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MEDITERRANEAN LANDSCAPE, DESERTIFICATION AND THE POPULATION-ECONOMY NEXUS: PERMANENT ASSESSMENT AND IMPLICATIONS FOR MITIGATION POLICIES

LUCA SALVATI

Abstract:

The United Nations Convention to Combat Desertification defines ‘desertification’ as a ‘reduction or loss of the biological and economic productivity’ resulting from land use mismanagement, or a combination of processes, such as soil erosion, deterioration of soil properties, and long-term loss of natural vegetation. Landscape Degradation (LD) is hence an interactive process involving multiple factors, among which climate, land use, and population pressure play a key role. Joint biophysical and socioeconomic aspects are the main factors negatively impacting the vulnerability of natural and agricultural land especially in Mediterranean-type ecosystems, and their interaction may become extremely complex over space and time, resulting in typical patterns of landscape degradation, molded by increased population density. In order to identify vulnerable areas and quantify the intensity of the associated environmental risk, understanding spatio-temporal trends (together with current status) of landscape degradation is a key issue both from ecological and policy perspectives. Diachronic studies may contribute effectively to policy implementation providing a knowledge base to environmental monitoring and conservation practices. In fact, they would allow, on the one hand, to identify degraded areas needing substantial intervention initiatives for biodiversity and landscape protection; on the other hand, they allow a permanent monitoring of the evolving landscape processes in the perspective of global changes.

Keywords:

Soil, Climate, Anthropogenic pressure, Southern Europe.

JEL Classification: R14, R58, J11

Authors:

LUCA SALVATI, Sapienza University of Rome, Italy, Email: luca.salvati@uniroma1.it

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Introduction

Economic globalization driven by technological, social and cultural integration and convergence among countries has reinforced the role of finance in planning and designing criteria that regulate and stimulate development, production and consumption chains. Traditional socioeconomic frameworks consolidated in long-established adaptation processes to territorial, socio-cultural and environmental challenges, were demonstrated to interpret only partly the progressive economic and cultural standardization characterizing Western societies, breaking down the last boundaries of communication, facilitating trade and allowing access to primary (and, sometimes, secondary) goods to wider population segments. Increased income and consumption levels worldwide had a greater impact on the exploitation of natural resources with ecosystem costs that often result in forms of environmental and landscape degradation, interpreted as ecological disturbances in an evolutionary perspective.

In such a context, global warming, albeit with effects largely varying over space, was mainly reflected into a relevant increase in air temperatures relative to the reference climatic values, being also associated with alterations of rainfall regimes, that include a progressive reduction of average annual precipitation, and greater intensity and frequency of extreme events (e.g. heavy rain, droughts, heat waves).

To respond to these environmental challenges, coordinated strategies are increasingly required at multiple spatial scales (country, regional, local) to solve or mitigate the current socio-environmental problems to prevent future ones. A collective consciousness has developed with an increasing awareness of immaterial needs of human well-being and, consequently, a widespread sensitivity to the irreparable damages that derive from an unsustainable socioeconomic development. The holistic notion of 'sustainability' - based on the ability to reconcile livelihood and growth needs of today's society with priorities and limits of the environment - emerges as a response to effectively counter environmental degradation. As a consequence, the notion of "sustainable development" considers together societal, economic and environmental goals to be closely interconnected and mutually interdependent. The primary task of empirical research in the field of landscape degradation and sustainable development is therefore to provide the knowledge base useful for implementation of appropriate management tools capable of identifying, collecting, analyzing and interpreting empirical data that may support policies for sustainable development.

Given the amplitude and complexity of this challenge, a multi-dimensional approach is necessary, involving disciplines from economics to climatology, from soil science to sociology, from agronomy to geography. In many cases, the need to plan, manage, preserve, develop, and recover land has stimulated the emergence of new disciplines and thematic issues such as, for example, the integrated study of landscape degradation. By this way, landscapes should be investigated analytically by identifying the constituting elements subsequently merged into homogeneous aggregates and verified against known relationships, e.g. the population-economy nexus.

The present work proposes a reflection on desertification, landscape degradation and demo-economic issues evaluating jointly scientific approaches and implications for policy implementation. In particular, an interpretative scheme will be proposed to collect, organize and elaborate sets of indicators that illustrate and report spatio-temporal dynamics that characterize desertification in a specific ecological context, the Mediterranean region, that involves together biophysical, social and economic aspects.

