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DPSIR Analysis of Land and Soil Degradation in Response to Changes in Land Use

Análisis DPSIR de la degradación de suelos y territorio como respuesta a cambios en el uso del territorio
Análise DPSIR da degradação do solo e da terra em resposta às mudanças no uso da terra

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The connection between land degradation, deepening poverty, demographic explosion, and ultimately famine is rarely made.

(Mainguet 1991)

ABSTRACT

In this paper we analyze the causal chain, from the driving forces to the state, impacts and system responses, for several present and past human activities related to land use and land degradation. The DPSIR framework approach is used for analysing and assessing land degradation problems within a comprehensive view of interactions between human society and the environment.
With this approach, land use, land and soil degradation in several parts of the world (Mexico, Spain and Togo) are analyzed in relation to different land use types: the beginning of irrigation in the 1860's in a semiarid zone with calcareous soils in North-eastern Spain; influence of the land utilization type (LUT) on land degradation in Mexico; soil erosion and reservoir siltation as a global problem (Spain and Mexico); and the protective effects against degradation when soil is considered as a sacred area in Togo. These analyses allow us to learn from the past and could help us to develop strategies to prevent land and soil degradation. This approach provides a useful insight for a systematic analysis when trying to understand the causes of land and soil degradation in response to changes in land use.

RESUMEN

Este artículo analiza los vínculos entre las fuerzas motrices de la degradación del suelo y del territorio, presión, estado, impactos y respuestas (marco DPSIR) para analizar y evaluar problemas de degradación de tierras en el marco de las interacciones entre la sociedad humana y el medio ambiente.
Con este enfoque, el uso del suelo, y la degradación del suelo y las tierras en varias partes del mundo (España, México y Togo) se analizan en relación con diferentes tipos de uso de la tierra: el inicio del riego en 1860 en una zona semiárida con suelos calizos en España; influencia del tipo de utilización de tierras (LUT) sobre la degradación de las tierras en México; la erosión del suelo y la colmatación de embalses como un problema global (España y México); efecto protector contra la degradación cuando el suelo se considera un área sagrada (Togo). Estos análisis permiten aprender del pasado y podría ayudar a desarrollar estrategias para prevenir la degradación de la tierra y el suelo. Este enfoque proporciona una información útil para un análisis sistemático y para llegar a comprender las causas de la degradación de tierras y suelos como respuesta a los cambios en el uso de las tierras.

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RESUMO

Neste trabalho, estuda-se cadeia de eventos, desde as forças motrizes até o estado de equilibrio, os impactos e as respostas do sistema, de diversas atividades humanas, pasadas e presentes, relacionadas com o uso e a degradação do solo. O DPSIR utiliza-se para analisar e abordar os problemas da degradação da terra dentro de uma visão compreensiva das interações entre as sociedades humanas e o ambiente.

Com esta abordagem, analiza-se o uso da terra e a degradação do solo em várias partes do mundo (México, Espanha e Togo) em relação a diferentes tipos de usos da terra: o começo da irrigação nos anos 1860 em zona semiárida com solos calcáreos do nordeste da Espanha; a influência do tipo de uso da terra (land utilization types – LUT) na degradação do solo no Mexico; a erosão do solo, assoreamento como problema global (Espanha e Mexico); e a proteção contra a degradação do solo quando este é considerado área sagrada em Togo. Estas análises permitem aprender do pasado e podem ajudar a desenvolver estratégias para previr a degradação do solo e da terra. Esta abordagem provê de olhares úteis para análises sistemáticas que visam entender as causas da degradação do solo como resposta a mudanças no uso da terra.

KEY WORDS
Land utilization types, soil erosion, acidification, dam siltation, irrigation suitability

PALABRAS CLAVE
Tipo de utilización del territorio, salinización, erosión del suelo, acidificación, colmatación de embalses, adecuación para el riego

PALAVRAS-CHAVE
Tipo de uso da terra, salinização, erosão do solo, acidificação, assoreamento, aptidão para irrigação

1. Introduction

In current Soil Science, the concept of *time* — as a soil formation factor— has progressively evolved, mainly due to an increase in the importance of soil changes caused by anthropogenic factors. As a consequence, the concept of *dynamic soil properties* has been emphasized in many recent studies. Given this human influence, especially during the past 100 years, the recent period has been called the Anthropocene Age. It has been characterised by drastic and rapid changes of soil properties, which have been grouped according to rates of change in response to human factors by Richter (2007). As Tugel et al. (2005) have previously observed, land managers and policymakers need information about soil change in order to be able to predict the effects of management on soil functions, compare alternatives and take appropriate decisions.

