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## Land cover change as land degradation indicator in areas characterized by high anthropic pressure due to agropastoral activities

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**SUMMARY** - The overexploitation of natural resources due to agropastoral activities is considered cause of land degradation. Land cover changes in the period 1977-96 related to agropastoral activities were studied in an area of north-eastern Sardinia (Italy). The major changes identified were from naturally vegetated areas (maquis and forested areas) to improved pasture areas, the main land degradation phenomena were observed. On those areas where improvement actions on unsuitable land were carried out.

**Key words:** Land degradation, agropastoral activities, land cover, Mediterranean.

**RESUME** - "Le changement de couverture végétale comme indicateur de la dégradation des terres dans des zones caractérisées par une forte pression de l'homme dû aux activités pastorales". La surexploitation des ressources naturelles due aux activités agro-pastorales est l'une des causes de la dégradation des terres. Les changements qui se sont vérifiés dans la couverture végétale en relation aux activités agro-pastorales pendant la période 1977-96 ont été étudiés dans une zone de la Sardaigne Nord-orientale (Italie). Les changements plus importants ont été identifiés dans les zones à végétation naturelle (maquis et domaine forestier) qui ont été transformés en pâturages améliorés. Dans les zones où les actions d'amélioration ont été effectuées sur des terres inaptes, on a observé les plus importants phénomènes de dégradation des terres.

**Mots-clés :** Dégradation des terres, activités agro-pastorales, occupation du sol, Méditerranée.

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### Introduction

Land degradation is becoming the major environmental issue of drylands all over the world, interesting also south European Mediterranean countries, as outlined by Annex IV of the Convention to combat desertification (UNEP, 1994). Here, not only physical and climatic conditions, but also agricultural intensification on one side and land abandonment on the other, have led to an increase in areas affected or threatened by soil erosion (Giordano *et al.*, 1991).

Among the different causes, agropastoralism is considered one of the most important driving forces leading to land degradation and desertification. It acts: (i) directly by overgrazing and soil compaction (Harrington, 1981; Vallentine, 1990); and (ii) indirectly by favouring land cover changes to create new pastures (Margaris, 1992) or by adopting mechanical tillages on fragile areas to improve forage production (Pérez-Trejo, 1994). This is particularly true for certain Mediterranean areas (Sardinia, Crete, southern Spain, Aegean islands and others) subjected in the last century to high anthropic pressure due to agropastoral activities.

The main aim of this work is to highlight the land cover/use changes during the last 20 years in a representative area of central-eastern Sardinia (Italy) to understand the main causes which led to widespread land degradation phenomena (soil erosion, soil properties deterioration, loss of natural vegetation).

The present work is part of the Mediterranean Desertification and Land Use - MEDALUS research programme (EU-Environment and Climate Programme) focusing on practices and policies for mitigating land degradation (Geeson and Thornes, 1996).

## Materials and methods

### Study area description

The study area is located in the Basse Baronie region, in central north-eastern Sardinia, at a latitude between 40°18' and 40°51' North and a longitude between 9°12' and 9°51' East, over an area of 50,338 ha. Its morphology is characterized by quite heterogeneous landscapes and by the presence of uneven reliefs (elevation ranges from sea level to 862 m a.s.l.) with steep slopes. Geology is rather complex, although four main formations are particularly widespread: (i) Pleistocene basic effusive rocks (basalts); (ii) Mesozoic limestone and limestone; (iii) Palaeozoic intrusive rocks (granites); and (iv) Palaeozoic metamorphic rocks (schists).

With reference to land use patterns, the Utilized Agricultural Area (ISTAT, 1992) amounts to 23,870 ha, 60% of which represented by meadows and pastures. Wooded areas (10,531 ha) are mainly represented by maquis and seldom by real forest stands; the limited extension of the latter (copice of *Q. ilex* L.) is the result of the severe anthropic pressure during the last century. In the last decade, there has been a relevant tourist development in the coastal areas, mainly involving the municipalities of Siniscola and Orosei; notwithstanding, agropastoral activities are the most important economic activity.

### Data acquisition and land cover change analysis

Following the acquisition of the reference material (maps, aerial photographs and bibliographical data), its analysis and successive field checks allowed the identification of the main landscapes.

