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The global problem of land degradation and desertification

Ádám Kertész[1]

Abstract

It's a well known fact that land(scape) degradation is an ensemble of negative processes extending over immense areas. The methodologies of physical and social geography are the best tools for the investigation of land degradation processes, due to the complex nature of these processes. It is well known that environmental factors contribute to land degradation processes. Socio-economic factors and the role of human society is equally important, and in some cases, even more important, than natural factors. Degradation processes within subhumid, semi-arid and arid areas are defined as desertification processes to draw attention to the specific dangerous situation in these areas. Hungary signed the Convention on Desertification, as increasing aridity is a real national danger, especially on the Danube-Tisza interfluve. There are areas in Hungary corresponding to desertification definitions. Thus, desertification research is an important challenge for Hungarian geography.

Key words: water erosion, land degradation, desertificaton, Danube–Tisza interfluve

Introduction

The degradation of the Earth's surface (i.e. land degradation) is one of the most severe problems of our times. The concept of land degradation originates from soil degradation and it is often used as a synonym for soil degradation. It is evident that if soil is degraded it has huge impacts on both the land and landscape, because soil degradation prevents or impedes plant growth. Land and soil are not identical notions, but they are often used interchangeably. To avoid this confusion, I propose to use the term 'landscape degradation.' Landscape degradation means much more than just the degradation of the uppermost layer of the Earth's crust. It means the decline of all landscape forming factors and of their synthesis, which is called landscape in physical geography and landscape ecology. Landscape ecology and physical geography deal with various aspects of landscape development (Tóth, A.–Szalai, Z. 2007). However, despite its importance, few scientific papers in Hungary report degradation processes.

[1] Geographical Research Institute, Hungarian Academy of Sciences. H-1112 Budapest, Budaörsi út 45. E-mail: kertesza@helka.iif.hu

Soil degradation processes

Soil degradation processes are grouped in different ways by various authors. A more practical classification is presented below (EEA Environmental Assessment Report 2003).

(1) Soil sealing. It is not by accident that soil sealing is given first place amongst soil degradation processes. Soil sealing is the result of construction activities (including roads, railways and buildings). Due to soil sealing, the soil does not function properly, as it has no contact with the atmosphere and is devoid of vegetation. On the sealed soil surface, water runs off without being filtered, with increased velocity and volume. The highest share of sealed soil surface (16–20%) is in Belgium, The Netherlands and Denmark. The share of sealed soil has been continuously growing within the EU. reaching an average value of 8–9% in 2000.

(2) Soil erosion *(Photo 1).* In Europe water erosion is more important than wind erosion, but wind erosion also causes huge damage. As an example of the importance of wind erosion in the World we should remember that the establishment of the US Soil Conservation Service took place primarily because of the sand storms of the 1930s. Soil erosion risk and the damage caused by erosion are also very remarkable in Hungary (Jakab, G.–Szalai, Z. 2005).

Photo 1. Gully erosion near Bergville, South Africa

Photo 2. Saline spot on the Danube-Tisza Interfluve, near Apajpuszta

(3) Soil contamination can originate from both diffuse and local sources. Contamination from the atmosphere, from running water or from the soil belong to the first group. These processes may cause acidification, eutrophication and other severe damage. The direct application of chemicals (fertilizers, pesticides and sewage sludge), sometimes also containing heavy metals, are also diffuse sources. Local contamination sources can be of diverse origins and are usually connected with industrial activity.

(4) Salinization. Near-surface salt accumulation is present in several European countries, including Hungary. The most important areas affected by seashore, inland and secondary salinization due to irrigation are in the Mediterranean countries, Hungary and several countries of the former Soviet Union *(Photo 2).*

(5) Soil compaction is the result of the activity of soil cultivating machines. Subsoil compaction is an extremely damaging and is difficult to rectify.

The first World assessment of soil degradation is GLASOD (Global Assessment of Soil Degradation, Oldeman, L.R. et al. 1991), which assesses the following degradation processes:

– The extension of various forms of soil degradation
  - water erosion

- wind erosion
- chemical degradation
- physical degradation.

– The rate of degradation
  - Light
  - Moderate
  - Strong
  - Extreme.

– The causes of degradation (deforestation, overgrazing, improper farming, overexploitation, contamination).