In this sense, learning from the past can help us to avoid land and soil degradation associated with changes in land use (Diamond 2005; Juo and Wilding 2001). Dale and Carter (1955), Garde (1978) and Johnson and Laurance (2007) studied the failure of irrigated agriculture in Mesopotamia, ancient Earth's greatest civilization and probably the inspiration for the biblical Garden of the Eden (Richarson and Hussain 2006). In ancient times, much of the land surface within the Mediterranean basin was covered by forest (Hughes and Thirgood, 1982), but deforestation and soil erosion reduced agricultural production and income; this probably contributed to the collapse of some the ancient Mediterranean civilizations. The classic Mayan civilization collapsed between the 8th and 9th centuries (Harrison 1978; Fedick 1996; Diamond 2005) as a result of human population growth, nutrient depletion - particularly associated with a lack of phosphorous in the soil - and the decline in agricultural production (Webb et al. 2004; Fernández et al. 2005). Many of these analyses have been made by evaluating the sustainability of the soil management systems in question and taking into consideration socioeconomic factors other than just soil characteristics (Montgomery 2007; Diamond 2005).

Reich et al. (2001) introduced the concept of *land degradation stress*, which refers to a state of tension within an ecosystem characterised by an intensification of work within the system rather than an external transformation; soil degradation may remain hidden for a long time. According to this concept, it is possible to distinguish two general types of land degradation: soil displacement (mass movements, water erosion and wind erosion causing on-site and off-site effects) and internal soil deterioration (chemical deterioration and physical deterioration, also known as soil degradation stress) (Porta 2009).

In order to address hidden or missing connections between land and soil degradation and their causes, this paper focuses on the establishment of links between driving forces (D), pressures (P), state (S), impact (I), responses (R) and land use changes and land and soil degradation. The on-going degradation of land and soil quality and of the soil's productive capacity over many years has been studied as one of the main factors responsible for the decline of agricultural production whenever unsustainable environmental practices have been pursued.

2. Methodology

This research was performed in three phases. First, we selected relevant land and soil degradation problems of different types at global level: land degradation after the beginning of irrigation in the 1860's in an irrigated perimeter in a semiarid zone with calcareous soils in Spain; influence of the land utilization type (LUT) on land degradation in an area of Phaeozem soils in México; soil erosion and reservoir siltation as a global problem, studying the problem in Spain and in México; and the protective effects of considering soil as a sacred resource in West Africa. Secondly, field information has been completed by consulting the available literature and the historical archive of the Canal d'Urgell (irrigation canal) and the Arxiu Comarcal del Pla d'Urgell (Catalonia, Spain). Thirdly, the DPSIR framework (European Environmental Agency, 1999; Blum 2001, 2002; Kristensen, 2004) has been used to identify a series of core indicators and to establish the nature of interactions between the different driving forces, pressures, states, impacts and responses in relation to long term changes in land use associated with each specific land and soil degradation problem.

3. Results and discussion

Land use and management practices without soil degradation controls

a. *The transformation of the Urgell Plain (Spain) from a dryland to irrigated production in the 19th century: natural and socio-political constraints on failure and success.*

Problems of salinity in irrigated agriculture derive from the fact that the presence of soluble salts in the soil reduces crop yield and land becomes less productive each year as salinization-related stresses increase. According to the FAO (2009), the irrigated perimeters of 103 countries represent about 203 Mha, and 45 Mha of these are affected by salinization processes.

