VEGETATION COVER AS AN INDICATOR FOR EFFECTIVE IMPLEMENTATION OF LAND USE REGULATIONS IN SARDINIA

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ABSTRACT

Land degradation is a worldwide issue which is often closely linked to human activity. In semi-arid environments common degradation processes are due to excessive soil losses, gully formation, surface sealing, and soil moisture depletion. Forest fire is increasingly an additional problem in the dry areas. In the present study, human interactions with land degradation are studied in a case study in Sardinia, Italy. Land degradation risk assessment was carried out using a desertification indicator method, the obtained result of which shows the prominent effect of vegetation cover. In the study area, high land degradation risk (and low vegetation cover) is found mostly in rainfed cultivation, overgrazed areas and those parts covered by olive groves or vineyards. Various strategies have been implemented, both deliberately and as a result of circumstantial effects, to alter vegetation cover over time. In the analysis, time series Normalized Difference Vegetation Index (NDVI) data was used for the period 1972 to 2009. Results show that not all human interactions with the environment are necessarily negative. The improvement of vegetation cover on the island is mainly due to good implementation of land use regulations. Three main factors seem to be responsible for the increase in vegetation cover: (1) government implementation policy on land uses; (2) reforestation in the over-grazed area; (3) the migration of the youngest generation of the population from the country side to the urban areas. The study demonstrates that vegetation cover on the island is improving as compared to the past, decreasing the land degradation risk even though the region is coping with climate change.

1. INTRODUCTION

Land degradation is a worldwide problem threatening food security and increasing the risk of desertification. A key driving force of land degradation is land use change. Land use change takes place due to various causes, but the main reason is often associated with increased population pressure. Degradation processes such as soil erosion, gully formation, surface sealing, soil moisture depletion and salinity development are often common in semi-arid regions. In Sardinia, Italy, clearing of forests for making new pasture lands has been a major cause of land degradation in recent decades (d'Angelo, Enne et al. 2000; Zucca, Canu et al. 2006; Zucca, Canu et al. 2010). Favorable markets for sheep milk and cheese, and regional governmental incentives to create pasture lands can be considered the main driving forces for land use changes (d'Angelo, Enne et al. 2000; d'Angelo, Enne et al. 2001). During 1981-1994, the sheep population in Sardinia increased 5-fold from 845,000 to 4,297,700, resulting in overgrazing of land, causing widespread land degradation problems. In the marginal lands soil erosion is a major problem. In the overgrazed areas, proper growth of vegetation cannot take place resulting in both quantitative and qualitative degradation of plant species and palatability (d'Angelo, Enne et al. 2000). Forest fires, which occur frequently, reduce the organic matter content of top soil and enhance erosion due to water repellency and surface sealing (Doerr, Shakesby et al. 2000; Shakesby and Doerr 2006). With reduced vegetation cover and infiltration the rain water runs off directly, increasing erosion and minimizing soil water harvesting. Together, these factors contribute to land degradation – a problem to which the regional government has started to respond through reforestation efforts and the demarcation of protected areas. The main objective of the research to see the effectiveness of the government implemented plans in minimizing land degradation problem in the island.

2. MATERIALS AND METHODS

2.1 Study area

The study area is in Sardinia, Italy. It is located between 38° 51' and 41° 15' N and 8° 8' and 9° 50' E in the Mediterranean Sea (Fig.1). The highest mountain is the Punta La Marmora (1,834 m asl). Sardinia has a coastline of about 1,850 km. Three main rivers (Tirso, Flumendosa and Coghinas) drain the area. Cagliari is the capital city. Sardinia is inhabited by 1, 671,000 people (ISTAT 2012). The climate is typical Mediterranean, with a major concentration of rainfall in the winter months (Oct-Feb) with possibilities of some heavy showers in the spring and snowfall in the highlands. Average annual precipitation is 656 mm (Estimation based on 1922-1992 data) with July being the driest month. The average temperature can very between 11 to 17 °C and the Mistral is the dominant wind, coming from north-west.