Landscape degradation: causes and effects

Landscape degradation implies a decrease in one or more environmental dimensions, while desertification represents the last stage of landscape and soil degradation and implies the irreversible loss of the original agricultural and forestry productivity, from both the ecological and the economic point of view (Costantini et al., 2007). The term 'desertification' is evocative of relevant transformations of the pre-existing environment into a neglected wilderness of sand and dunes. However, this phenomenon is more precisely defined when referring to the physiological expansion of deserts in surrounding areas. Landscape degradation defines all the (undoubtedly less exotic and evocative) processes that lead to the decline of soil and land quality with feedback consequences on biodiversity, deterioration of plant cover and, ultimately, soil fertility loss. Compared with desertification, land degradation processes are not confined to delimited ecological environments - being observed across continents, and occurring more frequently in ecologically-fragile and economically-marginal areas.

The United Nations Convention on Combat Desertification (UNCCD) is now the only legally binding international agreement recognizing the link to effectively tackle causes of (and reduce effects of) landscape degradation promoting sustainable management of land. The UNCCD, among the many accomplished tasks, has formulated an official definition of desertification, intended as "soil degradation in arid, semi-arid and dry sub-humid areas attributable to various causes, including climatic variations and human activities" (article 1, section a, UNCCD 1996). The official definition of the UNCCD has marked a step forward in the fight against desertification, as it explicitly recognizes the predisposing role of natural factors (e.g. climate change) and human responses to pressure generated by the environment. Anthropogenic impacts, driven by land-use mismanagement, urbanization and the increasing ecological footprint of economic activities, determine negative processes such as soil sealing, erosion and loss of plant cover, salinization and compaction, which result in chemical, physical and biological deterioration of soils (Menichini 2008).

The notion of "land" used in such a definition assumes the specific meaning of "bio-reproductive system including soil, vegetation and the ecological/hydrological phenomena that are produced within this system". In this regard, the concept of "land degradation" implies the decrease or the complete loss of biological and/or economic productivity (Article 1, sections e,f: UNCCD 1996). Processes of landscape degradation and desertification are more frequently observed under conditions of accentuated environmental vulnerability due to arid or semi-arid climate and where forms of land exploitation are practiced in un-sustainable ways. The well-known phenomenon affecting the Great Plains of the United States of America in the 1930s is probably one key example of landscape degradation. Following intense and long droughts, farmland that were subjected to particularly intensive cultivation experience a progressive degradation of landscapes that turned into "dusty bowls", with soils heavily eroded by the wind, giving rise to violent storms of dust. At that time, a large population segment was forced to abandon their land, leading to an unprecedented economic and social crisis (Salvati et al., 2009).

Causes of such processes were usually split into environmental factors and human factors (Francaviglia 2011). Environmental factors include (i) altered climatic regimes (desertification is triggered by specific conditions, such as prolonged dryness with structurally low rainfall levels); (ii) meteorological droughts that can affect arid or no areas indifferently and occurs when the rains are much lower than the normal levels of the time period considered, (iii) heavy rainfalls causing erosion of the surface layer of the soil removing a fertile soil portion; (iv) landscape degradation (under the hypothesis that mountain and hillside landscapes favor soil erosion, especially when slopes are very steep). These factors together cause an increase in soil erosion. Agricultural machineries (e.g. plowing) can rise soil loss risk due to water erosion. In addition, depending on the exposure of the slopes, microclimate conditions that are unfavorable to the regeneration of vegetation can be observed (Salvati et al., 2008).

Landscape degradation may be also triggered by a progressive degeneration of plant cover. A simplified vegetation structure reduces the overall level of biodiversity, decreasing the protective effect on soils, until the process becomes irreversible. Even in this case, man may aggravate local conditions by stimulating a progressive reduction in plant cover, especially with regard to the most attractive livestock species that are also the most useful to the protective functions of the soil. In this regard, the soils most exposed to desertification are the less-structured ones, in particular those with low content of clay and organic matter. These components contribute to keep soil particles together, resulting in a micro-porous structure that favors better environmental conditions for roots, micro-flora and micro-fauna of the soil, as well as storage of the soil, water and nutrients. Humans can compromise the nature of the soil through urbanization-driven soil sealing.