In Spain, irrigated lands are very important for agricultural production due to the semiarid climatic conditions in many parts of the country. We selected the Canal d'Urgell irrigation perimeter in Lleida (Catalonia, Spain) within the Ebro basin as our study area. The idea of building the Canal d'Urgell was very old (dating from the 14th century), but it was only in the mid 19th century that a vast area of about 64 345 ha was transformed from dryland into an irrigated perimeter. The main objectives were to eliminate fallow periods and to make cereal yields more sustainable (Anonymous 1863-1866, 1867-1956; Zulueta 1920). The irrigation system was gravity fed. The main section of the Canal d'Urgell is 144 km long, but is about 3 000 km long if we add the combined length of all of its branches.

In order to identify issues of concern relating to this irrigation perimeter, the DPSIR framework provides an useful insight into how different conditions have interacted since the building of the irrigation canal and through to the present day. The initial state of the system in 1800-1860 is described in **Table 1**.

Finally, in 1817 some work began, but the local landowners were not able to invest in the construction of the irrigation canal. In order to achieve this, a company with share capital was set up in 1853, but water was not available for irrigation until 1864. Many of the initial state characteristics became the initial driving forces (D) at the moment of building the Canal d'Urgell (**Table 2**). The main stakeholders at that moment were: (1) the company which built the channels and canals with a view to selling water to the local farmers, (2) the local landowners, (3) the peasants and (4) the government. The driving forces (D) and pressures (P) at the moment of building the irrigation channels are analyzed and shown in **Table 2**.

Table 1. Initial state of the system in 1800-1860

Land ownership:
Mainly big agricultural landowners Low land prices Low investment
Land use:
Dry farming Cereal production with low yields and fallow
Peasants:
Low density of human population Peasants used to do simple labour but who did not work during long periods of the year Lack of agricultural training

Table 2. Driving forces and pressures at the moment of building the Canal d'Urgell irrigation canal (1850-1870)

D. Initial driving forces. In the area:		P. Pressures
(1) Water stress (1) Large flat countryside (1) Very cheap or even free (convict) labour	→	(1) Interest in building the irrigation canal
(2) Big agricultural landowners with a low capacity for investment	→	(2) Lack of capital in the case of local landowners (2) Several stakeholders: landowners, farmers, peasants, company and government
Socio-political situation in Spain		
(3) Consolidation of liberalism (3) Development of industrial capitalism (3) Availability of money to set up companies with share capital (3) Growth of demand for agricultural products	→	(3) Need to improve the national economy (3) Interest in building hydraulic works
(4) No Agriculture High School in Spain until 1855	→	(4) Lack of an irrigation project (4) Lack of information on the soils to be irrigated (4) Lack of knowledge about irrigation water (4) Lack of knowledge about soil irrigation engineering (4) Lack of farmer and peasant training (4) Lack of knowledge about water management
Legislative situation		
(5) Lack of legislation relating to water	→	(5) The farmers needed to organise themselves into a irrigation community (*Comunitat de Regants*) (5) Establishment of rights and obligations of the stakeholders (5) Setting up of a canon to pay for irrigation water

The analysis of the state (S) of the system when water was finally available for irrigation in 1864 must be made in relation to the different stakeholders and to the land and soil. The Canal d'Urgell Company had as its main constraint (D) the lack of the legal regulation of water in Spain. In 1855, the first Agricultural Engineering College (*Escuela Central de Agricultura*) was created in Spain by Alonso Martínez (Liberal party), the Minister for Public Works, who also created a Commission to draw up the Bill of Waters law. This law, which was the first of its kind in Europe, was passed in 1866, but the Revolution of 1868 frustrated its application. Without this law, paying a canon for the use of water could not be compulsorily imposed on farmers, nor could any tariffs for them using any other available water for irrigation. For this reason, some of the landowners (representing 8 000 ha out of a total of 64 345 ha) were reluctant to accept irrigation and this produced a negative economic impact on the company.

Irrigation was by gravity but water use was deficient because the local peasants were not trained in how to manage the water in their fields, while soil degradation due to salinization took place as a result of the wet geological materials which acted as salinity distribution centres. On the other hand, the creation of swamp areas was favoured by the microtopography which was inappropriate for this type of irrigation, while mosquitoes began to appear which transmitted malaria. At the beginning not all the irrigable lands were irrigated; about 50% were kept fallow. Furthermore, the criteria for establishing the canon to be paid for water were not appropriate as they were based on crop production and not on the quantity of supplied water. What is more, farmers initially paid the canon with products, not in cash. This system did not encourage farmers to improve crop production and it was very difficult to apply because the available statistics on crop production were very deficient during the first set of years. Positive and negative impacts that have been recognised are shown in **Table 3**.

