the development model we want for drylands. Among which development models in drylands can we choose?

The inherent fragility of drylands and the high risk they are exposed to under conditions of global change can only be overcome with knowledge, planning, political will and investment. There also needs to be a consensus on the style of development which will be implemented to overcome this fragility and risk. This may change among different scenarios and models that fluctuate between the extreme of those who propose huge transformations in the natural conditions of desert areas – with major investments in capital and infrastructure, best known as “Cadillac” (Ezcurra Ed., 2006), of which the best current exponent is Las Vegas or the megacities of the Gulf, completely separating society from nature - and those in the opposite extreme who want to “leave everything as it is”, not modifying anything in the ecosystem. This last position is supported by groups of extremist “ecologists” who are opposed to any kind of intervention. Midway between these extremes is the view of a sustainable development of drylands, directed towards territorial balance and social equity: the so-called “development in patches” that attempts – based on deep knowledge of the potentials and restrictions of drylands and of the demands and needs of the population – to develop those desert environments showing the least restrictions and the best conditions for settlements and production (corridors, wadis, oases, terraces, sand dune bases) and to restore and preserve the rest of the territory. This model is what we call the Gobabeb model in the Global Deserts Outlook (Ezcurra Ed., 2006), after the homonymous locality in the Namibia desert, where these experiences have been successfully developed. Whichever model we choose, the consequences are quite predictable, and the inherent fragile conditions of degraded lands can only be overcome with: knowledge, planning, political decision, investment, and agreed/equitable development models directed to territorial balance, social equity and sustainable development.

These models can be linked in their effects to the scenarios developed by global climate change experts for worldwide scenarios of climate change associated with the development styles adopted (Figure 4).

Whatever the development model selected, it must be implemented within the frame of a planning and management process, where the generation of knowledge to monitor changes can be given hierarchy and earn importance. This measurement of the status, pressure, impacts and responses, incorporated into an integrated assessment and follow-up system, must be part of a new attitude that values the contributions of science and technology, as a guide for decision-making. If, in addition, this can be achieved through a participative process of knowledge construction, we would be able to advance with more certainty on the road to sustainability, with a more equitable society, in harmony with dry environments.

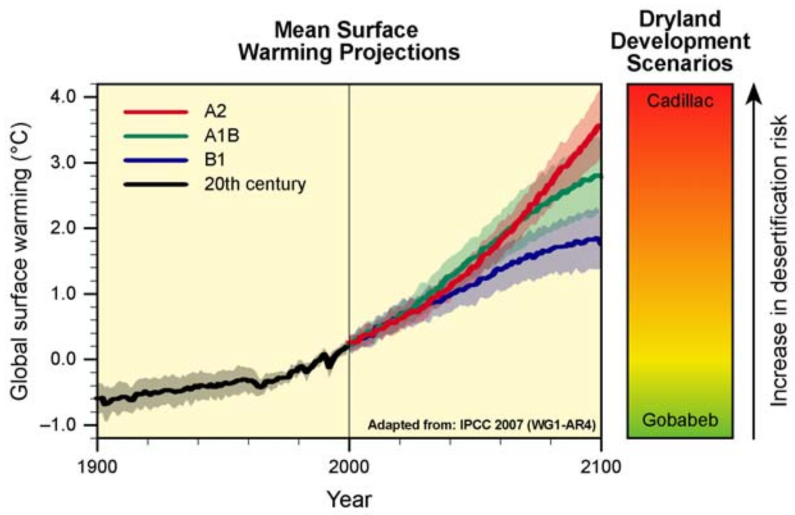

Figure 4. Scenarios of Global Warming and Desertification during the 21st century.

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Agriculture in African Drylands – A Poverty Trap?

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Introduction: Africa and Change Over the Last 50 Years

Africa is a continent blessed with a unique blend of culturally rich peoples with a myriad of traditional knowledge, innovations and practices that have contributed significantly to natural resource management, and more specifically, to sustainable land management and biodiversity conservation. The pressures of modern change dictated and driven by the northern hemisphere has however, been too fast for Africa to keep pace with, especially given the many pressing priorities that African governments are facing. At the same time, global climate change is making its presence felt ever increasingly all over the planet, including Africa, who may perhaps be the least prepared for the significant challenges that climate change will pose to many African governments. Regarding climate change, the main challenge will be the capacity to cope with and adapt to its consequences. This paper will focus on the development issues facing Africa today, with a special focus on global change and its impacts on soils and development in Africa.

Around 50 years ago, the winds of change blew over the African continent and many African countries obtained their independence from their colonial masters. Many of these countries were just at the beginning of modernisation at independence and together with that, also inherited a vast social and environmental debt.

