Evaluation of Productive Potential and Factors Involved In Degradation of Pastures in Albania

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Abstract

This paper presents the evaluation of potential productive of the whole pasture area of Albania as well as factors involved in pasture degradation, by using a methodology which combined remote sensing and GIS algorithms. In particular, cover components of pastures were mapped by means of remote sensing. GIS was used to derive several thematic maps of abiotic, biotic and pasture use variables. A matrix of these variables was also produced in GIS and analyzed statistically by applying discriminately analysis and correlation analysis, with the purpose of investigating the relative contribution of abiotic and pasture use variables to pasture degradation.

The major part of the pasture ground (53.6%) was covered by vegetation. The remaining part (46.4%) was covered by non-vegetation components, i.e. rocks and bare soil. Pastures occurred mainly in mountainous areas, steep to very steep slopes, south facing aspects grew brown and grew dark soils, moderately to heavily eroded, close to roads and water sources, in a medium distance from the villages and more than half of them were improperly grazed. Statistical analysis showed that pastures degradation (characterized by bare soil) was high especially on moderate to high slopes, south and west aspects, close to medium distance from villages, roads and water bodies, and it was associated particularly with moderate to high erosion level. These areas were moderately to heavily grazed and associated particularly with moderate to high erosion level.

It is concluded that degradation of pastures in Albania can be attributed to the interaction of unfavorable abiotic conditions and irrational grazing management practices. Therefore, it is necessarily to develop management plans of pasture resources for their restoration and proper utilization in the future.

KEYWORDS: Albania, Pasture, Degradation, GIS, Remote Sensing, Statistical analysis.

Introduction

Pastures in Albania are considered as wild lands covered by native herbaceous vegetation and a small proportion of woody species (Papanastasis, 2003). Historically, they have been mainly used for direct grazing by domestic animals and secondarily for hay conservation (meadows). This grazing use was rather rational and favored pasture vegetation to get adapted to livestock pressure.

In the middle of the previous century however grazing management became irrational because a large part of pastures was converted into arable lands resulting in the overgrazing of the remaining part while wildfires were also used to control the unpalatable to animal's vegetation. Until 1938, pastures and meadows were covering 44 % of the Albanian territory (Shundi, 2006). The latest inventory (ANFI, 2004) showed that this area was reduced by 62% indicating a dramatic decrease compared with 1938. Consequently, they have received a high grazing pressure over the last 60 - 70 years resulting in poor range state characterized by accelerated soil erosion, invasion and dominance of unpalatable species and reduced productivity (Papanastasis, 2003).

A number of authors (Gezahegn, 2006; Popp, 2007) affirmed that degradation of rangelands and pastures can be result of biotic and abiotic environmental factors. According to Popp, 2007, the combination of biotic factors (especially human intervention) with abiotic ones (edaphic and climatic factors) cause changes in vegetation structure leading to degradation. The human factor related to inappropriate management of livestock grazing, fires, weed control, etc, influences acceleration of erosion resulting in the decline of pastoral production system (Michailidis et al. 2006).

On the other hand, abiotic factors as well, affect the structure of rangeland vegetation causing a non equilibrium state (Mountousis et al. 2006). In particular, eco-physical factors combined with inadequate rainfall and soil erosion, lead to degradation of rangeland vegetation (Gezahegn, 2006). Topography affects strongly pasture productivity due to its influence on grazing distribution, it regulates forage quality and quantity values of a rangeland, and causes areas of runoff (Mountousis et al. 2006). According to Bailey et al., 1996, the deterioration of rangelands is more frequent in steep and very steep slopes combined with a low vegetation cover and high rain fall. In addition, the interaction of various environmental variables such as soil texture and distribution of rainfall also affect productivity, creating a complex system (Whittaker et al. 2006).In order to restore pasture productivity to its potential, the location and magnitude of degradation, as well as factors involved needs to be mapped and identified. Such an inventory will greatly contribute to their proper grazing management.