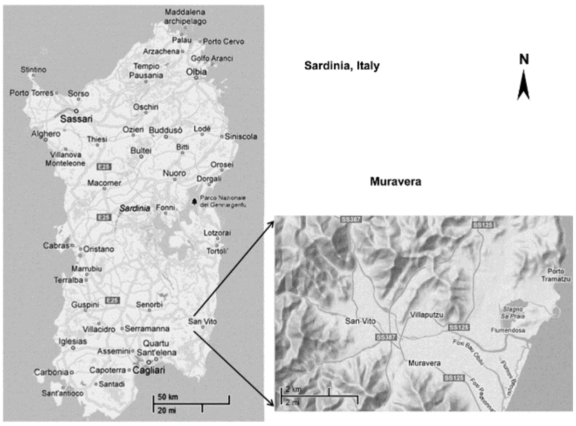

Fig. 1: Study area showing Muravera and the island of Sardinia

The most common vegetation type is the Mediterranean maquis which is a broad-leaved evergreen shrub. In the mountainous and the hilly areas, forest types consist of broad-leaved (oaks, cork-oaks) and coniferous trees. In many areas the natural vegetation has been cleared for creating pasture land or for rainfed cereal cultivation. In areas close to settlements, vineyards and olive groves can be found. A study area covering 582 km^2 was selected in the Muravera region, which is located in the south-eastern part of the island, (Fig.1). Elevation ranges from 1 m to 806 m asl. It consists of nearly level summits (plateau landscape), mountain ridges, dissected upper slopes, foot slopes, valley complexes and coastal plains. Annual precipitation can vary from 370 mm in a dry year to 1088 mm in a wet year (Muravera station). Rain falls mainly during October to March, December being the wettest month. Average annual temperature is 25°C and the lowest (around 10°C) are in January and February. The warmest months are July and August (average 26°C).

2.2 Land degradation risk assessment

To identify the main indicators of land degradation risks, the method described by Kosmas et al. (Kosmas, Poesen et al. 1999) was applied. The indicators are divided into four main quality categories: soil, climate, vegetation and management. The Soil Quality Index (SQI) takes into account soil characteristics, such as the geological substrate, soil texture, stoniness, the layer involved in the vegetation growth, drainage and the slope gradient. Stratified random sampling based on geology and geomorphological units was carried out for collecting soil data. In total 118 samples were collected for laboratory analysis. The Climate Quality Index (CQI) takes into account the total amount of rainfall, aridity, and aspect. The Vegetation Quality Index (VQI) considers fire risk, erosion protection, drought resistance and plant cover. A value of 40% vegetative cover is considered critical, below which, accelerated erosion prevails on the sloping land (Thornes 1988). Land degradation can start when a large portion of the land's surface is denuded. Vegetation cover is classified into 3 main classes: >40% cover, 10-40% cover and less than 10% cover. The

Management Quality Index (MQI) analyses the land use intensity and the policy protection for the environment. In order to identify the indices a calculation for indicators in each category is necessary. To every indicator an index value is associated. The geometric average of the index values for each category gives the values of SQI, CQI, VQI and MQI. The final index of desertification risk (ESAI, Environmental Sensitivity Areas Index) is obtained calculating the geometric average of several indicators, with the following relation:

$$ESAI = (SQI \times CQI \times VQI \times MQI)^*1/4 \qquad (1)$$

Where, SQI = (rock x texture x stoniness x soil depth x drainage x slope gradient)*1/6 ; CQI = (rainfall x aridity index x aspect)*1/4; VQI = (fire risk x erosion protection x drought resistance x plant cover)*1/4 ; MQI = (Land use intensity x Policy)*1/2 . The resulting ESAI values are used to define the types of environmentally sensitive areas to land degradation and desertification as follows: Critical (>1.37), fragile (1.23 to 1.37), potential (1.17 to 1.22) and not affected (< 1.17).