Many countries were faced with and continue to be faced with rural and urban poverty, skewed distribution of income, and poor education, health and housing for the rural majority. In addition to these problems, there was the quest for development. In this quest for development and modernisation, there was a significant alienation of people from natural resources such as wildlife (plants and animals) on which they depended for their sustained survival and existence. Although the emergence of nature conservation was already visible, it was seen as the responsibility of the government and simply an issue of parks and wildlife management. At the same time, agriculture was seen as a means of transforming the African economy through change from subsistence agriculture to commercial agriculture. Huge tracks of land were thus converted into agricultural lands to produce cash crops for foreign markets.

The African soils are inherently poor and lack essential minerals needed for healthy crops. The soils could cope with subsistence agriculture which, however, was on the decline as many rural farmers shifted towards cash crops. Over the years agricultural productivity declined, however, due to a combination of factors, the major ones being: loss of biodiversity, bush-encroachment, deforestation, overgrazing, soil erosion and loss of fertility of croplands. Another significant contributor to loss of productivity was nutrient mining of African soils. Attempts to remedy environmental conditions resulted in the application of Eurocentric and rigid agricultural policies imposed on a highly variable environment.

1. Africa Today

The policies and strategies employed over the last fifty years on the African continent have had some impacts on the course of development on the continent. There has been headway in addressing some of the problems mentioned above. However, the battle has not yet been won, especially in the environment sector. The problems continue. This time, they are driven and exacerbated by the loss of traditional knowledge, innovations and practices relevant to the conservation and management and sustainable use of biodiversity, globalisation, conflict and war, land and resources tenure, livelihood insecurity and poverty, and, most significantly, population growth.

The rise in population numbers of the African people in particular has had an impact on the ability of African soils to continue to provide. There are more and more mouths to feed and less and less natural resources. The curse of natural resources has also been very evident in those African countries blessed with minerals and other significant natural resources of international importance. This curse has left many countries, which could under other circumstances provide for their nationals and still be left with a surplus of food, unable to do so due to the wars and conflicts that have afflicted them. The next section will take a closer look at African soils.

2. Africa and Her Soils: Can They Save Her?

One of Africa's most urgent issues today is food security; this is amidst all the other development issues that are just as urgent and pressing. Food production in many African states, as mentioned before, is not able to keep pace with the expanding population growth and the ever-increasing demand on diminishing natural resources. This leads to continued declines in its already low food production per capita. Africa is an old continent and as such has also the prevalence of very old soils. Most of Africa's soils are formed from weathered rocks that are low in nitrogen and phosphorous. Dominant clay minerals are such that the nutrient storage capacity of most of the soils is limited. Not only are the soils poor, but the climate is also extreme, rainfall being irregular and erratic or too high and intense. The soils are also characterised by low organic matter content which contributes to the lack of nutrient storage capacity and to low water retention capacity. This is worsened by the fact that African soils are very prone to erosion.

The situation described above has significant implications for agriculture in Africa. Agriculture is a challenge for many African countries. The poor quality of African soils is the most important limiting factor to African agriculture. Agriculture accounts for more than 25% of the Gross Domestic Product (GDP) of most African countries, and is the main source of income for and employment of at least 65% of Africa's population of 750 million. Thus, agricultural development is vital to Africa's economic growth, food security, and poverty alleviation (Henao and Baanante, 1999).

By 2020 Africa is projected to import more than 60 million metric tonnes (t) of cereal yearly to meet demand. Africa's food security situation has deteriorated significantly over the past two decades (Henao and Baanante, 1999). With population growth of about 3% yearly, the number of malnourished people in Africa has grown from about 88 million in 1970 to more than 200 million in 1999-2001.

Conventional agriculture is also hampered in terms of production in much of Africa. This is because of the predominance of fragile ecosystems, low inherited soil fertility, and low use of modern inputs such as mineral fertilizers and improved varieties.

Farmers in sub-Saharan Africa have traditionally cleared land, grown a few crops, then moved on to clear more land, leaving the land fallow to regain fertility. However, today population pressure and thus the more mouths that need to be fed forces farmers to grow crop after crop on the same land, thus raping or mining already poor soils from the remaining nutrients while giving nothing back. With little access to fertilisers, the farmers are forced to bring less fertile soils on marginal land into production, at the expense of wildlife and forests (Henao and Baanante, 1999).

The propensity for nutrient mining of Africa's agricultural land and the severity of its consequences are the highest in the world. Continued nutrient mining of African soils would mean a future of increased poverty, food insecurity, environmental damage, and social and political instability (Henao and Baanante, 1999).