The objectives of this study were (1) to evaluate the productive potential of pastures in Albania by means of remote sensing technology as well as GIS analysis, and (2) to analyze the environmental and pasture use variables involved in pasture degradation through statistical analysis.

Methodology

Remote sensing

Satellite and ancillary data

Two different datasets (satellite and ancillary) were used in this study. The satellite dataset consisted of four Landsat Enhanced Thematic Mapper (ETM+) images covering the whole area of Albania. The images were already geo-referenced and geo-corrected by using topographic maps of the Albanian Military Geographic Institute (map-to- image) at the scale of 1:100.000 (Jansen et al. 2006). The ancillary dataset used in the analysis was produced in the framework of Albania Watershed Assessment Project and consisted of a Digital Elevation Model (DEM) of Albania, thematic maps of administrative units (districts), soil types, village's location, hydrologic and road networks, erosion and grazing pressure. The data were prepared in the context of Albanian National Forest Inventory (ANFI, 2004) and were granted to be used in this study.

Image pre-processing and analysis

Pre-processing included image mosaicking, atmospheric correction and clipping of pasture areas from the image. Mosaicking was necessary in order to provide full coverage of Albania. The atmospheric correction consisted of haze removal from the images because a considerable area (especially in the western part) of them was affected by this component. Clipping of pastures on the images was done by using the polygons of the pasture areas extracted from the land cover /use map produced in 2002 (Jansen et al. 2006).

Subsequently, pixel based image analysis was applied to the imagery. The images were analyzed spectrally by using a combination of Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA) and Supervised Classification (SC). NDVI was computed in order to differentiate among vegetation and non-vegetation areas (presented by a range of positive and negative values respectively) and used as an additional layer for further spectral analysis. PCA was applied on 6 bands (five spectral bands + NDVI) in order to improve data interpretability and enhance several features on pastures (Chuvieco, 1999). In order to establish the spectral characteristics of various components of pastures and validate the imagery classification (accuracy assessment), we used points with known cover from the field inventory (ANFI, 2004). Supervised Classification of pixels similar in their reflectance characteristics produced four different classes of cover components of pastures: herbaceous species, woody species, bare soil and rocks. The accuracy of the entire map was assessed by constructing an error matrix using 107 randomly selected plots with known cover from the field inventory (ANFI, 2004). The overall accuracy of image classification was estimated to be 75.7%.

GIS analysis

The thematic map of cover components of pastures was imported into a GIS system for calculating the area covered by each of them for the whole country. In addition, several thematic maps were produced based on the ancillary data. They included maps of slope, aspects and elevation classes based on DEM, distance maps showing the distance (close < 1km; medium 1-3km; far >3km) of cover components of pastures from the hydrologic network, road network and the location of villages. All the above maps, including also the erosion and grazing pressure map, were classified into a number of classes and used in further analysis.

Statistical analysis

A matrix of abiotic, biotic and variables of pasture use was prepared in Arc Map, using the data derived by GIS analysis. The polygons of cover components map (in hectare) were cross-tabulated (overlapped) with abiotic and pasture use variable maps. In addition, the polygons of cover components map were also cross-tabulated with themselves (rows- area, columns- cover component to which it belongs). In this way, it was produced a matrix with rows composed of polygons (area) of different cover components and columns composed of classes of abiotic, variables of pasture use and cover components. The matrix was then exported in SPSS for further statistical analysis. Prior to performing any statistical analysis, the matrix was normalized (by rows) using a procedure which forces the classes of each variable to sum to one. This step was necessarily to avoid differences in polygon sizes in order to make them comparable (Congalton, 1991).

The statistics of the database (matrix) consisted of Discriminant Analysis (DA) and Correlation Analysis (CA). DA was performed on abiotic, biotic (NDVI) and pasture use variables with the purpose of testing if they can discriminate significantly, in terms of variability, the four cover components of pastures. CA was carried out to identify the most important abiotic and pasture use variables affecting significantly each cover component of pastures, particularly the bare soil component which indicates pasture degradation. The threshold for significant correlations was set at $P \leq 0.05$.