A preliminary photointerpretation was carried out on aerial photographs taken in 1977 (1:10.000) and in 1989 (scale 1:33.000) and six main land cover/use categories were found: artificial surfaces, agricultural areas, pastures, wooded areas, bare areas, and water. Field surveys and final photointerpretation allowed the classification of the following land cover typologies relevant to our investigation: arable crops, permanent crops, complex cultivation patterns, pastures, improved pastures, shrublands, forest areas, maquis and forest plantation. In order to consider the main land cover typologies before 1977, 1:33.000 aerial photographs taken in 1955 were acquired and carefully analysed.

The multitemporal land cover/use maps (1977 and 1996) were then drawn up and the land cover changes map was derived. By overlaying the land cover change map and other thematic maps (morphological and pedological maps) produced during the MEDALUS project, environmentally sensitive areas to land degradation/desertification were identified. On these areas, detailed field surveys were carried out to characterize their main features with particular reference to land degradation processes.

## Results and discussion

Table 1 summarizes the various land cover typologies in 1955, 1977 and 1996 and the land cover dynamics during the period 1976-1996. The data reveal that during the 20-year period several land cover changes occurred; in particular a decrease in areas covered by maquis (32.1%) and shrublands (17%) was highlighted, corresponding to an average loss of 252 and 120 ha per year respectively. On the contrary, woodlands (forest areas and forest plantations) increased by 71%; such increase is due to the evolution of maquis towards forest stands and to the establishment of forest plantations in the municipalities of Irgoli, Onifai and Orosei.

With reference to pastures, the data show an increase in 3,187.3 ha (30%), mainly due to the shrub clearance by fire, a particularly widespread practice in rural areas; the lower increase in improved pastures (943 ha) can be ascribed to the fact that land improvement actions were mostly carried out before 1977 largely favoured by the past regional agricultural policies.

This is confirmed by considering the marked increase in improved pastures (2,772 ha) occurred between 1955-1977. The current high incidence of arable crops (+1,835 ha) is related to the spread of

irrigated crops on suitable flat areas, following a decrease occurred in the previous 20-year period (-1,043 ha). These data reveal that the ephemeral industrial development in Sardinia during the '70s employed labour mainly from agriculture rather than from agropastoralism which, on the contrary, faced an opposite trend.

Table 1. Multitemporal land cover and its evolution during the period 1977-1996

Land cover/use typologies	Surface (ha)			Change 1977-96	
	1955	1977	1996	Difference (ha)	%
Arable crops	3,122.4	2,079.0	3,914.8	1,835.9	88
Permanent crops	41.8	610.3	667.3	57.0	9
Complex cult. patterns	2,344.7	2,817.7	2,724.0	-93.7	-3
Pastures	6,966.8	5,383.8	7,627.5	2,243.7	42
Improved pastures	2,546.8	5,318.9	6,262.6	943.6	18
Shrubland	12,605.0	14,296.6	11,898.6	-2,398.0	-17
Natural forest areas	2,085.3	1,524.3	2,628.8	1,104.5	72
Maquis	18,438.9	15,669.5	10,632.6	-5,036.8	-32
Forest plantation	842.0	1,194.7	2,031.1	836.4	70
Other	1,344.4	1,443.2	1,950.6	507.4	35

Figure 1 shows the land cover change map drawn up for a representative part of the study area. The comparison between the land cover change map and the map of land suitability to grazing previously drawn, highlighted that many pasture improvement actions were carried out on unsuitable lands characterized by steep slopes and shallow and poor soils prone to erosion. Field surveys allowed the identification of widespread land degradation processes; the most evident effects are both the loss of the surface horizons due to stone and brush removal carried out with heavy machinery, and the related appearance of sheet and rill erosion processes which caused the appearance of lithosols whose depth is lower than 20-25 cm. In the least deep soils, it was also observed a decrease in fertility due to the mixing up of their profile following deep tillages. On these areas, grasses have undergone a quanti-qualitative degradation in terms of number of species and their palatability and, in some cases, to the almost total disappearance of grass and seed storage.