Table 3. Impacts of the transformation of the Urgell Plain from dryland to an irrigation perimeter in the second half of the 19th century

Positive impacts	Negative impacts
Increase in agricultural production Good times for farmers with middle-sized farms: direct work Change in human population size (immigration)	More work for peasants than with dryland farming Only small improvements to crops and irrigation Population death due to malaria Soil degradation: salinization The canon system did not encourage farmers to produce more The canon system created storage and sales problems for the company The income for the company depended on product prices Financial problems for the company and its shareholders Economic difficulties for big landowners who had to make large investments to prepare land for irrigation

In 1879, the first Water Law was passed and established a compulsory payment that was to be made by all the landowners included within a given irrigation perimeter. The aim was to overcome the reluctance of some of the local people and to stimulate the construction of major irrigation works. At the end of the 19th century, the state (S) of the Urgell irrigation perimeter was characterized by the financial problems of many large landowners: agricultural failure was associated with the change from dryland farming, with a monoculture of cereals combined with fallow, to the irrigated cultivation of cereals (wheat and barley), potatoes, alfalfa (with limited water), some orchards, and vines and olives, with the last two being grown on dry lands (Zulueta 1920). After that, many positive responses (R) were received from farmers whose direct, patient and persevering work over many years showed an important level of interest in improving their land and soils.

The new driving forces (D) were: training in irrigation practices, technical innovations (machinery, new crops and varieties and knowledge about pests, soils and plant nutrition) and institutional support for farmers and financial facilities, which produced excellent results. Significant responses (R) were: (1) the installation of efficient drainage systems to prevent soil salinization and the appearance of swamp areas and thereby eliminate mosquitoes and malaria; (2) improvements in the efficiency of water use; (3) the replacement of cereals (wheat and barley) by fruit trees (apple and pear orchards), which along with maize and alfalfa are now the main crops grown in this area; (4) new local and export markets. According to the Water Law (1879), the concession of water to landowners was perpetual, while the maximum length of a concession to a company selling water to farmers was 99 years. Current water management (D) is carried out by farmers and their Irrigation Community. After 147 years of irrigation, the current state (S) of the irrigated perimeter is characterized by high quality soils, while very few areas are affected by salinization. There has been a change from the fail to success, with responses to pressing challenges having resulted in a very highly productive irrigated agricultural area.

b. *Influence of land utilization type (LUT) on land and soil degradation in México.*

In La Barreta (Querétaro State, México) the influence of land use type (LUT) on soil protection and land degradation has been studied at adjacent sites (**Figures 1 and 2**).

Figure 1. Land use type: forest of *Quercus* in La Barreta (Querétaro State, Mexico). Image J. Porta.

Figure 2. Land use type: at the front, a miscellaneous area, and at the back, a forest of *Quercus* at La Barreta (Querétaro State, México).

Site 1 (**Figure 1**) is characterized by a high quality forest of *Quercus (encino)* and by *Phaeozem* soils characterized by a mollic epipedon; at site 2 (**Figure 2**), only a few tree specimens are left, the soil cover has been removed and a large percentage of the soil and land surface is characterized by rock outcrops. In **Table 4**, a comparative analysis has been made using the DPSIR approach to land degradation.