Amidst all these pressures there is the eminent threat of global warming and global climate change as already alluded to above. This in itself will have significant impacts on the ability of Africa to feed her people. Vulnerability to climate change will be a major issue, posing a significant challenge to the sustainable management of Africa's drylands especially in sub-Saharan Africa. Climate change in southern Africa is likely to add only further incremental stress to ecosystems already under pressure due to population growth, increasing subsistence needs, endemic droughts in most of the region, unequal land distribution and very limited coping ability, especially in communal rangelands.

3. Is Agriculture Indeed a Poverty Trap?

From the above it can be argued that agriculture in African drylands may constitute a poverty trap for many of the already marginalised rural poor. It may serve only the interest of the elite rich minorities who are able to afford large tracts of land, the expensive fertilisers and other agricultural inputs. These elites can then provide employment at a pittance to the rural majority. It is thus difficult to see how rural people can become empowered and increase their assets and income by engaging in conventional agriculture in drylands. Perhaps it is time for a new shift away from conventional agriculture in some parts of Africa. This shift will be especially important in African drylands.

4. A New Mindset: Namibian Case

To get to this mind shift, it is important for the rural communities, their development partners, service providers and government officials to consider the comparative advantages for their specific areas within the given parameters of the environmental constraints imposed upon them. The focus should shift to other land use options in addition to conventional agriculture. The focus must be on income and livelihood diversification.

Namibia as an example boasts the following comparative advantages:

- Vast open spaces and wilderness areas;
- Abundant and rich biodiversity and wildlife populations that are well adapted to Namibia's harsh climatic and physical conditions, and have extremely high direct and indirect use value;
- Uncontaminated meat and fish products;
- Rich cultural diversities and valuable traditional knowledge;
- Efficient service industries.

The above comparative advantages enables Namibia to engage in a number of indigenous biodiversity production systems within the parameters of Namibia's harsh, dry, climatic and physical conditions. Examples of these activities are:

a) Bio-trade and bio-prospecting and natural product development

This constitutes the search for interesting bio-molecules and other pharmaceuticals and natural products. Namibian stakeholders have developed and refined an innovative coordinated approach to proactively create sustainable economic opportunities based on harvesting, processing and trading in indigenous plants/natural products. Namibia has already successfully completed a number of new bio-trade products and has a number of projects aimed at finding new opportunities together with local communities. Examples of these are the export of Hoodia, Marula oil, Ximenia oil, Devils Claw (*Harpagophytum Procumbens*), wild silk, Kalahari melon seed oil and a range of other natural products.

b) Sustainable eco-tourism

Namibia's vast open spaces, wilderness areas, scenic landscape, significant numbers of wildlife (plants and animals) and her deserts (the Namib Desert on the west and the Kalahari Desert on the east) provides opportunities for excellent tourism potential. The challenge is how to involve the rural majority in tourism development as opposed to leave it entirely up to the private sector. The Namibian government has promoted Community Based Tourism and Community Based Natural

Resource Management extensively. Income and other benefits have accrued to many communities who were encouraged to get involved in various tourism initiatives in combination with natural resources management.

c) Community Based Natural Resource Management

The Namibian government has further initiated policy and legal framework adjustments that have devolved rights over wildlife and natural resources to organized Community Based Natural Resources Management (CBNRM) groups. These groups fall under two categories, one known as Conservancies and the other as Community Forests. These are most prevalent in Namibia's most marginalised rural areas. These initiatives have had a significant impact on the livelihood of community members and has provided them with unprecedented incentives to manage and conserve their wildlife and areas, but also most importantly it demonstrated the user value of natural resources and the economic benefits that accrued to communities. In turn, this resulted in mass recovery of game populations outside national parks. Community members can thus derive benefits from trophy hunting, the sale of non-timber forest products and other tourism-related activities.

d) Game and game meat products

The potential of Namibia to provide world class venison and other game meat products is virtually untapped so far. Most of Namibia's game meat is consumed within the local market whereas the international market may provide significant returns if managed properly. Namibia has done well in terms of the management of game stocks and has seen significant increases in the number of game on communal lands, commercial land and state land as a result of innovative policy and legal instruments. Namibia can thus afford to create local, regional and international markets based on game and relying on the comparative advantage of organically sourced and uncontaminated venison.

5. A New Paradigm

The Namibian experience has elucidated that a paradigm shift from a focus on only conventional agriculture to initiatives such as sustainable eco-tourism provides for effective and sustainable development in dry areas. It provides for, amongst other things:

- New hope and job opportunities for the rural majority;
- A profound change to local economy;
- More jobs and especially an improvement in job opportunities for women;
- Reasonably well-paid jobs;
- An increase in education levels;
- An increase in land value;
- An increase in people's sense of caring for the land and wildlife;
- Tourism as the only means of subsistence for many;
- People taking pride in their traditional products which are now marketed in formal markets;
- Recognition of the value of traditional knowledge, innovations and practices; and
- Empowerment of people to take their own future into their own hands.

