Mediterranean rangeland response to human intervention: a remote sensing and GIS study

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Abstract

Human intervention in Mediterranean and semi-arid ecosystems results in complex vegetation patterns and threat for soil degradation and deterioration of primary production. Range management of large areas under such conditions requires adequate and updated information regarding the status and dynamics of vegetation patterns. This paper investigates the usefulness of Landsat TM and JERS-1 satellite images for determining effects of goat grazing and clearing treatments on the recovery processes of Mediterranean shrubland. Eight slope units representing different histories of grazing pressures and clearing treatments were selected for this purpose. Spatial variations of vegetation cover, as determined by NDVI (Normalised Difference Vegetation Index) distributions in the slope units, were analyzed on the basis of summer images from 1992 and 1997. The use of temporal data allowed the assessment of natural vegetation regrowth rates. The results show that image statistics correspond well with: grazing intensities; length of the regrowth process; and grazing habits of goat herds. Proximity analysis conducted using GIS (Geographic Information Systems) techniques revealed that grazing intensity pattern follows the shortest path connecting the water source and the corral rather than spreading in wide areas across the slopes. It is suggested that remote sensing and GIS analysis can be used for monitoring slope-scale impacts of grazing and treatments on woody vegetation such as Mediterranean scrubland and woodland.

Introduction

Spatial mapping of rangelands vegetation is essential for the improvement of their management and conservation. Accurate and up-to-date information may provide ecologists and managers with a valuable tool to determine the actual status of geobotanical landscapes (Pickett et al., 1998), to estimate the probability of fire development (Chuvieco and Salas 1996), to determine the timing of clearing treatments (Perevolotsky and Haimov 1992), and to improve our knowledge regarding controlling grazing pressures in order to ensure maximal biodiversity (Lorimer et al., 1999). In Mediterranean regions and especially in the Mediterranean Basin, where large areas are under reoccurring grazing and treatment processes, there is a particular interest to explore and document vegetation recovery in rangelands.

Many remote sensing studies (e.g., Thomson and Milner 1989; Thomson 1995; Wylie et al., 1995; Pickup et al., 1998) were proved useful for spatial mapping of rangelands in wide and relatively homogenous regions. However, the assessment of remote sensing techniques in complex Mediterranean environments was most limited (e.g. Kennedy 1989; Shoshany et al., 1995; Hill et al. 1998). The patchy pattern of forage resources vegetation formations in the region and the variability of forage ratio between shrub and herbaceous species (Perevolotsky and Pollak, 2000) encouraged ecologists to often focus on a scale of a few square meters (Whiteman and Brown 1998) - the size of an individual shrub or tree. Accordingly, the low spatial resolution of satellite imagery - comparing with field heterogeneity - deterred researchers, livestock owners and managers from using remote sensing techniques for range management.
Here it is claimed that by shifting the attention from the single picture element (pixel) into slope units, there is a possibility for satellite remote sensing analysis, which yet represents a tangible spatial unit relevant for the field ecologists and range managers. The aim of this study is to determine whether satellite remote sensing could be a useful tool for monitoring the actual status and the recovery process (as determined by the natural rate of vegetation regrowth) of the vegetation in the studied area, and to examine whether the vegetation patterns obtained could be related to grazing pressures and range treatments. The examination covers three aspects: (1) the sensitivity of satellite data to changes in vegetation cover that result from various grazing pressures and treatments; (2) the recovery processes of the Mediterranean shrubs after the activities were terminated; (3) and the vegetation pattern that resulted from the herd daily migration pattern in the field.