2.3 Analysis of time series vegetation data

To study the inter-annual changes in vegetation cover, the geo-referenced SPOT 4 10 days Normalized Difference Vegetation Index (NDVI) images at 1 km resolution (S-10 product) were acquired for the year 2009 from the Flemish Institute for Technological Research, Belgium (http://free.vgt.vito.be). Considering the average precipitation pattern as computed from 1922-1992 meteorological data, the month having the lowest precipitation (July) was identified as being the driest month. In this month high NDVI value is assumed to come primarily from perennial vegetation cover (forest and shrub lands) since most of the field crops, apart from irrigated fields in the plain areas, are assumed to be harvested. Thus, in order to study changes of natural vegetation cover (forest and shrub lands) in Sardinia, the NDVI images from the driest month were downloaded for the period 1998 to 2009. In addition to the SPOT NDVI dataset, the available Landsat MSS data from 12 August 1972 and Landsat TM5 data from 11 Sept 1984 were also used in the analysis. Finally the long-term average NDVI value ($NDVI_{avg}$) was computed to assess NDVI changes for the period 1972 to 2009 as follows:

$$NDVI\ change_i = NDVI_i - NDVI_{avg} \qquad (2)$$

Where, $NDVI_i$ is the mean NDVI for the dry month (July or Aug or Sep) in a given year and $NDVI_{avg}$ is long term average. Resulting positive values indicate that vegetation cover for that year is higher than the long term average while negative values indicate that vegetation cover for that year is lower as compared to the long term average.

3 RESULTS AND DISCUSSION

3.1 Land degradation assessment

The results shows that less than 3 percent of the case study area is in a critical condition, 39 percent is fragile, 30 percent faces a potential hazard and 27 percent is not affected (Fig. 2). Critical areas fall mainly under rain-fed agriculture and grazing land but also including orchards (vineyards and olive groves). In terms of slope classes, they are within the rolling to steep and very steep terrain (slope > 30%). The fragile areas fall under agriculture, agroforestry, grazing land and orchards and in rolling to steep slope classes (8-45% slope). The potential areas fall under all the land cover classes in rolling to steep sloping areas (8-45% slope). The not affected areas are dominantly in maquis shrubland and in nearly level to gently sloping areas. The land use classes with critical hazard ratings are the rainfed agriculture and grazing areas which constitute 62 percent of the area within the hazard class. Most of the territory has been identified as “fragile”, or potentially subject to degradation phenomena that could be limited or avoided by more responsible land management. Areas with fragile or potentially subjected to degradation statuses are shown by low NDVI values (< 0.6). These are mainly agricultural areas including orchards (vineyards and olive groves) and also grazing land which has lower vegetation cover (Table 1). The areas with lower vegetation cover (NDVI 0.4 to 0.55) are towards the eastern coastal areas and close to the river and settlement areas (Fig. 5).

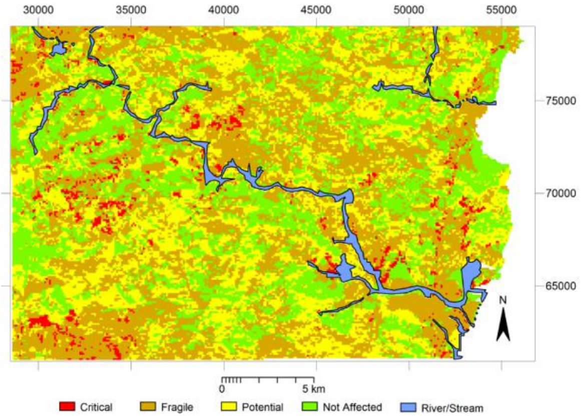

Fig. 2: Desertification vulnerability in the Muravera area

Table 1: Average NDVI per land us/land cover class

Land cover class	NDVI 2009	
	Average	St. dev
Agriculture including grazing land	0.52	0.11
Orchard	0.57	0.11
Forest	0.62	0.06
Maquis shrubland	0.62	0.12