Anthropogenic factors include (i) misuse of water resources (excessive and unplanned groundwater exploitation often prevents rains from recharging bogs. Along coastal strips, an excessive embankment from the aquifers results in contamination by intrusion of saline wedge; irrigation of brackish water crops causes long-term soil salinization, lowering fertility and potential productivity); (ii) deforestation (excessive exploitation of forests and their physical destruction result in an increase of the soil surface exposed to degradation, resulting in a substantial reduction in soil water retention capacity). In addition, forest cleaning practices cause much worse damage than benefits, as they prevent the formation of new humus by eroding soils.

Leaving the ground uncovered, wildfires have adverse effects on some of soil and landscape properties, such as the structure and content of organic matter. Fires also forms water-repellent substances that accelerate surface water rippling and sediment transport. Moreover, the use of agricultural machinery unsuitable for soil quality can significantly alter the soil structure by reducing the water infiltration capacity and increasing erosion. The use of unbalanced fertilization that does not provide proper fertilization with organic products impoverishes soils that will eventually lose the ability to retain chemical nutrients. In some cases, the excessive loading of animals on the ground may, in addition to the already mentioned degradation of vegetation, determine the compaction of the terrain. Finally, urbanization is perhaps the process with the most immediate and serious effects among those analyzed (Ceccarelli et al., 2014). The specific contribution to desertification can be direct, e.g. due to soil sealing, and indirect, due to destruction of natural resources, interference with the renewal cycle of land resources, and other land-use impacts. Landscape degradation processes are widespread all over the world. In this regard, areas subject to desertification are typically characterized by fragile ecosystems, sensitive to the exploitation of natural resources (especially soil, water and landscape resources), requiring implementation of specific protection measures (Aru, 2002).

Monitoring landscape degradation in Mediterranean Europe

Identification of areas at risk of desertification and deep knowledge of the causes of landscape degradation are the preliminary steps to implement a strategy to counteract this process in prone areas (Colombo et al., 2006). To determine the level of risk in a given geographical region, specific methodologies have been proposed and various indicators have been considered leading to biophysical and socioeconomic metrics expressing vulnerability or ecosystem response to environmental disturbance caused by external pressures (Luise et al., 2004).

Each metric has to fit given quality criteria: (i) specific for the area of interest, (ii) measurable, (iii) scientifically sound and relevant, (iv) easily available and, finally, (v) temporally specific (Brandt and Geeson, 2008). A widespread model for assessing desertification risk in Mediterranean regions is the "Environmentally Sensitive Areas" (ESAs) approach developed in the framework of the European MEDALUS (MEditerranean Desertification And Land Use) project, producing a standardized index adaptable to the availability of input data in different environmental contexts (Kosmas et al., 1999). The ESAI (Environmentally Sensitive Areas Index) defines a notion of environmental quality determined by 4 components: soil, climate, vegetation and land management. Starting from the elementary indicators chosen to represent each component dimension, 4 partial indices have been calculated (by assigning a weight to each indicator depending on the importance of its contribution, assessed through dedicated analysis) and then calculating the ESAI through the geometric mean of the 4 partial indices. The ESAI was then reclassified with the aim to express the different risk levels, identifying critical, fragile, potentially-sensitive and not threatened land (Kosmas et al., 1999).

The operational definition of 'areas at risk of desertification' requires the use of biophysical indicators and of selected variables assessing human-induced pressures and disturbances. Depending on the particular type of management, territorial resources can be used in forms (more or less) compatible with ecosystem equilibrium. Land management calls into question a set of factors including environmental, climatic, social, economic, political and technological dimensions. The selected indicators have to report extremely complex and intricate phenomena. An example is the abandonment of land following industrialization policies which has led to phenomena of deterioration or improvement in soil characteristics depending on soil type and climatic conditions (Kosmas et al., 1997). However, the adoption of environmental protection measures may mitigate negative impacts of a mismanagement in the use of land (Montanarella et al., 2000).

Assessing desertification risk in the Mediterranean region

The total area of the European continent is about 300 million hectares, of which nearly 97 million are affected by soil and landscape degradation (Colombo et al., 2006). Empirical data and statistics derived from country and supranational surveys over recent years, have formed a greater awareness of severity and extent of desertification,. Even in highly developed socioeconomic contexts, desertification may exist, sometimes due to climate change, sometimes due to unsustainable socioeconomic systems, in most cases due to a complex set of intertwined causes.

