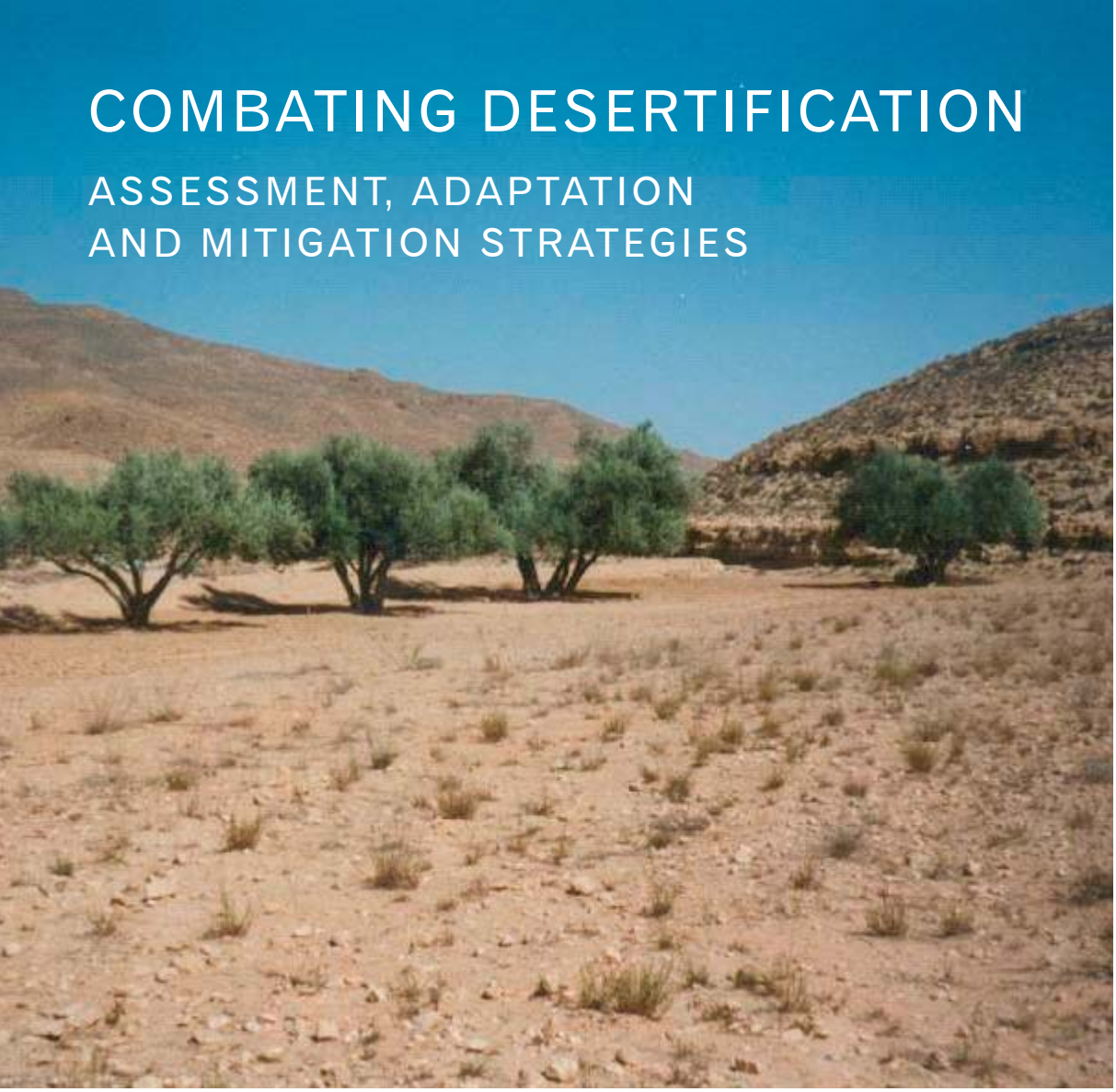
COMBATING DESERTIFICATION

ASSESSMENT, ADAPTATION AND MITIGATION STRATEGIES



Edited by Donald Gabriels, Wim M. Cornelis, Murielle Eyletters and Patrick Hollebosch

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THE INFLUENCE OF SHORT-TERM LAND USE CHANGE ON SOIL EVOLUTION IN THE CENTRE-SOUTH COASTAL AREAS OF SARDINIA