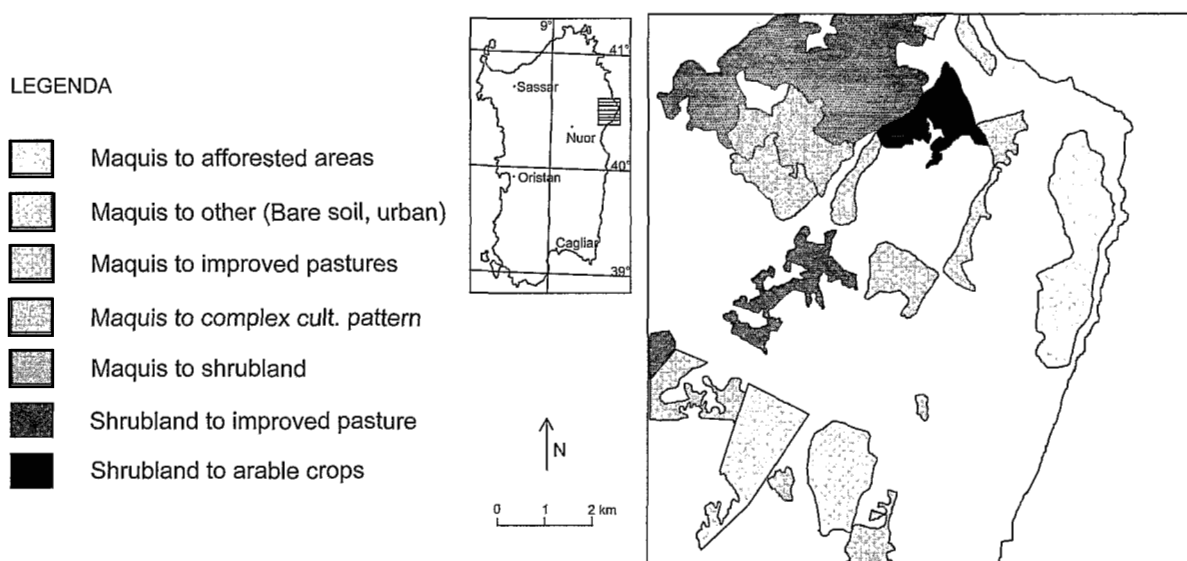


Fig. 1. Land cover change map (1977-1996) for part of the MEDALUS project study area.

The above-mentioned changes, and in particular the marked decrease in natural and artificial forest areas and the increase in pasture lands, are undoubtedly related to the shift from extensive to semi-extensive grazing systems. According to the data of the agricultural censuses, in the period 1971-1991 there was an increase in the total livestock numbers exclusively due to the marked increase in sheep numbers (Table 2). As a matter of fact, cattle and goats numbers decreased of 699 and 188 LSU respectively; on the contrary, sheep numbers increased of 2390 LSU for a total number of 56,470 sheep, corresponding to an average stocking rate of about 1 sheep/ha, with peaks up to 1.71 sheep/ha in municipalities where agropastoralism is the only economic activity.

Table 2. Livestock number dynamics between 1971 and 1991 (row data from ISTAT, 1992)

Cattle <sup>†</sup>			Sheep <sup>†</sup>			Goats <sup>†</sup>		
1971	1991	Differ.	1971	1991	Differ.	1971	1991	Differ.
4,184	3,485	-699	3,256	5,647	2,390	1,009	821	-188

<sup>†</sup>LSU: Livestock Unit

Such an increase, particularly severe during the '80s, was mainly caused by the marked gap between sheep milk price and production costs which allowed the survival of low management farms. This contingency resulted in a higher need for pasture which caused the cultivation of unsuitable areas formerly covered by natural vegetation. In addition the remarkable use of concentrates, further increased stocking rate, livestock numbers being no more linked to grassland carrying capacity.

## Conclusions

The research highlighted that land cover dynamics is a useful indicator for areas threatened by desertification, being it closely related to anthropic pressure. This is particularly true in Mediterranean areas where progressive loss of forest cover, also due to fires, irrational tillages and overexploitation of available resources contributed to favour land degradation processes.

The study on land cover changes also highlighted the role of agropastoral activities on land degradation; with reference to Sardinian rural areas, the pasture improvement actions carried out on unsuitable land and closely linked to sheep husbandry have caused a modification of the landscape. Land use history being an important variable in land evaluation, land cover monitoring constitutes an important tool when decision support systems for land management are considered. With reference to this, the modern GIS technology can constitute an important support in the identification of environmentally sensitive areas at regional scale.

A sustainable development for rural areas must allow the recovery and protection of affected and threatened areas by providing aids for farmers no more linked to the number of grazers. This can contribute to reduce pressures on low productive lands threatened by desertification with particular reference to common lands.

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