According to Oldeman, L.R. et al. (1991) 3.7% of the Earth's surface is affected by physical and chemical degradation and 12% by water and wind erosion (*Tables 1* and *2*). Especially high is the proportion of physical and chemical degradation in Europe and in Central America and the share of the areas affected by soil erosion is also the highest here. Studying these tables, it is evident that soil degradation is a major problem in Europe.

The concept of land degradation

As mentioned above, land degradation means much more than the degradation of the land/soil. Because of the complex nature of land degradation processes it is essentially a geographical subject matter. In this paper, land degradation will be discussed from the perspective of physical geography. However, land degradation can result from both physico-geographical and socio-economic causes. An evident example is overpopulation of humans and animals launching well-known degradation processes. The investigation of land degradation processes together with land use change studies represent the most up-to date and innovative research trends in modern geography.

According to Barrow, C.J. (1991) it is impossible to give a precise definition of land degradation. It may be defined "as the loss of utility or the reduction, loss or change of features or organisms which cannot be replaced" (Barrow, C.J. 1991). The land is degraded when "it suffers a loss of intrinsic qualities or a decline in its capabilities" (Blaikie, P.–Brookfield, H. 1987). The UNEP (1992) definition emphasized the reduction of the potential of natural resources as a result of processes acting in the landscape. Johnson, D.L.–Lewis, L.A. (1995) underlined the role of human interventions in land degradation and focused on the reduction of biological production and/or utility of an area. Distilling the essence of these cited definitions, it is evident that there are common elements in them. Hence, even thought it is difficult to give a precise definition acceptable to all disciplines, the concept of land degradation is fairly clear. It means the reduction or loss of biological productivity

Table 1. Global extent of chemical and physical soil degradation, by region (OLDEMAN, L.R. et al. 1991)

Region	Chemically degraded area				Physically degraded area			Total degraded area	Total degraded land as % of total land used
	Loss of nutrients	Salinization	Pollution	Acidification	Compaction, sealing and crusting	Water-logging	Loss of organic matter		
	(million hectares)								
Africa	45	15	+	1	18	1	–	81	4,8
Asia	15	53	2	4	10	+	2	86	3,0
South America	68	2	–	–	4	4	–	78	5,1
Central America	4	2	+	–	+	5	–	12	6,0
North America	–	+	+	+	1	–	–	1	+
Europe	3	4	19	+	33	1	2	62	7,7
Australia	+	1	–	–	2	–	–	3	–
World	136	77	21	6	68	11	4	323	3,7

The „+" sign means negligible, the „–" sign means none reported.

Table 2 Global extent of soil degradation due to erosion, by region (OLDEMAN, L.R. et al. 1991)

Region	Area eroded by water erosion				Area eroded by wind erosion				Total area eroded	Total area seriously eroded	Total area seriously eroded as a % of total land used
	Light	Moderate	Strong and extreme	Total	Light	Moderate	Strong and extreme	Total			
Africa	58	67	102	227	88	89	9	186	413	267	16
Asia	124	242	73	441	132	75	15	222	663	405	15
South America	46	65	12	123	26	16	–	42	165	93	6
Central America	1	22	23	46	246	4	1	251	51	50	25
North America	14	46	–	60	3	31	1	35	95	78	7
Europe	21	81	12	114	3	38	1	42	156	132	17
Oceania	79	3	222	83	16	–	27	46	99	3	3
World	343	526	223	1094	269	254	26	548	1642	1029	12

and negative effects on the functioning of the land and related ecosystems (Hudson, P.F.–Alcántara–Ayala, I. 2006). Functioning of the land involves the interaction of environmental factors and connections between landscape components, such as hillslopes and floodplains. These definitions and explanations show very clearly that land degradation is much more complex than soil degradation.

Land degradation processes can have both natural and human (anthropogenic) origins. It is obvious that since the appearance of human beings on the Earth the importance of anthropogenic processes is enormous and has grown exponentially with time. Among natural processes, climate change is extremely significant, considering that the rapid rate of climate change today is largely a human-induced process. However, most authors who have tried to define land degradation restrict it to human-induced processes. In this sense, landscape development always involves degradation processes of natural origin, but these processes will then be compensated by the regenerating capacity of the landscape (Bádonyi, K. 2001). This approach excludes the influence of natural processes, such as natural climate change, natural catastrophes or geologic soil erosion.

Global processes like global climate change, land use and land cover change, together with population increase, accelerate and increase land degradation. Especially, Third World countries suffer from degradation processes. In these countries overexploitation of natural resources in environmentally-sensitive areas also contribute to the acceleration of degradation processes. The effect of global warming on already degraded land also increases the intensity of degradation.