It has also become apparent during the last five years that wildlife, tourism and other indigenous biodiversity production systems are now the most economically important forms of large-scale land use in Namibia. The value of the land adjacent to national parks has gone up significantly when used for wildlife and tourism as opposed to farming. Agricultural production for the year 2005 in terms of income was much lower compared to that of indigenous biodiversity-based production (see Tables 1 and 2[1]).

Table 1. Agricultural Production – 2005.

Commodity	Output value (million N$)	
	Commercial	Communal
Cattle	637.1	5.8
Small stock (sheep & goat)	285.1	
Other livestock (pigs, dairy, karakul, hides & skin)	258.2	
Crops (cereals, grapes, etc.)	188.7	154.5
Other agriculture		290.0
Construction for agriculture	59.0	
TOTAL	1,878.4	

[1]The data provided here has been provided by the Namibia Nature Foundation.

Table 2. Indigenous Biodiversity-based Production – 2005.

Commodity (Commercial only)	Output value (million N$)
Trophy hunting	316.0
Live game sales	14.3
Wildlife viewing	2,700.0
Fuel wood sales	63.0
Charcoal	75-100
Selected plant products	21.6
TOTAL	3,200

It has also become clear over the years that conventional farming in drylands will never make people and countries rich – in arid zones, farming is a poverty trap especially for the already poor and marginalised rural majority. The Namibian experience has demonstrated that wildlife, tourism, etc., have the demonstrated potential to create much more wealth, employment, improved livelihoods and development of skills, and can provide people with a set of options (Shikongo, 2007).

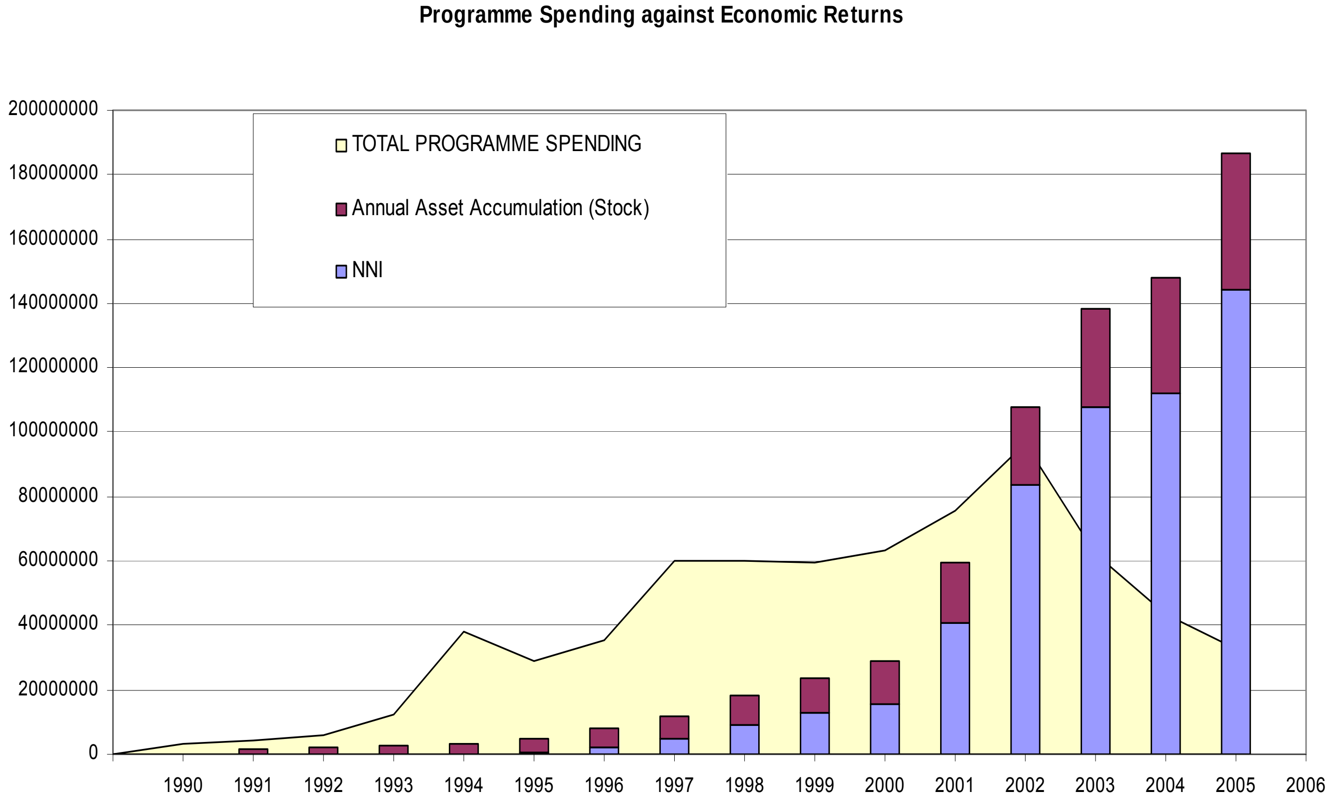

Figure 1. Programme Spending against Economic Returns in Namibia.