At present, the European countries facing the Mediterranean basin (Portugal, Spain, Italy, Greece, Albania, Bosnia and Herzegovina, Croatia, Cyprus, France, Malta, Slovenia, Spain and Turkey) are more exposed to desertification than central, eastern and northern countries. As a whole, there are about 37 million hectares classified at desertification risk in Europe due to land vulnerability, as far as possibly irreversible degradation processes. Critical conditions can be recognized locally in some regions of the above-mentioned countries, where the percentage of the threatened territory is even higher, for example in southern Portugal, in various regions of southern Spain and Greece, Sardinia and Sicily (EEA, 2005). Desertification processes in the northern-Mediterranean basin are generally attributed to a set of causes including biophysical and anthropogenic drivers that generate untenable environmental pressures (Geeson et al., 2002).

A further contribution to estimate the extent of areas at risk of desertification was provided by the Desertification Information System to support specific National Action Plans developed under the Desertification Information System for the Mediterranean Project (DISMED). The project has taken account of climatic, soil and vegetation factors (Colombo et al., 2006) with the aim of providing decision-makers with scientific knowledge useful to improve effective policy measures to counteract the effects of drought and to fight desertification. This goal is pursued through the strengthening of international communication, facilitating the exchange of information and establishing a common information system to monitoring biophysical and socioeconomic conditions of risky areas, assessing the extent, severity and progress of landscape degradation. Results of the program indicate that Spain has the largest vulnerable area (8.5% of the country's land affected by a high risk of desertification) followed by Greece (with an extension of about 5.8% of the national territory), considering also that this country has the largest surface area affected by average desertification risk conditions (36.9%). Italy has an extension of vulnerable land close to 3.1%, with 32.1% of total land exposed to average desertification risk. Based on the results of this assessment, Spain is still the country most affected by desertification, in relation to both "Intermediate" and "High" risk classes (Colombo et al., 2006).

The role of research and policies

Desertification, together with climate change and biodiversity loss, is one of the biggest challenges for sustainable development and, as such, has been recognized since the world summit in Rio de Janeiro (1992). In this regard, the United Nations Convention to Combat Desertification (UNCCD) was set up in 1994. The problem of desertification is so widespread in the world that there are now 194 countries signing and participating to this Convention. In the context of an integrated approach compatible with the Agenda 21 program, the UNCCD identified the "international cooperation and partnership agreements" as the indispensable instrument for establishing a sustainable development path in affected areas (Article 2.1). Coordinating collection, analysis and exchange of data is intended as a key tool to prevent environmental (and social) damage resulting from desertification processes, to restore soil productivity, to mitigate the negative effects of drought, to improve living conditions in arid areas and to combat poverty promoting environmental sustainability (Brandt and Geeson, 2008). To underline the type of participative approach, attentive to every aspect of conservation of natural resources, the UNCCD collaborates with other two conventions, the United Nations Convention on Biological Diversity (UNCBD), signed in Rio de Janeiro as well, and the United Nations Framework Convention on Climate Change (UNFCCC).

Countries in the Mediterranean are part of the UNCCD under Annex IV, including Albania, Bosnia and Herzegovina, Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, San Marino, Slovenia, Spain and Turkey (Corona et al., 2009). The convention produced guidelines on identifying and processing desertification indicators that are most useful for monitoring land vulnerability in Mediterranean environments (Kosmas et al., 1999). These indicators are based on multiple available materials, including satellite imagery, topographic data, climatic and geological data, as well as land-use information reflecting the negative impact of socio-economic dimensions (Kosmas et al., 1999).

The countries of Annex IV for the Northern Mediterranean basin intend to fulfill the objectives of the Convention in terms of planning practical interventions to mitigate environmental degradation. In Italy, the National Committee for the Fight Against Desertification, established by a Prime Minister act dated September 1997, aims to coordinate the implementation of the Convention with the following objectives:

(i) to identify strategies and priorities, within the framework of sustainable development plans and policies, to combat desertification and mitigate the effects of drought;

(ii) to prepare and implement a National Action Plan to combat desertification;

(iii) to specify indicators of desertification risk;

(iv) to implement an inventory of local technologies, knowledge and traditional practices that contribute to resource saving and fight against desertification;

(v) to promote training and research activities;

(vi) to coordinate activities with other Mediterranean countries, and in particular those of Annex IV to the Convention.