According to Menshing, H.G.–Seuffert, O. (2001) it is very important that no irreversible damage occurs in the landscape due to improper land use. This is actually the application of the principles of sustainable development (i.e. the regenerating capacity and potential of the landscape should remain under the circumstances of any kind of land use or landscape use).

As mentioned before, soil and land degradation are often used interchangeably (e.g. Imeson, A. C.–Emmer, I. 1992). Consequently, the salient processes of soil degradation and land degradation are identical (i.e. various processes of physical and chemical degradation belong to them). It is extremely important whether these processes are understood as landscape degradation or soil degradation processes.

Some 38% of the agricultural area of the Earth can be considered as degraded *(Fig. 1).* Most of the areas in question are in the Third World (the share of degraded territories in Africa is 65%, in Central America 74% and in South America 45%). The proportion of degraded pasture and forests is much smaller (21 and 18%, respectively). Considering only used land (agricultural area, permanent pasture and forests; *Table 3*) the proportion of degraded area is 23% and that of strongly degraded land is 14%.

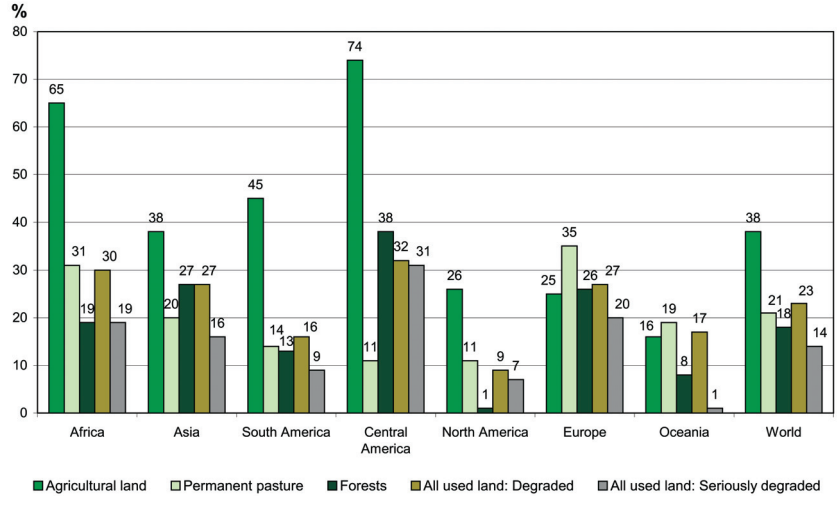

Fig. 1. Estimates of soil degradation in the world, by region and land use (after FAO 1990, Oldeman, L.R. *et al.* 1991 and Scherr, S.J. 1999).

Table 3. Global estimates of soil degradation, by region and land use (sources: FAO 1990, Oldeman, L.R. et al. 1991 and Scherr, S.J. 1999)

Region	Agricultural land			Permanent pasture			Forests		
	Total	Degraded	%	Total	Degraded	%	Total	Degraded	%
	(million hectares)			(million hectares)			(million hectares)		
Africa	187	121	65	793	243	31	683	130	19
Asia	536	206	38	978	197	20	1273	344	27
South America	142	64	45	478	68	14	896	112	13
Central America	38	28	74	94	10	11	66	25	38
North America	236	63	26	274	29	11	621	4	1
Europe	287	72	25	156	54	35	353	92	26
Oceania	49	8	16	439	4	19	156	12	8
World	1475	562	38	3212	685	21	4048	719	18

Region	All used land				
	Total agricultural land, pasture and forests	Degraded	%	Seriously degraded	%
	(million hectares)			(million hectares)	
Africa	1663	494	30	321	19
Asia	2787	747	27	453	16
South America	1516	244	16	139	9
Central America	198	63	32	61	31
North America	1131	96	9	79	7
Europe	796	218	27	158	20
Oceania	644	104	17	6	1
World	8735	1966	23	1216	14

Desertification processes

Desertification processes represent a special group of land degradation processes. According to the United Nations Intergovernmental Convention to Combat Desertification "Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climate variation and human activities" (UNCOD 1977). The term 'desertification' has emotional connotations and therefore its use is preferred to the term "land degradation." It must be emphasized, however, that desertification has a different meaning than "desertation" (i.e. the formation of deserts).