In a previous study (Shoshany, 2002) changes in vegetation patterns in this region were examined using historical air photographs, however the fact that the airphotos provide panchromatic data most limit their sensitivity to differences between green and dry vegetation. The satellite data used in the current study provide an excellent opportunity to explore changes in green vegetation cover based on multi-spectral data and the well used technique of vegetation indices. The normalized difference vegetation index (NDVI) is the most commonly used index of green vegetation, which is based of the contrast between the reflectance of the red (R) and the infrared (IR) spectral bands (equation 1).

$$\text{NDVI} = \frac{\text{IR} - \text{R}}{\text{IR} + \text{R}}$$  

This ratio represents the contrast between the tendency of photosynthetically active pigments to absorb radiation strongly in the red region and the high reflectance of plants in the infrared region (which depends on the mesophyll structure within the leaves). The NDVI has been widely used to distinguish between vegetation and other landscape components, and later it has been found to be highly correlated with vegetation cover in the studied area (Svoray 1996) and in other several environments (Tucker 1979, Townsend and Justice 1986, Baret and Guyot 1991). In order to reduce the soil background effect in areas of sparse vegetation, the NDVI was further developed into other vegetation indices such as the Soil Adjusted Vegetation Index (Huete 1988) and the Perpendicular Vegetation Index (Richardson and Wiegand 1977). However, although some parts of the study site are characterized by open shrubland and some effect of soil and rock background could be suspected, a previous study (Svoray 1996) has shown that the vegetation cover of the study area was best represented using NDVI.

### Materials and methods

The area studied is the Judean Lowland (hilly terrain) in central Israel (Fig. 1), 350 m above sea level. The dominant rock formation is chalk, with an uneven cover of Calcrete and the dominant soil is Brown Rendzina (Haploxerolls). The vegetation formations comprise dense shrubland dominated by Quercus calliprinos and Phillyrea latifolia, in a wide range of transitional stages of woody formations. Dominant among these formations is shrubland in which the most abundant vegetation comprises the above-mentioned species and moderate-size shrubs such as Calycotome villosa and Pistacia lentiscus. These shrubs may appear in various successional stages as a result of human intervention, including grazing, crop cultivation, wood cutting and burning practices, which has continued over thousands of years, and contributed to the heterogeneity of the environment. This status of the dominant formation implies that the geobotanical landscape has assumed a form that is sensitive to grazing management. In rangelands of the Mediterranean regions, this sensitivity could play a key role in the development of the vegetation through cutting treatments and overgrazing. Dwarf shrub communities in the studied area are dominated by Sarcopoterium spinosum and patches of herbaceous vegetation comprising a variety of species, mostly annuals (Perevolotsky and Haimov 1992). The landscape heterogeneity of the region results from complex environmental conditions combined with approximately 6000 years of human activity (Perevolotsky and Seligman 1998). The lowlands have been extensively populated, and the hundreds of residential and burial caves dug into the soft chalk, which have been dated to 100-200 CE, provide evidence for this widespread settlement activity (Stern et al., 1993). At present, land use comprises mainly agricultural cultivation, nature reserves and beef cattle ranching. The agriculture is modern and the dominant crops are wheat, cotton, orchards, watermelons and sunflowers. In a study performed in Avisur Highland area (sites western to the slope units studied here), significant vegetation recovery rates were found between 1956 and 1990 (Shoshany 2002). North facing slope had reached almost complete recovery while in the south facing slope such recovery is expected to be reached before 2010. This information suggests that landscape changes in the studied units represent mainly the current grazing and cutting and thining treatments rather than historical landuse practices.

In the studied area, eight slopes units (each covering 6 to 17 ha and under a variety of management regimes)
were selected (Fig. 2). The selected slope units share the same environmental characteristics (soil, rock, topography and climate): the dominant rock is chalk; the soil is brown Rendzina rich in clay; all the ridges are oriented along an east-west direction, resulting in clearly defined north- and south-facing slopes with a mean slope of 7-9 degrees.

Due to the field conditions and other technical limitations we could not provide standard replicas to the different treatments. However, as an alternative, the mean value of NDVI of each treatment is based on large number of pixels that represent a relatively large unit (including the entire pixels population on each slope). The strategy of averaging a large unit is known from ecological studies that deal with natural, uncontrolled large areas (e.g., the study of Perevolotsky and Haimov 1992) that was conducted in the same study area) as oppose to the more controlled research that is conducted in small, well-defined plots that are easily replicated.