Results

Remote sensing and GIS inventory results

Distribution of pasture area with respect to elevation revealed that less than half of pastures were located in the altitude up to 800m which corresponded to 48% of the total pasture area (Table 1). The remaining part (52%) was found to be located in a range of elevations varying from 801-2750m. Considering the elevation classes, the allocation of pasture area was almost the same for the first three classes (up to 1200m), but it varied considerably in the other classes. The major parts of pastures were located in very steep slopes followed by steep slopes and only a small part of them were spread in undulating areas. A large area was found to have south facing aspects (south, south-east, south-west), indicating a limited plant growth. Pastures exposed to the north facing aspects (north, north-east, north-west) had a lower proportion. Most pastures were found on grey brown soils followed by grey dark, meadows and brown soils. The percentages of pastures with respect to the erosion level showed that only a small part of them had no erosion on the surface. Most of them were characterized by low to moderate level of erosion, while one third were found to be heavily eroded. Herbaceous vegetation dominated all over the pasture area. The second largest cover component was rocks, followed by bare soil with a slight difference and lastly woody species (Table 1). More than half of pasture area was characterized by positive NDVI values, indicating high vegetation activity. The analysis of pastures distance from water sources showed that a very high percentage of them were found close to water sources (Table 1). The areas found in a medium distance were less and the remote ones even less. Pastures distance from roads showed the same pattern like the distance from the water sources. Pasture distance from the villages appeared to be somehow different compared with the previous two variables. More than half of pastures were located in a medium distance from the villages, a large part of them were found to be close, and only a small portion of the pastures were distributed far away from the villages. Considering the grazing use, more than half (53%) of the pastures are improperly grazed (characterized either by a light grazing intensity or by a high grazing intensity) and the remaining part is properly grazed.

Table 1. Inventory results of abiotic, biotic and management variables showing areas (ha) and proportions of pastures (%) classified according to information obtained by remote sensing and GIS inventory.

Abiotic variables	Area (ha)	%	Biotic and management variables	Area (ha)	%
Altitude			Cover components		
0-400 m	122353	25.4	Woody species	93275.2	19.4
401-800 m	110334	22.9	Herbaceous species	164433.6	34.2
801-1200 m	111854	23.4	Bare soil	110103.2	22.9
1201-1600 m	77048	16	Rocks	112988	23.5

1601-2000 m	46083	9.6	NDVI		
>2000 m	13128	2.7	<-0.5	62 504	13.0
Slope			-0.5-0	158 664	33.0
Undulating (<15%)	102796	21.4	0.1 to 0.5	187 512	39.0
Steep (16-30%)	173211	36	0.51 to 1	72 120	15.0
Very steep (>30%)	204793	42.6	Distance from water		
Aspects			Close (<1km)	346176	72.0
Flat	587	0.1	Medium (1-3km)	110584	23.0
North	40786	8.5	Far (>3km)	24040	5.0
North-east	56649	11.8	Distance from roads		
East	58579	12.2	Close (<1km)	322136	67.0
South-east	56488	11.7	Medium (1-3km)	120200	25.0
South	66147	13.8	Far (>3km)	38464	8.0
South-west	84357	17.5	Distance from villages		
West	71565	14.9	Close (<1km)	38.0	38.0
North-west	45646	9.5	Medium (1-3km)	51.0	51.0
Soil type			Far (>3km)	11.0	11.0
Grey brown	163472	34.0	Grazing use		
Brown	76928	16.0	Light grazing	105600	22.0
Grey dark	149048	31.0	Moderate grazing	225600	47.0
Meadow	91352	19.0	Heavy grazing	148800	31.0
Erosion level					
No erosion	76928	16.0			
Low erosion	139432	29.0			
Moderate erosion	120200	25.0			
High erosion	144240	30.0			

Drivers of pasture degradation

Discriminated analysis identified three canonical functions describing the data variability (Table 2). The first function carried 43.1% of the variance and showed the highest correlation with dependent variables (0.868), the second one 31.8% (0.833) and the third one 25.1% (0.8) respectively. The first function indicates greater significant and discriminatory ability of the cover components, followed by the second and third one.