Given that the initial natural factors (climate, slope, soil and vegetation) were the same at both of the sites studied, land degradation at site 2 must have been attributable to anthropogenic causes and particularly to inappropriate land management. The different land ownership systems of the Hacienda (LUT 1) and Ejido (LUT) sites have been identified as the main driving forces (D). LUT 2 has been subjected to deforestation and

Table 4. Comparative analysis on land utilization type (LUT), land management and land degradation at La Barreta (Querétaro, México)

Location	La Barreta (Querétaro, México) Altitude 2 400 m	
Climate	Tropical sub-humid Annual rainfall: 600 mm Soil moisture regime: ustic (NRCS-USDA, 2010)	
Position	Slope – Shady slope (north-facing)	
	Site 1	Site 2
Driving forces	Land ownership: Hacienda (private property) LUT: Forestry (*Quercus*) Mountain ecosystem Application of forest use and conservation criteria	Land ownership: Ejido (communal area) LUT: Agriculture Human population growth Land use Growth of demand for agricultural and forestry products
Pressures	No unsustainable pressures	Deforestation Exposure of bare soil Overexploitation Changes in water infiltration and flow
State	Forest of high quality Landscape quality	**Soil degradation** Physical deterioration Biological deterioration Nutrient depletion **Soil loss** Soil erosion Increase of rock outcrops
Impacts	Only positive impacts (No change from initial state)	Deterioration of soil quality Habitat destruction Loss of biodiversity Water stress Decline in agricultural and forestry production Decline in agricultural income Change in human population
Results	Conservation of biodiversity Soil class: Phaeozem High soil quality High forest quality Landscape value	Abandonment Soil class: Lithic Leptosol Study of rehabilitation strategies
	Recreational Park La Joya (2003)	

overexploitation by farmers, while in the case of LUT 1 a forest ecosystem has been maintained.

Soil erosion and reservoir siltation: a global land degradation problem

The problem of reservoir siltation is very common in many countries with semiarid and arid climates. There is no doubt that a reservoir, whatever its location, always acts as a trap for sediments and that this often causes its lack of functionality. The rate of siltation can be interpreted by using a DPSIR framework for analysis to identify the core indicators. This reservoir degradation study deals with the state of several reservoirs that silted up shortly after they were built: the Níjar or Isabel II reservoir [Almería, south-east Spain (Junta Consultiva Agronómica, 1904; Porta et al. 1980; Cara and Rodríguez 1988; Fernández-Bolea 2007)] (**Figures 3 and 4**), the La Peñita reservoir (Fuerteventura, Canary Islands, Spain) (**Figure 5**), the La Esperanza reservoir (Hidalgo, México), (Becerra, 2000), the Joaquín Costa reservoir (Huesca, Spain) (**Figure 6**) and the Terradets reservoir (Lleida, Catalonia, Spain) (**Table 5**).

The DPSIR model allows the possibility of subdividing the process to obtain a better understanding of this important off-site effect of soil erosion. The results of DPSIR analysis for the Níjar and Terradets reservoirs are shown in **Table 6**.

Table 5. Characteristics of the reservoirs studied (ab: abandoned)

Reservoir	Year of construction	Initial reservoir capacity Hm^3	Evolution of reservoir capacity						
			1870	1904	1957	1977	1995	2005	2010
Níjar or Isabel II	1859	5	2.5	0.002		ab	ab	ab	abandoned
La Peñita	1942								abandoned
La Esperanza	1944	3.92					1.33		
Joaquín Costa	1930, enlarged in 1972	71 (1930) to 92 (1972)					76 to 85 (see text)	76	
Terradets	1935	33			23*	13*		8**	

* data from ICONA; ** Sols (2008)

The study of the state of the Joaquín Costa reservoir deserves some explanation. It was constructed in the early 1930's, mainly for irrigation purposes (D), with an original capacity of 71 hm^3 and it was later enlarged, in 1972, to reach a total capacity of 92 hm^3. For almost 75 years, the reservoir was progressively silting up at a rate of between 0.3 and 0.5 hm^3 of deposited sediment per year (P) (Francke et al. 2008). By the beginning of the 1990's it was not able to supply enough water for the whole irrigation period (S). Engineering work carried out during the period 1995-1997 to release sediment through the dam-bottom outlets resulted in around 9 hm^3 being sluiced through the reservoir (**Figure 6**) (Palau 1998; Avendaño et al. 2000), but no conservation work was carried out in what had been previously identified as the source areas of this sediment within the watershed (R) (Fargas et al. 1997). Nowadays, the reservoir capacity is again equal to that of 1990 (I) (i.e. 76 hm^3) (Mamede 2008).