Table 1 shows the treatments – thinning, goat grazing and control - applied to the various landscape units and the compositions of their vegetation formations. Unit 8 is the Nahal Yoresh Natural Reserve, where human interference in the vegetation landscape has been kept minimal. Goats were chosen for this study since they are notorious for their high preference to browse (Malechek and Provenza, 1983; Papachristo, 1997). The goat herd is mainly fed on natural pasture which includes woody and herbaceous vegetation. Goat grazing was applied at three levels of intensity: high; medium; and low intensity. The combination of thinning of woody vegetation and high grazing pressure represents the most severe impact by human activity on the vegetation landscape.

The remote sensing method used in the current study is based on using the mean value of NDVI as a measure of vegetation cover pattern in each unit. On the same basis, temporal differences between mean NDVI values may represent a process of regrowth of the vegetation. Since the investigated images used in the present study were taken in the summer, the NDVI in this case mainly represents the cover of evergreen shrubs and some of the dwarf shrub species (Svoray 1996, 2000).

Two summer images were available for the current study: (i) a Japanese satellite JERS-1 image with 18-m ground resolution, dated August 10, 1992; and (ii) a

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**Table 1:** NDVI distribution and composition of vegetation formations in the studied units

<table>
<thead>
<tr>
<th>Vegetation formations composition [%]</th>
<th>Mean NDVI 1992</th>
<th>Human activity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>High shrubland</td>
<td>0.38</td>
<td>Cutting and thinning and grazing</td>
<td>1</td>
</tr>
<tr>
<td>Moderate shrubland</td>
<td>0.39</td>
<td>Cutting and thinning and grazing</td>
<td>2</td>
</tr>
<tr>
<td>Low shrubland</td>
<td>0.38</td>
<td>High grazing intensity (80 goats ha⁻¹)</td>
<td>3</td>
</tr>
<tr>
<td>Dwarf shrubs</td>
<td>0.42</td>
<td>Moderate grazing intensity (40 goats ha⁻¹)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>0.43</td>
<td>Low grazing intensity (20 goats ha⁻¹)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.46</td>
<td>No grazing</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.46</td>
<td>No grazing</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>Nature reserve</td>
<td>8</td>
</tr>
</tbody>
</table>

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*Fig. 2: The selected research units of the study area. The panchromatic (visible band) airphoto represents the plots at summer 1986. The Northern plots - 1 and 2 - show the heavily grazed area including the clearing treatments while the southern plots and the Natural Reserve plot - 8 - characterize relatively dense vegetation cover.*
LANDSAT TM image with 30-m ground resolution dated June 17, 1997. The sensors of both satellites recorded radiation in the visible and near infrared regions of the electromagnetic spectrum. The two images covered overlapping areas, therefore, a temporal analysis of the study area was possible from the technical point of view (Fig. 3). However, in addition, a temporal comparative analysis of the two years must assume that inter-annual changes (in our case between June and August) are neglected. We assumed neglected inter-annual changes between June and August based on large scientific documentation of the phenology of Mediterranean woody and herbaceous formations in Israel, as is summed up in Orshan (1989). Due to drastic seasonal changes, Orshan (1989), Gutman et al. (1990) and Seligman (1996) showed that from the beginning of May, herbaceous vegetation in this part of the world withers up and by early June it is totally dry. It is also well known that woody species, mostly ever-green, do not change significantly their biomass/cover values along a period of two summer months. This phenomenon is well demonstrated in Fig. 4 that illustrates that NDVI values of herbaceous vegetation and open areas in the studied area are very low and do not differ between June and August. In addition, mean NDVI values, calculated from regions of undisturbed woody formations do not differ between these two months.

