Factors and Processes leading to Desertification in the Canary Islands (Spain)

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Résumé

La dégradation de la terre a conduit à un accroissement de la desertificación dans les zones arides des Iles Canaries, considérées comme secteurs de priorité A dans le Plan National Espagnol de Lutte contre la Désertification. Dans ce travail ont été analysés les principaux processus de désertification dans les îles, en rapport avec la dégradation du sol causée par l'érosion hydrique et éolienne et la salinitée/sodicitée, la perte de ressources hydriques et la transformation de la couverture végétale dans des communautés de substitution, ainsi que leurs causes, tant naturels comme celles en rapport avec les changements d'utilisation du sol durant les dernières années.

Introduction

Desertification, defined as the decrease of the biological potentiality resulting from a negative impact of human activities and of the models of occupation of space, has turned into one of the main global environmental issues that affect the human kind, together with the loss of biodiversity and the previsible climatic change. The arid, semiarid and subhumid island ecosystems, like the Canarian archipelago, are especially sensitive towards desertification, with numerous synergies and feedbacks with the process of loss of biodiversity, as they are a hot spot of biodiversity in Europe. They are also regarded as one of the European zones in which the impact of climatic change will foreseeably be more important. The Canary Islands are severely or very severely affected by desertification (up to a 68.3% of the total Canarian surface) (MMA, 2001). The main desertification processes in the islands related to soil degradation, loss of water resources and plant cover transformation, as well as their causes, both natural and those related to land use changes in the last years, have been analyzed in this work.

Materials and Methods

The Canary archipelago is made up of seven main volcanic islands, rising over the NE of the Central Atlantic, over an approximate surface of 100,000 km^2, close to the northeastern African coastline, from which it is separated by a 100-km wide strip sea. Zonal geographical factors such as the proximity of the African continent and the trade winds, as well as regional factors such as the diverse relief of the islands and their orientation relative to trade winds in any given same island, give rise to a large number of climatic conditions. The geological materials have been generated from subaerial volcanism and comprise mainly basalts and salic rocks, both as lava flows and pyroclastic deposits. The predominant soil types in the islands are Leptosols, Regosols and leptic and lithic subunits of other soils (25.3% of the total surface of the archipelago) (Rodriguez Rodriguez *et al.*, 2001). In plain areas, over ancient parent materials, the main soil types are Andosols, Cambisols and Luvisols, whereas in the driest areas Calcisols and Solonchaks are the most frequent soil types. The relative significance of the main biophysical processes of land degradation that lead to desertification in the islands (soil degradation, loss of vegetation cover, water resources degradation and

other), have been estimated by remote sensing and field surveys. In the case of soil degradation processes, the means of study include: (i) remote sensing for water erosion after extrapolating field measurements (plots and USLE data, Wischmeier and Smith, 1978), (ii) remote sensing for wind erosion, also by supervised classification from field data, according to Woodruff and Siddoway (1965), and (iii) field and laboratory studies, as well as geostatistical (i.e., kriging) interpolation techniques for salinization and sodification.

Results

There have been three main historical phases of land degradation in the islands: deforestation after the Conquest (15th Century), forest exploitation in the 19th century and the change from an agricultural-based socioeconomic model to another one associated with the tertiary sector during the last 50 years. These transformations have been especially intense after the 50s, with the development of the touristic industry, so the islands are currently overpopulated, with 1,800,000 residents, together with a floating population of 12,000,000 tourists that visit the islands annually.

The land degradation has led to an increasing desertification in the arid zones, regarded as A-priority areas in the Spanish National Plan Against Desertification. Desertification relates to soil degradation (40% of the cases), the loss of vegetation cover and biodiversity (35%) and degradation of water resources and other processes such as soil sealing, abandonment of traditional agriculture, etc. (25%).

Soil degradation

The main processes of soil degradation in drylands of the Canary Islands include both water and wind erosion, salinization and sodification.

Soil water erosion.- Approximately 44% of the surface area of the archipelago is affected by severe processes of accelerated water erosion involving about 326,000 ha. Fuerteventura and Gran Canaria islands are those most affected by water erosion (Table 1), mainly because of the sparse plant cover in the first case and of intense human pressure on the land in the latter one. The least affected islands are El Hierro and La Palma, where a dense vegetation and high infiltration rate of soils, coincide with low human pressures on the land.

Table 1. Surface area estimated as affected by water erosion

	Surface area (km^2)	% of total surface area
Fuerteventura	976.0	58.7
Gran Canaria	894.2	57.3
La Gomera	188.3	50.9
Tenerife	841.7	41.3
Lanzarote	276.4	32.6
El Hierro	23.9	8.9
La Palma	55.4	7.8
CANARY ISLANDS	3255.9	43.7

Wind erosion.- Approximately 38% of the soil surface of the archipelago is affected by wind erosion, involving approximately 283,000 ha.(Table 2). Wind erosion is most important in the eastern islands, basically because of the frequent northeast and south winds, that affect low-quality soils (i.e., sandy, organic matter-poor soils with a weakly developed structure and aggregates highly susceptible to wind transport). In addition, the eastern isles are flatter and are more exposed to winds, and most of the soil cover is not protected by the vegetation, whereby soils are in general highly erodible.