3.2 Vegetation cover in Sardinia

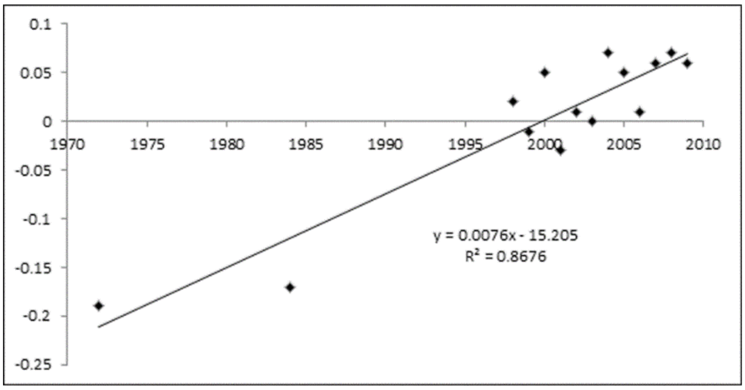

Fig. 3: Improvement of vegetation cover in Sardinia as from 1998

The time series NDVI analysis of vegetation cover in the period 1972 to 2009 shows considerable improvements in vegetation cover in Sardinia. The surface area covered by perennial vegetation seems to become more extensive in Sardinia as from 1998 onwards, which should have helped to decrease land degradation risks on the island. In Fig. 3 the improvement of average NDVI is shown for the period 1972 to 2009 by plotting NDVI variations from its long term mean, displaying high correlation ($R^2 = 0.87$). In 1972 average NDVI value was only 0.25 indicating a lot of bare surface areas, which can be translated into areas having severe land degradation problems. In 2009 average NDVI value increased twice as much, indicating high vegetation cover (Table 2). Computing and plotting the NDVI variations during the period 1998 – 2009, thus using only SPOT derived NDVI images, also shows the improvement of vegetation cover in Sardinia.

Table 2: Mean NDVI during the dry month (July) in the study period

	1972	1984	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mean NDVI	0.25	0.27	0.46	0.43	0.492	0.412	0.45	0.44	0.51	0.49	0.45	0.5	0.51	0.5
St. deviation	0.19	0.15	0.13	0.13	0.13	0.12	0.13	0.12	0.13	0.13	0.13	0.13	0.14	0.13
NDVI deviation from long term av.	-0.19	-0.17	0.02	-0.01	0.05	-0.03	0.01	0	0.07	0.05	0.01	0.06	0.07	0.06

There seems to be not any distinct change in climate if we consider the temperature and precipitation data of Sardinia over an 81 year period (1922 – 2003). The annual temperature variations shows wavy pattern, with the line fitting the third order polynomial (although the correlation is rather poor ($R^2 = 0.10$)) (Fig. 4). In terms of precipitation, there are some variations in the annual rainfall received by different meteorological stations which is mainly related to orographic effect. No distinct pattern is noticeable in the long term annual precipitation, with almost no correlation (R^2 = 0.06) (Fig. 5). From this we can conclude that the increase of vegetation cover in Sardinia cannot be due to favorable climatic conditions since it does not show any distinct pattern.

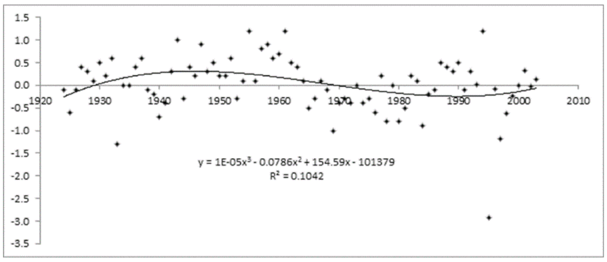

Fig. 4: Mean annual temperature variations during 1922-2003.