To facilitate an accurate analysis of the satellite signal, all spectral bands were calibrated against reflectance units according to the empirical line technique (Smith and Milton 1999). This was done based on field measurements of the reflectance of water bodies and highly reflective limestone bare rock carried out using CROPSCAN and FieldSpec radiometers (Jarmer et al., 1996). File coordinates of the two images were transformed to the Israel Grid, based on 1:50,000 topographic maps and differentially corrected GPS (Global Positioning System) measurements, through a first-order transformation. The root mean square error of the retransformed ground control points was of less than one pixel (for more details on the preprocessing stage see Shoshany et al. 1994) in both cases. To allow a comparative study between the 18-m JERS-1 data and the Landsat TM 30-m data, the JERS-1 image pixels were resampled to 30-m ground resolution using the nearest neighbour technique.

After preprocessing for both dates, NDVI values were calculated for the entire image domain. Boundaries of the studied units were delineated, with topographic structure of every slope taken into consideration. Extreme values of topographic parameters, at the margins of each slope were considered to be outside the unit boundaries, and were excluded from the analysis. The analysis of the study units comprised three stages, each addressing a different aspect. Firstly, mean NDVI values were calculated for each slope unit. Secondly, a temporal analysis, of the differences between NDVI values in 1992 and in 1997, was performed and the results were related to the 1992 NDVI values, thus reflecting the regrowth of natural vegetation after the above-mentioned treatments had been terminated. Correlation between the 1992 NDVI and the difference image was based on the GIS matrix algorithm that had been used previously in another Mediterranean vegetation analysis, designed to characterize patterns of vegetation cover in the transition zone of a climatic gradient in central Israel (Shoshany et al., 1995, 1996). The matrix algorithm creates an intersection matrix for the two classes of pixels i.e. in our case the 1992 NDVI and those of the difference image (ΔNDVI). This intersection matrix was used to determine the frequencies with which pixels of the respective classes overlap. In other words, the use of matrix analysis allowed to explore how NDVI of each of the image pixels changed from 1992 to 1997 correspondingly to the initial conditions of 1992.

In the third stage, the temporal algorithm was applied along the path of herd movement (from the corral to the

![Fig 3: Overview of image and GIS analysis](image-url)
water source) on the basis of a proximity analysis of the growing distance (gradually) between the predetermined sources within the image. In addition to the common distance measure, we had calculated and added to the statistical analysis an effort measure. The effort measure was calculated using a methodology presented in Ganskopp et al., (2000) to define the difficulty encountered when the herd is traveling in the grazing area. A comprehensive description and rational of the method is provided in Ganskopp et al., and will not be repeated here, however, in short, the effort surface could be defined by equation 2:

\[
\text{Cost} = (\text{Slope} + 1)^{\cos^2 \alpha}
\]

where Cost is a variable that represents the effort of the herd to travel according to two integrated components: the local slope and the direction of movement of the herd (downslope, uphill, etc...). Therefore, Slope is the local slope of the pixel in degrees and \( \alpha \) is the difference angle between the angle of travel of the herd and the direction from which the force is maximum. In our study, these parameters were calculated using a 50-meters resolution DEM (Digital Elevation Model) of the Geological Survey of Israel and the well-known course of the herd.