It has to be pointed out that this transformation needs a combined effort by the rural majority themselves, the government, community service providers, and the private sector. It also requires a significant financial and capacity development investment over time, and with time the income generated will become significantly higher than the initial investment and the community will see a build-up of real assets. Figure 1 illustrates this point, as it summarises the CBNRM programme spending in Namibia. The initial financial investment, be it from donors, public funds, the private sector, or public-private partnerships, can be regarded as seed funds or low hanging fruits[2], which provide room for bigger fruits later on (Figure 1).

Conclusions

For Namibia, tourism and wildlife has provided a significant comparative advantage to conventional agriculture. It is now up to Namibians to take care of this advantage and to manage and use it sustainably. Other dryland nations will have to

[2]The concept of low hanging fruits refers to interventions that provide the basis for further larger interventions. Thus, the initial funding is used to find ways to reap small benefits, which in turn reap the higher hanging fruits, i.e. the larger benefits.

determine their comparative advantages and work with them to create a meaningful livelihood and empower their people to reach greater heights.

Finally, it is important to point out that the strongest incentives for wise and sustainable use of dryland wildlife and indigenous biodiversity production systems and their long-term conservation are created by these resources having a high and tradable value – the higher the value the better.

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Iceland's Century of Conservation and Restoration of Soils and Vegetation[1]

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Introduction

The 1100 years of human settlement in Iceland have been marked by extensive soil erosion and a large scale degradation of terrestrial ecosystems. This has had a wide ranging effect on these systems and people's livelihoods. To stop the destructive forces, a unique legislation was passed by the Icelandic Parliament in 1907 aimed at halting soil erosion and restoring lost and degraded woodlands: the *Act on Forestry and Protection against Soil Erosion*.

Iceland's 100 years of such national operation are characterized by numerous success stories of stabilizing desertified land and restoring land quality (Olgeirsson, 2007). However, the task of protecting and restoring Icelandic ecosystems is still enormous. The aim of this paper is to describe some of the important lessons that can be drawn from the long history of land degradation in Iceland, and the country's century-long effort of soil and vegetation conservation and restoration of damaged land.

1. Human Settlement and Subsequent Land Degradation

The nakedness of many parts of Iceland may be regarded as one of its most striking features. Most of this reflects a millennium-long damage to ecosystems caused by the interaction between unsustainable land use and natural forces in a sensitive environment.

The first human inhabitants were met by lush vegetation and fertile ecosystems. Up to two-thirds of the country may have been vegetated and at least 25% of the area was covered with woodlands, mainly birch (*Betula pubescens*) (Arnalds, 1988). The country became settled by Scandinavian Vikings around AD 874. The short Settlement period and the subsequent Commonwealth period – the first few centuries of human history in the country – was a time of prosperity. Human population density soon increased, increasing the pressure on the land.

There are several indications that land decline was triggered and greatly accelerated by settlement. The woodlands were cut for fuel and timber, or burned to provide space for agriculture and grazing. As their distribution and cover reduced and grazing pressure increased, the sensitive volcanic soils lost their shelter and became more vulnerable to the erosive forces of wind and water. Ash and tephra from frequent volcanic eruptions started blowing over the surface, damaging the sward and further exposing the soil and vegetation to these forces of destruction. Cooling temperatures reduced the capacity of the vegetation to recover. Thus, it is believed that the coupling effects of human-induced activities and natural forces to a large extent caused the great deterioration that Iceland faces today (Arnalds, 1987).

The peak of the ecosystem destruction may have been reached in the late 19th century, caused by the interaction of increasing livestock numbers and climatic fluctuations. Without adequate incentives for conservation, this severe degradation lasted until a few decades ago. Catastrophic soil erosion and desertification has damaged ecosystems in large parts of the country. Arnalds (1988) summarises some of the various sources that can be used to reconstruct the vegetation of the past and trace some of the major changes in cover and composition through the centuries. These include historical records, site names, pollen studies, remnants of former vegetation and land use indicators. About half of the vegetation may be lost, with the clearest example being the extensive deforestation of the birch woodlands. Only about 5% of these woodlands still remain. A national survey on the extent of soil erosion revealed that serious soil erosion characterizes about 40% of Iceland (Arnalds et al., 2001). Much of the remaining vegetation is severely degraded, biological diversity reduced, land fertility diminished and hydrology altered.