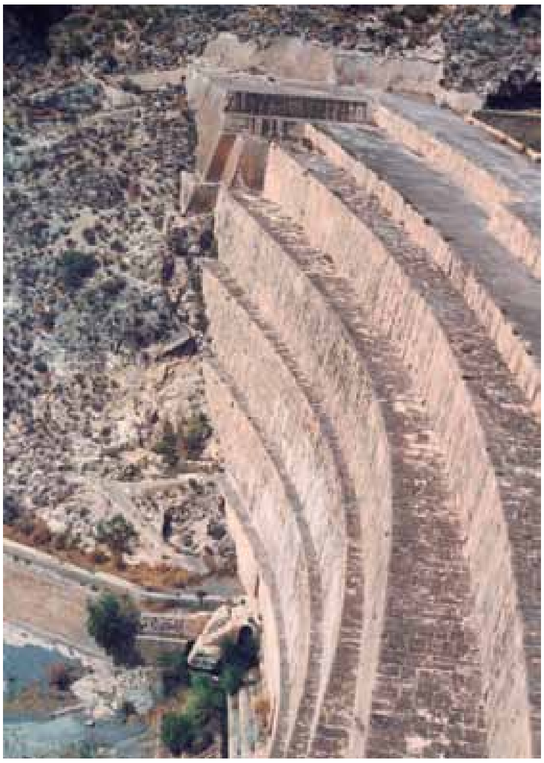

Figure 3. The Níjar reservoir (downstream view): a 35 m high hydraulic work built in the 1850's using ashlars. Image J. Porta.

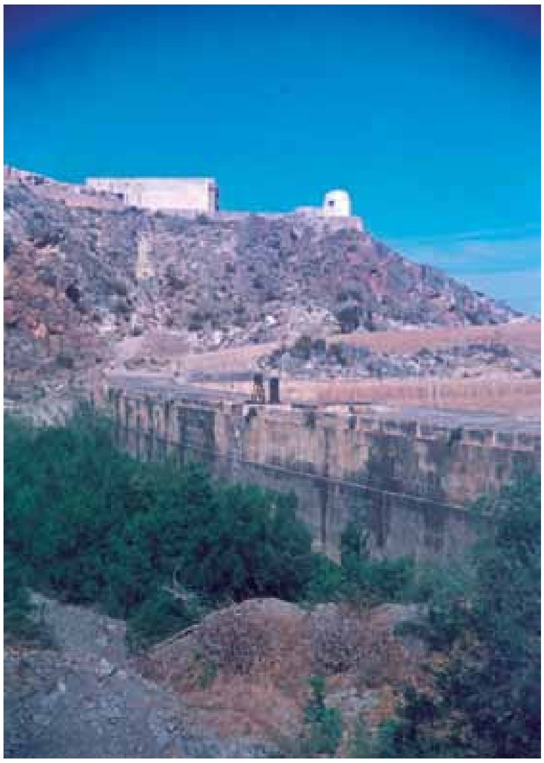

Figure 4. The Níjar reservoir (upstream view): the dam is completely silted up and has been abandoned since the beginning of the 20th century. Image J. Porta.

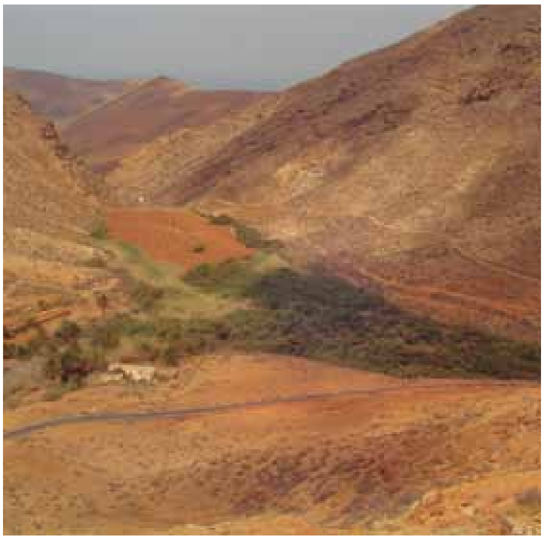

Figure 5. The La Peñita reservoir (upstream view), completely silted up. Image J. Porta.