Table 2. Statistics of the discriminated analysis of cover components of pastures

Function	% of variance	% cumulative	Canonical correlation	Lambda di Wilks	Chi-square	df	Sig.
1	43,1	43,1	,868	,027	668641	87	,000
2	31,8	74,9	,833	,110	408956	56	,000
3	25,1	100,0	,800	,359	189794	27	,000

The most important independent variables discriminating the cover components associated with the first function are: elevation above 1000 m, low to moderate erosion, road distance less than 1km and positive NDVI values, whereas the second function is mainly discriminated by elevation lower than 1000m, low to moderate slopes and light grazing (Figure 1).

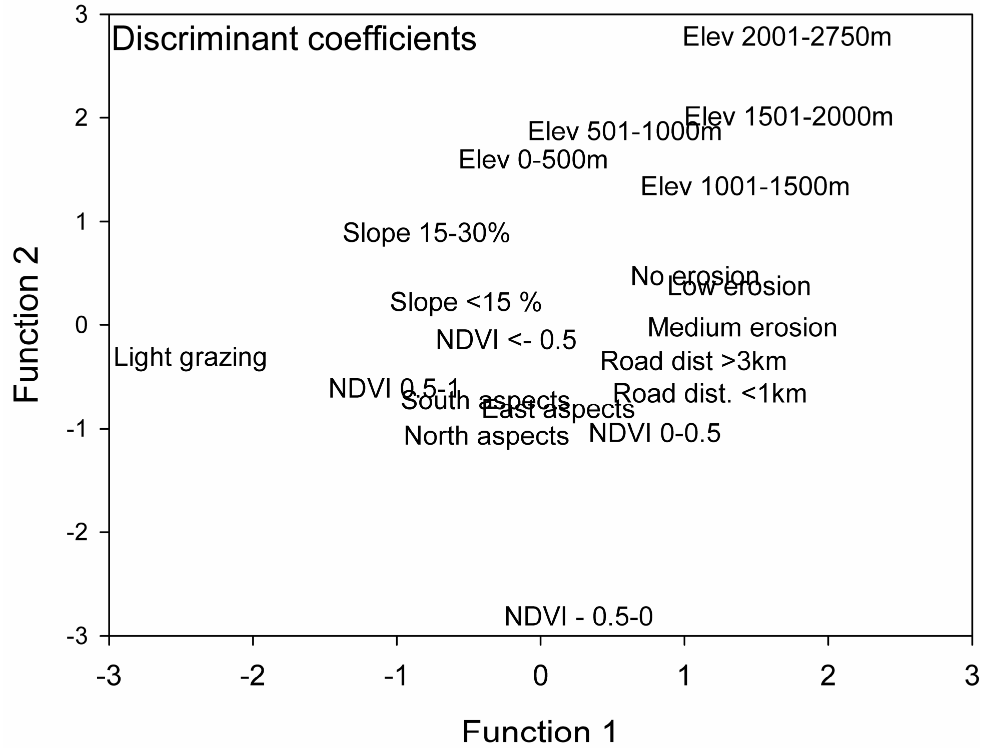

Figure 1. Discriminated coefficients showing the contribution of abiotic, biotic and pasture use variables to the respective discriminated function.

The discrimination of cover components of pastures by cases indicates a clear separation among them. The first function discriminated herbaceous and woody species which tend to be by the opposite site of the dimension 1 whereas the second function separated rocks and bare soils (Figure 2).