2. Initiation of Efforts to Combat Soil and Vegetation Loss

Repeated disastrous events occurred in the last decades of the 19th century. Sandstorms in the early 1880s were especially harmful, and numerous farms were decimated by the erosion (Olgeirsson, 2007). This catastrophe triggered some action against the destruction. In 1895, the first formal and organized measures aimed at curtailing erosion were taken with the *Act for Resolution on Sand Erosion and Reclamation* passed in the Icelandic Parliament. However, the effect of this legislation was negligible and of little value since it provided no means or incentives for erosion control (Runólfsson, 1987).

The first tangible fruits of the first actions against soil erosions in Iceland was the *Act on Forestry and Protection against Soil Erosion*, passed by the Icelandic Parliament in 1907. This marked the beginning of organized battle against the erosion. By later amendments of this law, two state institutes were subsequently established: the Soil Conservation Service (SCS) and the Forest Service (FS) of Iceland. Both have emphasized conservation of soils and vegetation; the SCS is primarily concerned with soil erosion control and revegetation, but the FS is responsible for protection of the remaining birch woodlands, reforestation and afforestation.

[1]This paper is based on the presentation "Iceland and the Global Picture" given by Andrés Arnalds on 31 August 2007 and the presentation "Iceland's Century of Conserving and Restoring Soil and Vegetation" given by Sveinn Runólfsson on 4 September 2007 at the International Forum on Soils, Society & Global Change.

3. Lessons from the Past

During the 100 years of soil conservation in Iceland, much has been achieved in the battle against soil erosion, despite limited resources during most of this time. The first sixty years were almost entirely devoted to the urgent task of halting sand dune advance and other forms of catastrophic soil erosion and vegetation destruction in pastures and rangelands that left barren deserts behind and threatened the existence of several communities (Arnalds, 2005a). By the late 1950s, the most serious sand drifts had been halted (Runólfsson, 1987) and many districts and farms saved from destruction (Olgeirsson, 2007). This work was mainly conducted by fencing off areas of severe erosion and seeding the native sand stabilizer, *Leymus arenarius*, the only native plant capable of halting moving sand in Iceland (Runolfsson, 1987).

By the 1950s, when sand encroachment had become a lesser threat to inhabited areas and with more availability of fertilizers and better equipment, revegetation of some of the vast areas of denuded land slowly began. Experiments on the use of a variety of exotic grass species for revegetation led to a large-scale seeding of grass species and fertilization (Magnússon, 1997), largely by means of aerial distribution using aircrafts (Runólfsson, 1987). Initially, grasses such as *Festuca rubra* and *Poa pratensis* were seeded and the area fertilized for 3-4 years with 300-400 kg/ha of a mixed N-P fertilizer. The use of this method has turned out to be successful in improving site conditions and speeding up the natural processes of recovery. The grasses start disappearing soon after fertilization ceases, and species from adjacent native vegetation start colonizing. The direction and rate of this secondary succession depends on many factors, including availability of seed sources in adjacent areas. Since 1990, lower amounts of fertilizers (150-200 kg/ha) have mostly been used, and it is becoming increasingly common to stimulate natural recovery using only fertilizers and no grass seeding.

The fight against the rapidly encroaching sand dunes and other forms of immediate destruction was highly successful, especially considering limited financial and human resources. Many districts and towns were saved from the sand storms (Olgeirsson, 2007). However, in retrospect, the first 70-80 years of SCS activities only managed to treat a small proportion of the affected areas and vegetation is still being lost through erosion today. In addition to limited financial resources, Arnalds (2005b) argues that reasons for the inadequate achievements on a national scale until after about 1990 may include:

- The soil conservation work was too localized, as only the spots of the most severe erosion and desertification were being treated;
- The conservation approach was too narrow, emphasizing single issue approaches, as the focus was on halting the erosion, not on preventive measures on a landscape basis;
- Low conservation awareness resulted from the lack of land user and public involvement, as the government conducted most of the work with its own personnel and machinery;
- Insufficient inventories existed on the state of the natural resources and on cause and effect relationships, leading to unfertile debates between land users and conservation people on the seriousness of the soil erosion problems and the role of land use in the land degradation;
- Governmental subsidies to sheep production were lacking environmental links. A high level of support led to an all-time peak in sheep numbers in the late 1970s, but poor grazing management resulted in severe overgrazing in many areas. The government was paying at both ends, indirectly for the damage to the land, and directly for its reparation;
- Weak laws on soil conservation, meaning that the SCS had no actual means to enforce proper protection of sensitive soils and vegetation. Theoretically, maximum numbers of livestock grazing in a given area could be decided where needed, but the legal procedure was (and still is) too complex, rendering this option for preventive measures useless.