Figure 6. Upstream view from the Joaquín Costa dam in 1995, just after the reservoir was emptied through the bottom outlets to release part of the sediments. Two thirds of the sediments remained in the reservoir. Image R.M. Poch.

The chain of causal links that was established using a DSPIR analysis of the degradation of the reservoir is shown in **Table 6**.

The driving forces that were identified show that it was impossible to act on any of them. Nevertheless, from a technical point of view, it is now possible to act on the on-site effects of soil erosion (I), using soil conservation measures (R) that can prevent off-site effects such as reservoir siltation. In order to emphasize the discussion of this problem, it was decided to omit one important driving force from **Table 6**. That was the fact that the reservoirs were built by companies which had no responsibility for basin management. When adopting an environmental impact assessment approach, two factors should be considered: the impact of the reservoir on the environment; and the impact of the environment on the reservoir. At the time when the reservoirs studied were built, knowledge of the environment was insufficient to take any of these impacts into account. The lack of connection between reservoir and basin management was therefore a determining driving force that speeded up reservoir degradation due to a relatively high rate of siltation.

Table 6. Land degradation: reservoir siltation (Níjar and Terradets) through a comparative DPSIR analysis

Driving forces	
Níjar reservoir	Terradets reservoir
Mining development Increase in the demand for wood Human population growth Growth of demand for agricultural and forestry products Growth in the demand for water Development of the irrigation perimeter	Human population growth Industrial development Increase in the demand for electricity
↓	
Building of the reservoir	
↓	
Pressures	
Níjar reservoir	Terradets reservoir
Overexploitation of wood Deforestation in the basin Bare soils in the basin Low annual rainfall: 120-320 mm (arid climate) High intensity rainfall	Deforestation in the basin Geological characteristics of the basin: highly erodible marls and lutites (Teira et al. 2009; Porta et al. 2011)
↓	
State	
Níjar reservoir	Terradets reservoir
Soil erosion in the basin	Soil erosion in the basin Mass movements in the basin (Teira et al. 2009)
↓	
Impacts	
Níjar reservoir	Terradets reservoir
Reservoir siltation	Reservoir siltation

Protective effects against degradation when soil is considered as a sacred area

As soil is a non-renewable natural resource at the human scale, it should always be considered sacred. When a soil is considered *sacred* or a *Forêt Sacrée*, as it is in Togo, Bénin (Kokou and Sokpon, 2006) and Burkina Faso (Juhé-Beaulaton 2006) mystical considerations become the driving forces behind soil protection. In such cases, there are pressures (P) run in favour of promoting the view that the soil must be respected and that no productive use can be made of it. Although these areas have been threatened by religious (conversion to christianism), political and socioeconomical reasons (Juhé-Beaulaton 2006), these *sacred* areas are nowadays characterized (Ubalde and Poch, 2000) by the growth of dense vegetal cover, an intertropical forest (**Figure 7**) with very high biodiversity (Kokou and Sokpon, 2006), and containing Iroko tree (*Milicia excelsa*), which is known to cause the carbonatation of surrounding soils (Braissant et al. 2004; Cailleau et al. 2005). The outline of the studied unit occupied by the sacred forest is almost rectangular, and its surface is very small (half an hectare). These facts suggest that the differences of the mollisol under the forest with the adjacent ultisols are due to deforestation. These areas can be used as references to enable us to understand the effects of human actions on land degradation.

The existence of these *Forêts sacrées* surrounded by deforested landscapes makes it possible to compare the influence of different land use types on soil degradation induced by human land use within the Sudano-Guinean area (**Table 7**).

The negative impacts turned the ecosystem into a wooded savannah with a low density of vegetation cover (**Figure 8**). These impacts are almost irreversible, because it is very difficult to have a bearing on the driving forces and any attempt to act on the state of the system would show a poor understanding of the problem. Only prevention of the initial land degradation would have been an appropriate approach. The assessment of rehabilitation strategies, providing national and international advice and giving economic support to farmers are some of the solutions that must be explored.