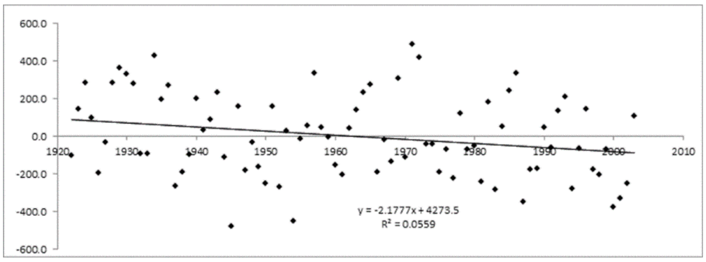

Fig. 5: Annual precipitation variations for the period 1922-2003

3.3 Implementation of land use policy in Sardinia

Realizing the land degradation problem especially associated with extensive clearing of the Mediterranean maquis for agro-pastoral development for sheep and goat farming in Sardinia, the regional government began mitigation measures such as reforestation and the demarcation of protected areas. National parks were developed according to the regulations mentioned in the Act 394/1991 in Italy (Campagna 2009). Many protected areas and natural parks have been established in the nineties such as the Archipelago di La Maddalena National park established in 1994, Asinara National park in 1997 and Gennargentu National park in 1998 with a view to rejuvenating vegetation cover. In addition, the Environmental Geo-mining Park of Sardinia has been established in cooperation with UNESCO in 2001. In the new regulations for the national parks (Act 394/1991) local stake holders were included in making the plan and management. Thus the regulations take into account both the preservation of the natural heritage as well as the improvement of the quality of life of the local communities (Campagna 2009). In addition to this many regulations were implemented strictly such as the law for the protection of cork forest (Sardinia 1959), law for preservation of the environment and protection of the regional territory (Sardinia 1989), law for the establishment and the management of nature park and monuments (Sardinia 1989) and recently a law for managing forest fire (Sardinia 2011). Moreover, the Regional Landscape Plan adopted in 2006 do not allow any development initiative in the coastal 2 kilometers buffer zone as a safeguard measure (Campagna 2009) with the result that coastal areas in Sardinia have still managed to retain the natural condition unlike elsewhere in the Mediterranean coastal areas which are often over-crowded with apartment buildings and hotel towers making the limited water and other natural resources even more scarce. The overall efforts seem to have positive effects in improving vegetation cover in Sardinia, as shown by the time series NDVI analysis. The result is also confirmed by another study carried out in Sardinia which shows a threefold increase in plantation forests during the period 1955 – 1996 (d'Angelo, Enne et al. 2000). Similarly, in the natural protected areas the general trend shows a dominance (>70%) of forest and semi-natural land uses (Campagna 2009).

4. CONCLUSION

The study shows that vegetation cover in Sardinia has improved considerably in the recent past which can be presumed to have a positive influence on mitigating land degradation problems on the island. With less than 3 percent of the case study area in a critical condition, nearly one third of the area (27%) not affected and another one third of the area having only potential risk, the overall land degradation status cannot be considered too bad in 2009. The progress in mitigating land degradation is attributed mainly to the strict implementation of rehabilitation and conservation measures in the area. The increase of vegetation cover in the island can be also attributed to some extent to migration of people from the countryside (the inner part of the island) to coastal urban areas to seek jobs in the growing tourism industry (Campagna 2009) or elsewhere in Italy or in Europe. Such demographic changes have resulted in the abandonment of land and rejuvenation of natural vegetation (Maquis). The findings do not mean, however, that land degradation problems are no longer a problem for the island. Conservation measures need to be implemented continuously to minimize degradation risks. The study shows that the land degradation problem is not necessarily always that bad. If good land management plans can be implemented, the land degradation problem can be minimized. The study also demonstrates how time series NDVI data can be applied in order to study vegetation cover dynamics related to land degradation hazards.

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