Guidelines and related plans were inspired to a bottom-up process of identification of strategies and objectives that stimulate and re-orient general policies combating desertification. The Italian National Action Plan provides the base for territorial management with guidelines implementing a strategy to combat desertification in the context of sustainable development. A permanent system of environmental monitoring of land ecosystems was established, which promotes the contribution of grassroots communities by enhancing active participation of relevant local authorities. In turn, the joint activity of the Mediterranean countries within the European Commission was aimed to redirect the interests of the Commission to problems of landscape degradation and desertification. Agro-forestry and hydro-geological resource utilization programs were specifically tailored to containment measures and fight against desertification.

Local communities and population of the most vulnerable regions still remain the largest cultural resource on which to base the integrated struggle against degradation of any given territory. An effective strategy of landscape protection have to promote a global effort to reconcile development and environmental protection by privileging the community's right to balanced land-use and quality of life (National Desertification Fighting Committee, 1998). Such a strategy may include education and awareness programs considering desertification and conservation of natural resources in school education and training, in relation to specific environmental and cultural conditions. These measures can be implemented when accompanied by appropriate social initiatives that reinforce the permanence (and return) of people to the land.

The Italian national plan is definitely oriented toward policies promoting a fine tuning between the impact of productive activities - especially agricultural production compatible with the structural attributes of each territory - and a high degree of environmental protection avoiding phenomena of depopulation and land abandonment that have so far marked the Italian landscape over the last century.

Based on these premises, creation of an integrated system of environmental monitoring and support to land management and decisions in vulnerable environments to desertification was relevant to both positive and normative issues. The ideas proposed in our study can contribute to the improvement of integrated environmental assessment and planning tools, with particular emphasis on the socio-environmental resilience of local communities in rural contexts.

The limits of reference frameworks

In the rural areas of the Mediterranean, the vocation of the territory changes over space as a result of worse agro-environmental conditions. Terminologies such as agro-ecosystem sustainability to desertification should take account of the joint impact of landscape degradation in rural areas, ranging from climate change to soil erosion, from water scarcity to tourism concentration. From the agricultural point of view, geographic and predictive information tools that meet the needs of estimating agro-ecosystem vulnerability to landscape degradation appear to be quite limited and partial.

National and international research projects have been involved in the development of decision support information systems, starting from MEDALUS projects (Kosmas et al., 1999), which have developed an integrated system of desertification indicators incorporating a module for understanding specific impacts of desertification on agricultural areas. The approach proposed in the MEDALUS projects and in some subsequent studies, however, has revealed shortcomings that can be summarized in the following points:

1. lack of a multi-time exploration of large-scale (e.g. national or continental) landscape degradation phenomena at high spatial resolution;

2. Little attention to quantification of the impacts of desertification on productive agricultural systems (e.g. estimating possible economic losses due to increasing soil degradation in specialized agricultural areas);

3. Reduced predictive capacity of some models of short-term desertification risk assessment, especially at regional or sub-regional scale.

With regard to the first point, a multi-temporal assessment of desertification risk at national and regional level is necessary, given the increasing human pressure driven by population density, tourist pressure, increased infrastructure, loss of agricultural land, climate change, erosion and salinisation of soils. All the aforementioned phenomena have shown over the last 50 years evident trends towards worse environmental conditions. The lack of a proper assessment of drought and desertification, expressed on a local scale, with particular reference to valuable crops, justifies mixed results gained by Local Action Plans (PAL). Local stakeholders, in fact, often lack sufficient economic information to effectively mitigate desertification risk. Finally, scarcity of readily updateable and geographically suitable data sources to evaluate and monitor this phenomena, seems to be an insurmountable constraint (Salvati et al., 2011).