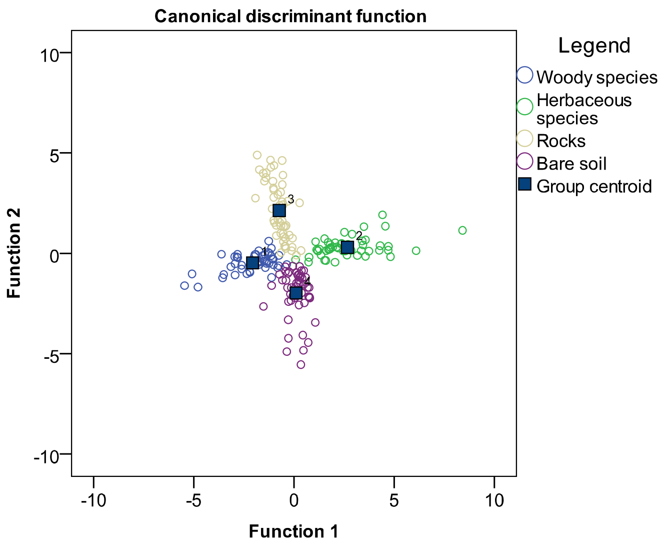

Figure 2. Scattergram of the discriminated canonical functions and the groups of variables.

The correlation analysis showed that the areas covered by woody species were mainly associated with elevations lower than 500 meters, low (<15%) to moderate slopes (15-30%), south and west aspects, close to medium distance from the villages, roads and water bodies, characterized by a moderate to heavy grazing, and mostly no to low erosion (Table 3). The herbaceous species were mainly correlated with elevations up to 1000 meters, moderate to high slopes, east and south aspects, close to medium distances from the villages, water sources and roads, moderate grazing and low to moderate erosion. The bare soil was mainly related with elevations up to 2000 meters, moderate to high slopes, south and west aspects, close to medium distance from villages, roads and water bodies, moderately to heavily grazed and significant signs of accelerated erosion. The rocks were mainly associated with elevations above 1000m, moderate to high slopes, all aspects, mostly in medium distance from the villages and roads but close to water sources and high erosion.

Table 3. Correlation of cover components of pastures with abiotic and pasture use variables

Variables	Woody species	Herbaceous species	Bare soil	Rocks
Elev. 0-500m	0.782**	0.681**	0.161	0.081
Elev. 501-1000m	-0.053	0.562**	0.414**	0.528**
Elev.1001-1500m	0.213	0.27	0.586**	0.570**
Elev.1501-2000m	0.352*	-0.118	0.666**	0.554**
Elev. 2001-2750m	0.178	-0.045	0.258	0.636**
Slope <15 %	0.744**	0.307*	0.603**	0.430**
Slope 15-30%	0.843**	0.634**	0.929**	0.948**
Slope >30%	0.626**	0.797**	0.911**	0.959**
North aspects	0.828**	0.523**	0.675**	0.765**
East aspects	0.745**	0.687**	0.448**	0.887**
South aspects	0.878**	0.919**	0.823**	0.806**
West aspects	0.874**	0.446**	0.820**	0.855**
Village dist. <1km)	0.767**	0.839**	0.406**	0.723**
Village dist. 1-3km	0.731**	0.756**	0.941**	0.856**
Village dist. >3km	0.257	-0.098	0.114	0.486**
Road dist. <1km	0.748**	0.765**	0.895**	0.855**
Road dist. 1-3km	0.437**	0.648**	0.741**	0.899**
Road dist >3km	0.292*	0.021	0.047	0.409**
Water dist. <1km	0.863**	0.959**	0.970**	0.934**
Water dist. 1-3km	0.382**	0.374**	0.551**	0.391**
Water dist. >3km	0.083	-0.09	0.083	0.063
Light grazing	0.330*	0.043	0.389**	0.729**
Moderate grazing	0.582**	0.785**	0.946**	0.930**
Heavy grazing	0.772**	0.535**	0.430**	0.433**
No erosion	0.788**	0.579**	0.469**	0.199
Low erosion	0.768**	0.933**	0.904**	0.426**
Medium erosion	0.612**	0.842**	0.974**	0.369**
High erosion	0.404**	0.695**	0.844**	0.975**