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INTRODUCTION

The land use change in short-term (time and space) in the Mediterranean context can be induced by phenomena like destruction of the autochthonous plant species, land abandonment, overgrazing, fire, urbanization (above all for touristic purpose), etc. These phenomena can lead to soil's degradation conditions causing a loss of physical and biological productivity and the consequent emphasis in desertification processes. Desertification is considered one of the biggest environmental problems in Mediterranean areas (ICCD, 1994), and Sardinia is one of the most affected regions in Europe (UNEP, 1992; Imeson and Emmer, 1992). In Sardinia changes happened during the last decades (such as industrialization, coastal urban areas expansion, etc.) have often resulted in repercussions on the environmental ecosystems and foremost on soils. An important decrease of fertile lands and a consequent increase of marginal and unproductive areas have been observed; this fact has taken to manifest environmental and economic repercussions. In Sardinia such degradation phenomena are particularly evident in coastal areas, where the uncontrolled urbanization and the natural touristic vocation represent relevant impact types. In fact, in 1897 km of coastal lands (500 km are represented by dunal systems) 40% is subjected to deep erosion phenomena, that often are caused by wrong management actions. For these reasons the knowledge of their nature and expansion is of primary importance to carry out correct choices in land use. This

work shows an example of a comparative investigation on coastal ecosystems particularly under human pressure. The investigated areas are located along the Centre–North coast of Sardinia. Particularly they concern: a) soils on limestone formations, forestry live oak cover and pasture land use (goat and swine); b) soils on fixed dunes, reforestation with pine and touristic-recreational land use foremost. In the areas several soil profiles have been realized to investigate the influence of the land use change, occurring in short-term in both places, on the evolution and degradation processes of soils.

MATERIALS AND METHODS

STUDY AREA

The study areas are located in the centre north-east coast of Sardinia. The first area (site 1) is located at Dorgali town, Nuoro province, in the centre-east Sardinia. This region has a typical Mediterranean climate, with cold and rainy winters and autumn, and warm and dry summer. The mean annual temperature is 18.3 °C with the warmest and coldest monthly mean temperatures of 26 °C in August and 11.7 °C in January, respectively. Mean annual precipitation is 647 mm. From a geologic point of view the research area consists of middle Triassic-lower Cretaceous bioclastic limestones, oolitic cherty limestones and mudstones (Carmignani, 2001). Geomorphologically, the region is characterized by undulating hilly lands. The natural vegetation is dominated by *Quercus ilex* forest with brushwood rich in shrubs such as *Cistus albidus*, *Cistus incanus*, *Cistus savifolius*, *Pistacia lentiscus*, *Rosmarinus officinalis*, *Euphorbia dendroides*, *Genista corsica*, *Juniuperus phoenicea*. However, as a consequence of the intense brushwood grazing (mainly goat and swine), in several areas the native shrubs had been cleared and the remaining natural forest has deteriorated due to short-term disorganized forest management. In fact, in pasture areas, in the last 25 years, brushwood clear-cutting is regularly carried out. This practice is very popular in Sardinia as a way to reduce fire risk. As a consequence of this forest management two main forestry covers can be identified: the first is characterised by a natural wood with brushwood very rich in bush and grass species. The second is characterised by wood hardly disturbed by human factors and presenting brushwood subjected to heavy pasture. This second type of wood, is periodically subjected

to a non-selective cut and for this reason it is very poor in bush and grass species; moreover, it presents a very low renewal rate of woody part. The main degradation risks for soils belonging to this area can be related to the high pasture pressure and to the wrong forestry management.