The mixed success of the early soil conservation work was influenced by many other factors, such as various sociological barriers to improved conservation. A general lack of incentives to care for the land, and similarly, a lack of disincentives to reduce unsustainable use, prevailed until recently (Arnalds, 2005b). Similar experiences have been described for many other countries. The top-down approach, lack of local involvement and "curing symptoms rather than causes" are amongst organizational and strategic mistakes that were frequently seen in many other, widely differing countries (Roberts, 1989; Douglas, 1996; Hannam, 2000; Sanders, 2000).

4. A Shift in Conservation Approach

It is clear that in order to prevent further damage to Iceland's ecosystems and to reclaim lost resources, a comprehensive framework is needed, based on long-term goals. Laws that affect land use and condition need to be harmonized; supporting factors such as research, planning, evaluation, outreach and education need to be strengthened; and incentives aimed at stimulating knowledge, awareness and conservation ethics need to be promoted. A lot can be adopted from international conventions and agreements that Iceland has already committed to.

A step in building such a framework was taken in 2002 when the Parliament of Iceland decided on a comprehensive programme, giving the SCS an operational framework for the period 2003-2014. This programme sets goals for mitigation of land degradation and desertification, revegetation of eroded land, and attaining sustainable land use. The main tools for the programme's achievements were described, and financing improved substantially, mainly for halting desertification, extending farmer involvement in healing the land, and by establishing a new land care incentives programme that was mainly intended for projects at the communal or co-operative level.

Since 1990, the SCS has increasingly promoted and initiated participatory approaches to soil conservation. Arnalds (2005a) argues that this has markedly increased the adoption and success of conservation projects. During this period, the soil conservation work has developed towards ecosystem management for multiple uses. The following describes the change in the conservation approaches that have gradually been adopted for soil conservation in Iceland.

4.1. Sustainable land use

The Icelandic experience illustrates that ecological sustainability of grazing and other land uses is a large determinant of land health. Most of the island is accessible for grazing, but land condition is poor over large areas. In areas of severe land degradation and desertification, grazing can have a dramatic effect. In many other degraded or denuded areas, livestock grazing can significantly slow vegetation recovery. Major management changes are needed in many areas of Iceland in order to reach goals of sustainable land use.

Sheep, and now increasingly horses, are the major large grazing animals in Iceland. Steps towards increased ecological sustainability must therefore carefully consider sheep production, grazing management and governmental agricultural support. Sheep production in Iceland is costly, mainly as a result of a long indoor feeding period in winter, and has been receiving a high level of governmental support. To meet public concerns and give the land users a larger conservation role, the current contract between the sheep producers and government now has a partial link between agricultural support and environmental conditions. Starting in 2003/2004, farmers must verify the ecological sustainability of their operation with the SCS in order to obtain a full subsidy (Arnalds and Barkarson, 2003). Farmers who do not meet certain standards must submit a conservation and land improvement plan for SCS approval. This policy has become an important measure towards increased land use responsibility of sheep farmers in Iceland, and a big stimulus for improvement of land condition.

Horse grazing is also an important, but in most cases more localized, determinant of land health. A voluntary ‘bottom-up’ quality control of sustainability is emerging in this sector. Other concerns include crop production, which has been limited in Iceland. However, with new strains of barley and a more favourable climate in recent years, crop acreages are rapidly increasing. A new soil conservation concern is therefore emerging in Iceland, especially with regards to tilling.

4.2. Involving land users and the public

Since 1990, there has been an increasing participatory approach to soil conservation in Iceland. This has markedly increased the adoption and success of conservation projects (Arnalds, 1999).

To increase participation of farmers in soil and vegetation conservation, the SCS operates two main programmes for financial support:

The *Farmers Heal the Land* project includes a ‘cost-share’ partnership with farmers, with conservation work jointly funded by the government and farmers. Using their machinery, own labour and about 15% of fertilizer cost, the farmers’ share may average around 50% of project cost. This ‘bottom-up’ approach encourages involvement and individual ownership of conservation projects. This approach has been important in building mutual trust between farmers and conservation authorities, which is a foundation for resolving many other issues. Participants have also been active in developing new methodologies, in cooperation with the soil conservationists, greatly advancing the knowledge base for local soil conservation.

The *Land Improvement Fund* was initiated in 2003. By providing financial support, this programme aims to shift responsibility, initiative and execution of the soil conservation work to local authorities, land owners, non-governmental organizations and other interest groups.

A participatory programme termed *Better Farms* has been evolving, aimed at good farming practices and sustainable land use planning. The programme’s goal is to combine the forces of soil conservation, forestry, extension and nature conservation in assisting land users to produce their own property plans. Another aim of the programme is to make farmers the active partners in the planning process, and to improve co-ordination between the various institutes and organizations that work with farmers. The participants of the programme are provided with good quality aerial photographs and taught the elements of reading the land, information seeking, and developing their own plans.