**Correlation is significant at P<0.01
*Correlation is significant at P<0.05

Discussion

The analyses carried out in this study by means of remote sensing and GIS provided an evaluation of pasture productive potential and the level of degradation. Several authors have recognized the benefit of using remote sensing and GIS algorithms in performing basic pasture inventories (Oetter et al., 2001; Booth and Tueller, 2003). Satellite images are advantageous because their use reduces to minimum the field work which is expensive, time consuming and requires a lot of qualified people (Booth and Tueller, 2003). The mapping of cover components of pastures indicated reduced potential productivity and relatively high level of degradation. This is reflected in the limited vegetative cover which occupies only about half of the ground surface and the relatively high proportion of pastures having rocks and bare soil (about 25% of the area). The results also indicated that the degradation of pastures in Albania it is caused by the combined effect of unfavorable abiotic conditions and biotic factors. This is based on the large pasture area located on mountainous areas, with steep to very steep slopes, south-facing aspects and high level of erosion. The combination of these factors designates poor site quality, which results in limited amounts of forage production (Papanastasis, 1989). This was evident, especially in high elevations and slightly populated areas, which were correlated with bare soil component indicating pasture degradation. Therefore, in these areas the rough topography seems to have stimulated the removal of vegetation particularly in the areas slightly covered by vegetation. However, it can be considered as positive the fact that most of pastoral areas in Albania are distributed on productive soils which have a high potential for sustaining vegetation growth, especially forage production. It should be emphasized that although the abiotic factors have some influence on pasture degradation, they are considered of less importance taking into account that pastures are heavily disturbed by the local communities leaving in the surrounding areas (Papanastasis, 2003). The location of a large pasture area close and in a medium distance from roads, villages and particularly water sources, affects intensity of grazing by animals. This is due to the fact that pastures located in the vicinity of roads, villages and water sources are more exposed to high grazing pressure than those situated in remote areas, leading to the removal of vegetation cover, accelerated erosion and degradation. This fact was confirmed by the statistical analysis which evidenced a high correlation of bare soil component of pastures with close to medium distance from villages, roads and water bodies, subjected to heavy grazing pressure and characterized by significant signs of accelerated erosion. The grazing pressure data showed that most of the pastures in Albania are not grazed properly. This evidence suggests that these areas have a high risk for degradation because either under or over utilization deteriorates their condition (Papanastasis 2003). As a matter of fact, Albanian pastures have low productivity, and the annual herbage production from mountainous grasslands is between 600 and 1000 kg ha^{-1} (Shundi and Buzi, 1991). These indications suggested that pastures must have been subjected to high grazing pressure resulting in such removal of vegetation cover (Papanastasis et al., 2003), making them vulnerable to soil erosion, creating so conditions toward degradation. Erosion is considered as one of the most important factors associated with pasture degradation, as revealed by correlation analysis. According to Deis (2003), in large areas of pastures found in the arid and semi-arid zones, it is common to find overgrazing near watering points and little or no use in remote areas away from water. An increased degradation of pastures close to watering points was also observed by Nanaj and Scapeta (1996), Bruce and Mearns (2002) and Kola (2006). In addition, Papanastasis (1981) found that grazing pressure was high around the villages, but very low in remote rangelands. The pasture area covered by woody species, although subjected to high grazing pressure due to the vicinity to villages, roads and water sources, did not show signs of accelerated erosion. Most likely this is due to the fact that shrubs and trees are able to regenerate due to the good soil properties and their height which makes them not totally exposed to the animals. In the same line, a part of the area covered by herbaceous species, characterized by no or low erosion, should be attributed to the nature of the dominant parent rock, i.e. limestone. Soils formed on limestone have moderately fine to fine texture, and low erodibility, compared with acid soils that have moderately coarse to medium textures (Conacher and Sala, 1998).

It can be concluded that the current state of pastures can be attributed to a combination of adverse abiotic and management factors. The findings provided about the magnitude and location of degraded pasture areas offer a good basis for the development of management plans of pasture resources for their restoration and proper utilization in the future.

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