The second area (site 2) is located in the dune coastal system of Siniscola in the south-east Sardinia. The climate is typically Mediterranean and is characterised by irregular rainfall events as well as a warm and dry summer period. The mean annual temperature is 16.9 °C with a maximum average of 26.0 °C in August and a minimum average of 10.1 °C in January. The mean annual precipitation is 710.6 mm. The dune system in this area of north-east Sardinia was formed in the quaternary period by transport and deposition of sands over a base of micashistis and paragneisses of the Hercynian metamorphic complex from the Paleozoic period (Carmignani, 2001). The natural vegetation of the dune system is dominated by a complex alternation of herbaceous and shrubs species in relation to characteristics such as distance from the sea shoreline, groundwater level, micro-topography, etc. In the stabilized dunes the higher strata of vegetation is formed by Mediterranean shrubs of *Juniperus phoenicea* and *Pistacea lentiscus*; in the mobile dunes, at summit positions, the vegetation is dominated by rhizomatous grasses of *Ammophila arenaria*; in the inter-dune areas the vegetation cover is normally denser than in the other positions, with species like *Juncus maritimus*. However, only in few areas the natural vegetation remains due to an important reforestation with *Pinus pinea* and *Pinus halepensis* carried out in the 1939 in order to avoid the movement of sand towards the inland. In addition, and as a consequence of the reforestation, this environment is subjected to very high human pressure due to intensive urban development and tourism recreational areas. This system has been heavily modified in a very short time, changing from a state of high naturality to one under a heavy human pressure. Table 1 shows the main characteristics of the two studied sites.

FIELD INVESTIGATION AND SAMPLING

In the two sites a pedological survey was realized. In site 1 ten profiles were investigated: five located in areas with grazing and period-

ical brushwood clear-cutting; five in areas with a smaller anthropic impact. In site 2 ten profiles were realized: five in areas subjected to a high recreational use, and the other five to a lower use. In both cases the level of use and the anthropic impact (grazing and brushwood clear-cutting for site 1, recreational use for site 2) was defined on the basis of observation in the field and statistical data provided by public administration.

The soils were described by standard soil survey methodology (Soil Survey Division Staff, 1993), classified according to the Soil Taxonomy (Soil Survey Staff, 2003) and analysed with the official procedures of the Ministero delle Politiche Agricole e Forestali (2000).

RESULTS AND DISCUSSION

SITE 1

The study showed that pasture of the under wood and the brushwood clear-cutting results in a significant soil degradation. In this kind of conditions soil showed scarce development, with an A–C/R, A-B-C/R type profile and a solum with an average depth of 15-20 cm. The solum development was considerably greater in areas with low pasture and without clear-cutting. In those pedons surface horizons were almost all characterized by the presence of a transition surface

Table 1. The main characteristics of the study area

	Location	Land cover		Land use	Main environmental problems
		Natural areas	Anthropized areas		
Site 1	centre-east Sardinia	Forest of live oak with a brushwood rich in shrubs and herbaceous species	Forest of live oak with a poor brushwood	goat and swine grazing	overgrazing and periodical brushwood clear-cutting
Site 2	south-east Sardinia	*Juniperus phoenicea*, *Pistacea lentiscus*, *Ammophila arenaria*, etc.	*Pinus pinea*, *Pinus halepensis*	tourism and recreational areas	increase of urban development and recreational demand

horizon (OA), with remarkable organic matter content, several times strongly humificated. The content of soil organic matter decreased in the areas with grazing and brushwood clear-cutting and this can be attributed to the significant reduction in litter, but also to the poor living conditions for soil organisms in compacted soils. Moreover the clear-cutting activities caused reduced vegetation cover leading to litter being washed away by heavy rainfall. The nitrogen contents results were instead particularly modest, especially in those areas with intense pasture. Consequently, elevated C/N ratios were often recorded in the surface horizons of the soils under grazing: this is an index of a low mineralization of the soil organic substance with relative low turnover. Particularly, a net predominance of humification processes in comparison to those of the mineralization of organic substance in soil is underlined. In fact, the determination of the humification parameters, in accordance with precedent researches related to this topic (Ciavatta et al., 1990; Trinchera et al., 1998), shows elevated levels of humification against low levels of mineralization. In such sense, the grazing seems to directly or indirectly influence the degradation processes of the SOM: in the first case, through a great input of hardly mineralizable organic substance; in the second case through a great selection of not pabular and often rich substances characterized by a slower mineralization (lignin, cellulose, etc.) species. In both cases, the result of such influence is: the stabilizing of surface horizons being strongly humificated; an elevated bringing in of hardly mineralizable organic substance; a slow turnover of the SOM; a net predominance of the humification processes.