The concept of desertification is much older than UNCOD. It dates back to the 1920s (Bovill, D.W. 1921, cited by Herrmann, S.M.–Hutchinson, C.F. 2005) when the extension of the West African Sahara into the Sahel zone was first observed. The term 'desertification' was first used by Aubreville, A. (1949) to describe the change of productive land into a desert (Herrmann, S.M.–Hutchinson, C.F. 2005). According to this first definition, the term desertification is always connected with human activities (i.e. with land mismanagement). The Nairobi UNCOD Conference (United Nations Conference on Desertification) in 1977 came about following extremely arid periods in Sahelian Africa.

Climate change as a consequence of the greenhouse effect is a major global process. As it is the main factor influencing desertification processes, the global importance of desertification will increase and it is and it will be the most important group of land degradation processes in those regions of the world where there the climate is arid, semi-arid or dry subhumid.

The atmospheric conditions of arid, semi-arid and subhumid climates are those that create large water deficits, that is, where potential evapotranspiration (ETP) is much greater than precipitation (P). These conditions are evaluated by various indices. One of these is the FAO-UNESCO (1977) bioclimatic index: P/ETP. The threshold values of the bioclimatic zones are given below:

- Arid zone:0.03 <P/ETP <0.20
- Semi-arid zone: 0.20 <P/ETP <0.50
- Subhumid zone: 0.50 <P/ETP <0.75

Whereas desertification occurs under the climate conditions given in the definition, desertification processes are also evident in other climate zones (e.g. associated with salinization). On the other hand, there are examples where drought did not lead to desertification under arid climatic conditions, because of proper land management. Desertification is the result of a combination of drought with land mismanagement (Le Houérou, H.N. 1996). Desertification processes affect 42 million km^2 (33% of the Earth's land surface, Eswaran, H.–Reich, P. 1998), effecting some 1 billion people.

FAO/UNEP (1984) proposed a system of criteria for the evaluation of desertification status *(Table 4).* The matrix contains data on plant cover, water

Table 4. FAO's matrix. Example of the criteria for the evaluation of desertification status proposed by FAO/UNEP (1984)

Variable	Class limits			
	Slight	Moderate	Severe	Very severe
Plant cover				
Perennial plant cover	>50	50–20	20–5	<5
Grassland condition (%)	>75	50–75	20–50	<25
Actual productivity (% potential)	85–100	65–85	25–65	<25
Water erosion				
Surface status (% area)	Gravel and stones <10	Stones and boulders 10–25	Boulders and rocks 25–50	Boulders and rock outcrops >50
Type of erosion[a]				
Exposed subsoil (% area)	<10	10–25	25–50	>50
Gully area (%)	<10	10–25	25–50	>50
Soil thickness (cm)	>90	90–50	50–10	<10
Soil loss				
Original soil depth <1 m	25	25–50	50–75	>75
Original soil depth >1 m	30	30–60	60–90	>90
Actual productivity (% potential)	85–100	65–85	25–65	<25
Wind erosion[b]				
Area covered by hummocks (%)	<5	5–15	15–30	>30
Surface gravel percent cover	<15	15–30	30–50	>50
Salinization				
Morphology[c]				
Soil electrical conductivity (mmhos/cm)	<4	4–8	8–16	>16
Exchangeable sodium (%)	<5	5–20	20–45	>45
Crop yield (% potential)	85–100	65–85	20–65	>45
Affected areas (%)	<5	5–20	20–50	>50

[a] Slight: slight to moderate in sheet erosion and rills. Moderate: moderate to severe in sheet erosion and rills. Severe: severe in sheet erosion, rills and gully erosion. Very severe: very severe in sheet erosion, rills and gully erosion.
[b] Includes several of the same characteristics used for water erosion.
[c] Slight: no salts. Moderate: salt spots. Severe: salt spots and filaments. Very severe: crystalline efflorescences and salt crusts (solonchak).

and wind erosion and salinization. Verón, S.R. et al. (2006) criticized the matrix from several perspectives, particularly the subjective nature of the data.

Desertification processes also affect Hungary, therefore Hungary is a signatory of the Desertification Convention. It is interesting that even Iceland belongs to the countries suffering from desertification problems and research activities on the topic are remarkably advanced (Arnalds, O. 1997; Arnalds, O.–Kimble, J. 2001).