The SCS has also greatly emphasized working with rural and urban authorities concerning grazing management and revegetation issues. A wide range of clubs and associations, along with individual volunteers, have become active in various aspects of the conservation work. Working with such groups can be important in bridging the divide between rural and urban communities.

4.3. Skills and conservation ethics

There are many factors that influence the long-term success of the protection of natural resources. Awareness, skills and conservation ethics building on scientific and practical knowledge are very important in this regard. Therefore, in the Icelandic 2003-2014 parliamentary approved soil conservation programme, research, education and knowledge transfer are among the key elements.

The SCS operates research, land information, and public relations departments that work closely with other agencies. Education related to soil conservation issues is a fundamental part of the institute’s work: in schools, with the public and in other sectors. The increase in participatory action has resulted in much better cooperation with land users. Among future objectives is to ensure that all government-funded services to agriculture incorporate due respect for the goal of sustainability.

4.4. Financing

The urgent task of healing the land in Iceland is a major challenge for a nation of only 320,000 people. In addition to government funding, farmers, volunteers and clubs, district authorities, and a number of other interest groups provide significant contributions towards the soil conservation work in Iceland. A large contributing donor is the Retailer Association of Iceland, which finances many conservation programmes with revenues generated by charging for plastic grocery bags in their stores. Further means of financial support for restoring degraded land in Iceland is urgently needed.

5. Iceland and the Global Picture

The silent crisis of ecosystem degradation, soil erosion and desertification is seriously affecting a growing proportion of the human population (UNCCD, 2008, Millennium Ecosystem Assessment, 2005). Despite the important linkages with a multitude of environmental, economic and social issues, – such as climate change, biodiversity, water supply, food security, poverty reduction and world peace – the severity of these problems and the need for land restoration are not gaining enough attention.

Iceland demonstrates clearly the vicious cycle of unsustainable land use, reduced land quality, and the struggle for survival that still further fed the loop of desertification in a subsistence-farming culture until the early twentieth century. The main underlying causes of the massive land degradation are the same as in many other parts of the world: clearing of land by burning, too much harvesting of trees and scrubs, and overgrazing that weakened the resilience of the ecosystems and hampered regeneration after disturbances.

The environmental consequences also have many parallels: large-scale changes in biological diversity, reduction in water holding capacity of the land, and loss of organic matter and nutrients. Changes in weather patterns at local and regional levels are probable.

Though the cost of the degradation has not been assessed, it results in a large-scale reduction in the number of ecosystem services provided, leading to less efficient and more costly agriculture, loss of shelter from wind and snowdrift, and more extremes in the flow of streams and rivers.

Every country has its own sets of solutions for resolving the land degradation problems and attaining goals of sustainable land use. Icelandic experience demonstrates the failure of ‘top-down’ approaches and the importance of helping people conserve and heal the land. Participation is now a main characteristic of soil conservation and land restoration in Iceland, and the success stories are an encouragement for other countries to adapt such land care approaches (Arnalds, 2005a, Olgeirsson, 2007).

Land restoration has an important role in reaching Iceland’s targets in mitigating climate change. Carbon dioxide (CO_2) is the most important greenhouse gas actor in climate change. The carbon atom located in soil as organic matter is the key to soil fertility, food production and other ecosystem services. Iceland has lost immense amounts of carbon due to ecosystem degradation and soil erosion, and there is an urgent need to return some of this carbon back to the land, recharging the ecosystems. Restoration of land quality by revegetation, reforestation and afforestation may increase carbon storage by millions of tonnes of CO_2 equivalents and improve land for future generations. Combined with Iceland’s many options for the urgent task of reducing emissions of greenhouse gases, Iceland could become a carbon neutral country within a few decades – a model country in caring for the environment (Arnalds 2004, Agústsdóttir et al., 2008).

Even if the human population were to cut emissions of CO_2, the decay of atmospheric CO_2 is slow, and climatic changes would still occur. Iceland’s experience shows how carbon projects can be planned for multiple benefits, generating income streams for the restoration of land quality.

In the 100 years of halting soil erosion and restoring ecosystem function in Iceland, much experience and knowledge has been gained, giving Iceland an important role in cooperation with other countries. This long-term experience forms the basis for a Land Restoration Training Programme that the Ministry for Foreign Affairs is financing as part of its development cooperation programme, following the lead of the successful United Nations University training programmes in geothermal energy and fisheries in Iceland.

Lastly, with the wide-ranging consequences of soil erosion in Iceland, and the multiple benefits of restoring land quality, the Icelandic experience demonstrates that soil is the vital, but often overlooked, link between environmental issues and the goals of the key environmental Conventions. Let us build the bridges, and not forget the soil.

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