Results and Discussion

**NDVI Distributions in the Studied Units**

Analysis of NDVI distributions in the studied units showed significant differences between those subjected to no human activity versus strong human intervention in both years. The nature reserve (unit 8), as expected, showed the highest mean NDVI value as all human intervention has been excluded for the last decade, whereas unit 1, in which cutting, thinning and goat grazing all occurred, provided the lowest NDVI value. Within the range of units a discrepancy from the expected order of NDVI values was found, with unit 4 (0.46 mean NDVI value), subjected to moderate grazing intensity exhibiting a higher mean NDVI value than unit 5 (0.44 mean NDVI value), on which the grazing intensity was low. This disagreement within the calculated hierarchy is understandable in the light of post-processing analysis. Visual analysis of the NDVI distribution within the units indicated that units 4 and 5 contained patches of notably high NDVI values, which strongly affected the mean NDVI value of the unit (Svoray et al., 1996). A careful field survey revealed the existence, in some units, of patches of calcrete crust characterized by an improved water regime (Dan et al., 1972). These patches support the development of localized dense woody vegetation, which grows beyond the reach of goats and is, therefore, not strongly affected by grazing. Such dense and highly developed vegetation increased the unit mean NDVI value. Using the high NDVI values appropriate to shrubland strips we separated the pixels of the dense patches from the rest of the slope, and thus removing these patches from the analysis. After this correction, the ranking seemed more logical and was correlated more strongly with the intensity of human intervention (table 1). Nevertheless, some slight discrepancies were found between the NDVI rankings and those of the actual vegetation cover density, i.e., corresponding mean NDVI values had shown that: high grazing (3) ≤ cutting and thinning and grazing (units 1 and 2). It should be also noted that absolute difference between NDVI values of moderate and low grazing are not significant. Application of Student’s 𝑡 test showed that significance levels allowed division of the units into four groups:

(i) units 1, 2 and 3 characterized by cutting and thinning and high grazing intensities;
(ii) units 4 and 5, with moderate and low grazing intensities;
(iii) units 6 and 7, with no grazing;
(iv) unit 8, the nature reserve.

The sensitivity of the NDVI to the density of vegetation cover that results from various range management activities is consistent with two previous studies involving NDVI to identify differential grazing on the relatively homogenous grasslands in the North Wales (U.K.) uplands (Thomson, 1995; Thomson and Milner 1989). This agreement suggests that it is feasible to monitor the status of rangeland vegetation (in terms of vegetation cover), under a variety of environments, management regimes and vegetation formations, and independently of scale, by means of NDVI distribution analysis calculated using optical satellite images.

**Temporal Analysis of Vegetation Recovery**

In theory, examinations are made at two points in time, and the difference between the actual status of vegetation cover at the earlier date and that at the later date will be the cover value added between the two dates. In the present study, recovery rates (the shrubs and dwarf shrubs regrowth) were demonstrated by means of the delta (\( \Delta \)) of NDVI calculated from the differences between the 1992 and 1997 NDVI values. Thus, \( \Delta \text{NDVI} \) is an indicator of the vegetation cover added during 5 years of growth between 1992 and 1997. Figure 5 illustrates the curves of 1992 NDVI relationship between

![Fig 5: Mean NDVI values at 1992 and 1997 of plots with different treatment effects.](image-url)
the mean values of ΔNDVI and the 1992 and 1997 NDVI mean values for the eight slope units. The difference between the curves is the ΔNDVI. The figures show that in the units the relationship between the 1992 NDVI and the ΔNDVI may represent the recovery rate of the units as a dependent variable, with vegetation cover at the starting stage (in our case 1992) as the independent variable. Figure 5 shows that in the unit with no grazing and in the nature reserve, no significant changes in NDVI values were found over the 5 years; this observation implies that the cover of developed vegetation had not significantly changed during the 5-year period. The hierarchy that ranges from units characterized by strong human impact to those under low pressure shows that the heavier the human intervention, the higher the ΔNDVI values. These results led us to perform a per-pixel analysis to enable a higher sampling rate and to use a continuous data set, rather than the categorical set on which Fig. 5 was based. The per-pixel attempt included examination of the relationships between the 1992 NDVI values of every pixel and its ΔNDVI, by means of the matrix algorithm.