Generally, from the taxonomic point of view (Soil Survey Staff, 2003), soils in areas with grazing and brushwood clear-cutting belong to Entisols and Alfisols, while the soils of non-grazed areas are Mollisols. It was particularly observed that the soils in grazed areas could satisfy the prerequisite for belonging to the order of Mollisols but this condition was not met, above all, due to the low organic matter content and the insufficient thickness of the surface horizons. The investigations developed in the area allow, in fact, to hypothesize that in past times the area was more markedly characterized by a great presence of Mollisols in comparison to the actual conditions. The intense exploitation of the native vegetable component

(above all live oak) inevitably affects the underlying soils, causing a marked accentuation of degradation phenomena. For such reasons future uses should foresee a more careful environmental planning and management, above all settled to a definite decrease of the grazing pressure and to a rational brushwood exploitation with total cessation of the indiscriminate non selective cutting.

SITE 2

The research showed that all the studied pedons had scarce development (O-A-C), mostly in those areas under the heaviest human pressure (O-C, C), and a degree of soil compaction significantly higher on the areas subjected to high use than the low-use areas.

In the area recreational impact also reduced the amount of litter and organic matter in the upper soil horizons. This process is very important in stabilised sand dunes because many soil properties depend on organic matter content (Kutiel, 1998-1999). In these environments the soil organic carbon is concentrated in the upper five cm, and this horizon is fundamental for properties such as soil stability and fertility. When the organic horizon is destroyed, we observe the rapid transition to unstable sand. In the research area, this process was often observed in sites with high recreational use.

In the study area the effect of short term land use change can be immediate not only for soils and geomorphic dynamics but also in terms of biotic processes and spatial fragmentation. For example, in the areas subjected to high recreational use there is a clear decrease of microbiotical crust (NRCS, 1997; Álvarez-Rogel et al., 2007), formed by the agglutinating effect of fungal mycelia on the particles, which have very important ecological functions (enrichment of the soil in organic matter, aggregates stability, atmospheric nitrogen fixation, stimulation of microbial activity, etc.). These crusts are particularly developed in areas with low anthropic impact and recreational use. For that concern spatial fragmentation, the high recreational use causes an increase in the number of marginal areas, and consequently a decrease in the ecosystem connection by the creation of ecological islands (Reed et al., 1996).

This work demonstrated how wrong past management decisions have resulted in observable recoils on state and pedogenetic evolution of the studied soils. Particularly, the following actions represent

the most dangerous threats for these dune soils: massive use of allochthonous species (mostly conifers), lack of careful forestry management actions subsequent to the reforestation phase and main land use destinations.

The influence of human activity was further confirmed by the presence of buried Ab horizons, with a higher organic matter content than the actual epipedon, that can be considered as relict evidence of the dune system state (Álvarez-Rogel et al., 2007) before the reforestation. Particularly, these horizons can be related to a dense ancient vegetation cover, which was probably destroyed to facilitate the reforestation with allochthonous species. This management practice contributed to the burial of the old soils due to the lack of vegetation cover against wind erosion.

CONCLUSIONS

The natural conditions in Sardinia coastal areas are characterized by a fragile environment very sensitive to human pressure. Land use change can exert a great influence on soil, landscape and environment. For example forestovergrazing and brushwood clear-cutting practices in limestone areas can result in significant soil degradation by declining organic carbon, nitrogen, loss of structure and increase of erosion phenomena. Also in coastal sand dunes ecosystems the high human pressure, increased in the last thirty years due to intensive urban development for tourism purposes, can lead to soil degradation with consequences in terms of geomorphic dynamics, biotic processes and spatial fragmentation. These kinds of environments are widely spread in Sardinia and they represent an important environmental and economic resource. For such reasons it is necessary to preserve the function and sustainability of these natural systems with the application of best management practices. From this point of view, since the end of 2007, two areas are subjected to long-term controls using the methodology briefly described above. In each site eight plots were realized with the following features: site 1) four fenced and four open plots (5 m x 5 m in size) in grazed and clear-cutted areas, with the aim to understand the effects of grazing and brushwood clear-cutting on vegetation dynamics and soil characteristics; site 2) four plots in areas with high visitor use and the other four subjected to a lower use (8 m length x 1 m wide). In each site the observations about the plants community (overall

percentage cover, overall average height, relative percentage cover of each species, species richness, species diversity, etc.) and some selected soil characteristics (organic carbon, total nitrogen, humic and fulvic acids, etc.) will be recorded for each season in the next three years.

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