Research actions have produced feasibility plans useful to produce short-term predictive assessment models. The main tools used in this regard are (i) climate scenarios, derived e.g. from Global Circulation Models, (ii) land-use change scenarios available through the use of neural networks and fuzzy sets, and (iii) small-scale demographic projections. The result of these efforts, however, did not lead to the creation of prediction models with sufficient reliability. Conditional projections characterized by a 'what ... if' philosophy, or through purely deterministic schemas that simulate some possible evolutionary paths, without giving them predetermined probabilistic reliability seem to be particularly appropriate for those aims and scope. Under heterogeneous and uncertain environmental conditions, these projections, based on the analysis of long data time series, can provide useful information tools if they are integrated with statistically predictable methodologies that may be used to provide a relevant information base (Salvati, 2010).

Towards a novel operational framework

Given the above considerations, it is increasingly necessary to develop an integrated support system for policy decisions mitigating landscaoe degradation, through implementation of a functionally homogeneous and structurally interacting set of operating modules including:

1. a model of long-term analysis (for example, from the 1950s to the present years) of the evolution of the degree of vulnerability to desertification;

2. a short-term projection system (e.g. 2020 or 2030) of desertification risk through multivariate analysis of climatic scenarios, land-use change, demographic and anthropogenic pressure (agriculture, tourism, industry);

3. a geographic information system, with adequate spatial resolution, of the most favored agricultural areas experiencing significant increases in the degree of vulnerability for policy purposes;

4. an econometric estimate of damages from soil and landscape degradation on specific cropping systems in traditionally designated agricultural areas.

Finally, a Decision Support System (DSS) can provide an integration between the 4 modules described above through a user-friendly geographic and spatial query procedure that can meet the user's cognitive needs. Two user profiles will benefit from the implementation of the DSS: political, national and regional actors, local administrators, infrastructure planners with specific expertise. The second profile is oriented to managers of local production activities, including reclamation consortia, associations of farmers, cooperatives and large producers (Recanatesi et al., 2016).

The main points of an operational framework to permanent monitoring of desertification can be summarized as follows (Ferrara, 2005a, 2005b):

1. Developing an operational training of a multi-temporal estimation model of desertification at national and local level from the 1950s;

2. Developing an operational training of a short-term desertification risk projection system, through multidisciplinary procedures;

3. Developing an econometric estimate model and its operation for some reference crops;

4. Integrating previous modules into a high-resolution geo-spatial DSS.

Ann operational framework directed to implement specific research sector is proposed as follows.

Climate: re-analysis of micro-data contained in national weather databases and improvement of the statistical estimate at micro-scale level through geo-statistical analysis. It is necessary to implement new indicators of aridity calculated over time series, together with indicators of concentration and precipitation intensity, drought (recurrence, magnitude, severity) and water balance.

2. Soil: implementation of a data warehouse integrating different data sources and environmental statistics. In addition, new indicators could be implemented on the issues of soil salinization and compaction. Acquisition and proper analysis of historical cartography is increasingly needed for the study of landscape transformations.

3. Anthropogenic pressures: this dimension requires an appropriate research framework based on continuous acquisition of new data sources and (consolidated and newly proposed) indicators. The main processes of degradation triggered by anthropogenic factors (demographic density, tourism, infrastructures, wildfires), agricultural practices (irrigation, mechanization, soil compaction, soil loss, overgrazing) and industrialization have to be assessed over time and space. Analysis of the relationship between agricultural policy, business dynamics and environmental sustainability deserves further implementation.

Conclusions

The objectives described above can be achieved through appropriate technological development and softwares using a relational structure in an appropriate computational environment. The identification of agricultural areas with mass production, based on reference crops, most vulnerable to desertification processes, appears to be a relevant goal of environmental prognosis and projection. This aspect can be integrated with an econometric estimate of monetary loss caused by landscape degradation.

A function of income loss can be parameterized from 4 themes (climate, soil, land-use, anthropogenic pressure) and tested on reference crops by simulation in homogeneous areas, having more agronomic information available on productivity and yield. At the same time, creation of a model estimating vulnerability to desertification of a given territory seems to be useful for the development of a short-term vulnerability projection module. This kind of studies repeated regularly through time may have practical effectiveness by providing a useful tool for environmental monitoring and enhancing conservation policies. In fact they would allow, on the one hand, to identify areas where landscape degradation needs sustainable intervention initiatives for biodiversity and landscape protection; on the other hand, they provide a permanent monitoring of the evolution of landscape degradation in the perspective of climate, soil and demographic changes.

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