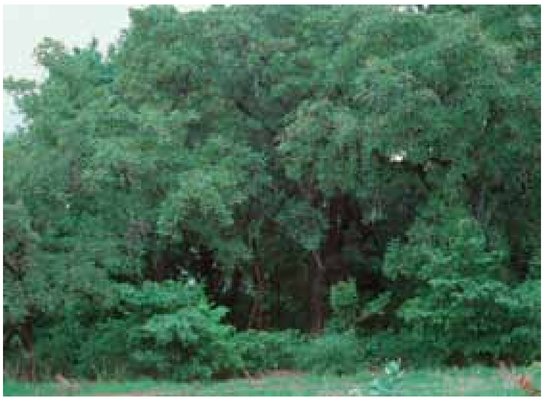

Figure 7. *Forêt sacrée* from the north of Togo in the Sudano-Guinean zone. Image R.M. Poch.

Figure 8. Degraded land, sparse forest and Haplustult soils. Image R.M. Poch.

Table 7. DPSIR framework applied to soil degradation in the Sudano-Guinean area

Location	North of Togo Sub-Saharan, Sudano-Guinean zone. Savannah region *Centre de Formation Rural de Tami* (CFRT)	
Climate	Annual rainfall: 1 000 mm Soil moisture regime: ustic Soil temperature regime: isohyperthermic	
	Site 1: Forêt sacrée	Site 2
Vegetation	Dry forest of high diversity, with *Milicia excelsa*	Wooded savannah with low density cover
Soil	Mollic horizon: organic matter: 22.7 kg OC m^{-2} pH: 7.7–8.6 P: 15 mg kg^{-1} K: 600 mg kg^{-1} CEC: 40 cmolc kg^{-1} Pachic Vermustoll (Phaeozem)	Umbric or Ochric horizon Organic matter: 2.6 kg OC m^{-2} pH: 6.0 Arenic Kanhaplustult (modal soil)
Driving forces	Mysthic area	Human population growth (7.6 children per woman) Decrease in mortality High demographic density Slash-and-burn system Growth in demand for agricultural and forestry products
Pressure	No pressure	Deforestation Forest and rangeland fires Abandonment of fallow Nutrient mining Exposure of bare soil Overgrazing
State	High density forest and biodiversity	Abandonment of traditional agricultural practices Soil degradation by erosion Soil acidification Nutrient depletion Biological deterioration
Impacts	Positive impacts: Soil conservation Forest development Increase in biodiversity High quality soil	Habitat destruction and loss of biodiversity Decline in agricultural production
Responses	Prevent anthropic interventions	No responses

4. Conclusions

Land managers and policymakers need information about soil changes and land degradation risks in order to be able to predict the effects of management on soil functions, compare alternatives and take appropriate decisions. The main conclusions drawn from this research are that land degradation after the beginning of irrigation in the 1860's in an irrigated perimeter in a semiarid zone with calcareous soils in NE Spain; the influence of the land utilization type (LUT) on land degradation in an area of Phaeozem soils in México; soil erosion and reservoir siltation, and a special case of soil preservation in the tropics could be analysed with the DPSIR framework approach. This tool allowed to find the primary causes of soil and land degradation in specific land utilization types within a historical context. The dynamics associated with land degradation could be understood by focusing on the links between the driving forces, pressures, state of the system and impacts in view to increase the eco-efficiency of the system.

The issues identified which derived from changes in land use allows us to state that the socio-economic and socio-cultural driving forces behind land degradation problems are the responsible for an increasing pressure on the system. For this reason, technical measures for improving the state of the system are not sufficient to prevent or to control land and soil degradation. This technical approach often leads to an inappropriate and/or inefficient use of available funds because the true causes of the problem are not tackled. As a result, the pressures that stress the system prevail and the problem tends to reappear at a later date. Responses must be related with driving forces and based on the application of scientific principles of soil behaviour in response to changes in land use. The introduction of technical innovations for soil and water conservation, institutional support for the training of farmers and institutional support to encourage land conservation and rehabilitation are clue aspects for solving the problems. It can be concluded that decision makers now have better tools available to them for making choices and should use them to help prevent future land degradation.

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