Table 2. Estimated surface area affected by wind erosion processes

	Surface area affected (km^2)	Percent of total surface area
Fuerteventura	1571.0	94
Lanzarote	503.6	56
Gran Canaria	410.5	27
Tenerife	329.7	16
La Gomera	12.8	3
La Palma	0	0
El Hierro	0	0
CANARY ISLANDS	**2827.6**	**38**

Salinization-sodification.- Table 3 shows that 24% of the soils in the islands are affected by salinity and/or sodicity phenomena, reaching an 84% when only the irrigated agricultural lands are considered. High salinity levels have been detected in all soils of several islands, with average EC_{es} values up to 18 $dS.m^{-1}$, being these concentrations highly variable in space and in time. Sodium chloride is in all cases the most abundant salt, which points to the marine origin of soil salinity and sodicity. In irrigated soils, the use of chloride- and sodium bicarbonate-rich waters, as well as of a great amount of chemical fertilizers (potassium nitrate and sulphate), is leading to an acute salinization and sodification of these soils, and a subsequent decrease in their productivity.

Table 3. Surface area affected by processes of salinization-sodification of the soil (EC_{es}>2 dSm^{-1})

	Surface area (km^2)	% of total surface area
Fuerteventura	976.2	58.7
Lanzarote	386.7	45.6
La Gomera	47.8	12.9
Gran Canaria	192.0	12.3
Tenerife	177.1	8.7
La Palma	18.9	2.7
El Hierro	0.4	0.1
CANARY ISLANDS	1799.1	24.2

Loss of vegetation cover and biodiversity

Soil and plant cover degradation processes are usually closely related. The degradation of the natural vegetation started in the islands immediately after the conquest, so that the forest surface has decreased progressively from 1940 km^2 in 1850 to 1420 km^2 in 1950, and to 980 km^2 nowadays.

Xerophytic scrub.- From the Castilian conquest until recent times, the anthropogenic pressure was limited to extensive grazing. At present time, intensive agriculture and accelerated urbanization have reduced the original scrub to areas largely unfavourable for human use, and non-accesible both to man and livestock.

Termophyllous forest.- Midland forests have been subjected to a strong anthropic pressure for centuries. Intense livestock-breeding, agricultural use and timber exploitation caused the substitution of the original forest by a sclerophyllous scrub.

Laurel forest.- In these areas, the original vegetation consisting of evergreen, broad-leaved forest has become restricted to small relicts. Exploitation of the vegetation as fuel, and intense pasturing and farming have greatly degraded the plant cover, reducing the biomass, cover capacity and diversity.

Pine forest.- Canarian pine forest has been (and it is) exploited as fuel or animal fodder and supports most the wildfires occurring in the islands.

Summit scrub.- At the summit, no clear soil processes associated with degradation/ regeneration of the ecosystem can be identified. The changes in vegetation are not associated with the anthropic influence, but rather responds to natural gradients related with the parent material and the topography.

Water resources degradation

The generalized scarcity of fresh and drinking water constitutes another evident symptom of desertification, being a reality in some islands as a consequence of the drought and the lack of rainfall. Both water resources management, distribution and uses have proved to be caotic in the islands, thus leading to aquifer overexploitation, exhausted water sources, salinization of coastal aquifers by marine intrusion, chemical and biological contamination of aquifers, etc. Water balance has been estimated to be negative in 89.1 $Hm^3.yr^{-1}$. Up to an 85% of the acuifers show evidences of marine intrusion and salinization of groundwater, and 60-75% of water sources are affected by urban, human-induced contamination

Other processes

Abandonment of traditional agricultural systems.- One hundred thousand ha of agricultural soils have been abandoned during the last 50 years. Most of this surface was cropped under traditional, conservative practices towards soil and water resources, whereby it contributes to worsen the global trend. Intense water erosion (in 97% of the cases), wind erosion (60% of the studied field plots), soil crusting (43%) and/or compaction (31%) processes have taken place in these areas.

Soil sealing.- The population density in the Canary Islands exceeds in some cases the 258 inhabitants per square km, but it may be as high as 635 $inhab.km^{-2}$ if only the actually populated areas are taken into account. The dense road network (1.67 $km.km^{-2}$), together with building and other facilities along the roads, gives raise to a soil loss estimated between 6 and 12%. This fact confirms that we are facing one of the most severe soil loss processes in the islands. A solution for this issue, that also contributes to desertification, is far more complex and harder to reach than for contamination or erosion processes, as it depends on politic decisions.

Discussion and conclusions

There have been three main historical phases of land degradation and desertification in these islands: deforestation after the Conquest (15th Century), forest exploitation during the 19th century and the change from a socioeconomic model mainly based on agriculture to another associated with the tertiary sector in the last 50 years. This transformation has been especially intense after 1950 with the development of the tourism. Desertification affecting 68.3% of the archipelago surface is related in a 40% of cases to soil degradation (44% of the surface area of the archipelago is affected by water erosion, 38% by wind erosion, 24% of the soils of the islands are affected by salinity-sodicity, a proportion which increases to 84% when only irrigated agricultural land is considered), in a 35% to a loss of vegetation cover and biodiversity and in a 25% to water resources degradation and other processes (soil sealing, abandonment of traditional agriculture).

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