The original concept of desertification from the 1920s and 1940s is slightly different from the UNCOD definition, which puts much more emphasis on the formation of deserts and considers desertification as a process leading to desert development. According to Menshing, H.G.–Seuffert, O. (2001) we can describe a landscape desertified only if geoecological characteristics of a landscape have already reached the representative values of the desert or these values will be reached within a certain period of time. Authors supporting this concept of desertification concentrate first of all on marginal and zones surrounding deserts, which are especially sensitive to desertification, as in the Sahara–Sahel marginal belt. There is continuous debate on the definition and understanding of desertification (Bádonyi, K. 2001). All concepts agree upon the fact that desertification means severe degradation problems of territories with water deficits and ongoing aridification.

The main triggering factor of desertification is usually the removal of natural vegetation by human society. This includes all forms of vegetation, not only forests, but also shrubs, weeds and grasses. Vegetation removal leads to climatic changes in the atmospheric boundary layer and increases aridification. Consequently, surfaces indurate, sometimes accompanied by crusting, and infiltration rates decrease.

Soil crusting and the lack of vegetation then exacerbates the destructive effects of both water and wind erosion. Soil erosion removes the upper soil layers, which are usually rich in humus and nutrients, so reducing the feasibility of both vegetation re-establishment and agricultural land uses. Thus, landscape potential diminishes. The chance of reclaiming and regenerating vegetation in arid areas is less feasible if the climate is variable, especially if extreme events like extreme changes of moisture conditions are frequent (e.g. long periods of drought and catastrophic high intensity rainfall events).

Reclaiming degraded, or desertified land is an important issue in combating these processes (Mitchell, D.J. et al. 1998). Prevention, if at all possible, may even be more important than reclaiming already damaged land. Just one example of prevention against runoff and soil erosion is conservation agriculture or minimum tillage (Bádonyi, K.–Madarász, B. 2004).

Desertification is first of all related to specific climatic conditions and vegetation destruction and consequent soil erosion. All physico-geographical (environmental) factors contribute to desertification, at least as modifying

agents. Relief, physical and chemical soil properties and soil parent material play important roles in the speed, rate and extent of desertification.

Desertification rate depends also on initial soil moisture content and human interventions, and the latter can be a positive interference. The course and consequences of the process are clear, from the initial status (i.e. subhumid, semi-arid or arid conditions) proceeding sequentially through the stages (e.g. if the area in question had a subhumid climate, then undergoing transformation to semi-arid and then arid conditions. As a consequence of ongoing aridification the area may become hyperarid. In terms of vegetation, steppe will turn into savanna, followed by thorny savanna and then into semi-desert, reaching the ultimate stage of a desert.

Conclusions

Land (landscape) degradation is an ensemble of negative processes extending over immense areas. The methodologies of physical and social geography are the best tools for the investigation of land degradation processes, due to the complex nature of these processes. It is well known that environmental factors contribute to land degradation processes. Socio-economic factors and the role of human society is equally important, and in some cases, even more important, than natural factors.

Land degradation was first appreciated by soil science as where the possibilities of agricultural use on degraded land are restricted or prevented because of soil degradation. Various forms of soil degradation are striking phenomena themselves, with saline areas being a good example. If the degraded area is not used for agricultural production, then the degradation of natural vegetation can also be striking. Land(scape) degradation processes are also present in Hungary, offering a major challenge to Hungarian geography.

Degradation processes within subhumid, semi-arid and arid areas are defined as desertification processes to draw attention to the specific dangerous situation in these areas. The poorest regions of the Earth belong to here, totalling 40% of the Earth's surface. These regions are continuously struggling with famine. There is debate about the definition of desertification. Should the threshold values of the P/ETP index be taken literally, in which case the term desertification does not refer to desert formation? Or should the definition relate to the possibility of desert formation? Or it should it be restricted to those territories where the result of desertification will or may really lead to desert conditions? Hungary signed the Convention on Desertification, as increasing aridity is a real national danger, especially on the Danube-Tisza interfluve. There are areas in Hungary corresponding to desertification definitions. Thus, desertification research is an important challenge for Hungarian geography.

Because of the complexity of the processes, future desertification research should concentrate on revealing all environmental and landscape ecological aspects of the problem, aimed at presenting a full ecological synthesis of the landscape. Based on this synthesis, precise and practical suggestions should be developed on how to arrest land degradation, or how to redirect it towards positive directions, that is towards landscape reclamation and rehabilitation.

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