Table 2 provides the results of a matrix analysis indicating the percentage of the region represented by each combination of NDVI in 1992 and its equivalent ΔNDVI. The left column of the table shows groups of NDVI values at 1992 and the upper line of this table shows the ΔNDVI values similarly clustered into groups. The numbers in the cells of the table represent the percentage of the region covered by each combination. According to Fig. 4 and to random empirical measurement of different variations of the shrubs cover in the study area, it is believed that the first two lines (of 1992 NDVI value 0-0.15) do not represent pixels covered by shrubs due to the very low NDVI values they provide. From line 3 to line 7 the regions covered by combination of high ΔNDVI decrease gradually down to a very low level of the two last categories (0.41-0.45 and even less in 0.46 and up). This result may indicate that beyond specific vegetation cover value, the addition of vegetation is very low, so that a formation with this degree of cover will not undergo significant further development. This statement should include an assumption that further growth of the shrubs could be too small to be detected by NDVI variance. In other words, the results may imply that the lower the vegetation cover in 1992, the higher the rate of vegetative growth during the recovery period. The rate of vegetative growth during the recovery period falls to a minimum level at the 1992 NDVI value of 0.41 and onward and remains at this minimum value for 1992 NDVI values above 0.41; thereby indicating that additional vegetation cover beyond the 1992 NDVI value of 0.41 provides very little additional vegetative growth during the recovery period.

**Vegetation Cover Variability along the Path of the Herd**

Another opportunity to examine the sensitivity of the satellite data to the recovery process was provided by an analysis of the relationship between the 1992 NDVI and the ΔNDVI along the herd’s pathway: grazing habits and movement of goat herd in the rangeland could create an interesting pattern of vegetation cover. This pattern depends upon the spatial distribution and intensity of grazing, since grazing impacts should depend on the movement of the herd within the area and its preferences for grazing in various units. In general, the direction of the movement is controlled by push and pull forces within the grazed area. In our case, the goat herd spends the night in a corral located at the top of unit 4 (see Fig. 2), whereas its water source is located at the bottom of unit 1. Thus, during each day, the herd moves from the corral to the water source and, where it spends most of its grazing time. Consequently, grazing pressure is hypothesized to diminish with increasing distance from the water source. In light of the relationship between grazing pressure and ΔNDVI discussed above, it is also expected that there would be a similar relationship between the distance from the water source and ΔNDVI.

The relationship between the distance from the source and ΔNDVI was examined by means of Proximity Analysis - a raster GIS algorithm which enables pixels to be graded according to their distances from a given source area. This algorithm allows estimating quantitatively (on a per-pixel basis) if the dilation of one phenomenon has some kind of impact on another phenomena.

In our case, the source area was defined as the water resource and the distances were measured in circles or one-pixel buffer zones from it to an outer perimeter. Correlation analysis indicated no significant relationship between the ΔNDVI values and the growing distance from the water resource. In other words, distant areas in which we hypothesized that the herd spends less time (and thus these areas suffer lower grazing pressure) did not show

<table>
<thead>
<tr>
<th>NDVI 1992</th>
<th>ΔNDVI</th>
<th>0-0.05</th>
<th>0.06-0.1</th>
<th>0.11-0.15</th>
<th>0.16-0.2</th>
<th>0.21-0.25</th>
<th>0.26-0.3</th>
<th>0.31-0.35</th>
<th>0.36-0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05-0.1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.11-0.15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>0.16-0.2</td>
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<td>1</td>
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<td>2</td>
<td>3</td>
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<td>1</td>
<td>7</td>
<td>3</td>
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<tr>
<td>0.31-0.35</td>
<td>3</td>
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<td>5</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
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<tr>
<td>0.36-0.4</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td>0.41-0.45</td>
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<td>7</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>0.46+</td>
<td>5</td>
<td>1</td>
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evidence of significantly lower vegetation recovery rate. However, when both the corral and the water source were designated as double source, results have presented a significant correlation. Figure 6 shows that $\Delta$NDVI decreases with increasing distance from the water source and the corral and vice versa. Although the coefficient of determination is only 0.65, the data demonstrate a clear linear and negative tendency. This observation may imply that the herd spends more time around the corral and the water source than elsewhere and, consequently that these areas suffer higher grazing intensities. In accordance with the results presented in the previous section, areas of higher grazing intensities exhibited higher recovery rates and vice versa. This observation was even strengthened when we added to the analysis, using a multiple regression procedure, the impact of the directional component of the herd movement (the effort measure described in equation 2). This had shown that there was small although significant improvement for the explained variation of the dependent variable $\Delta$NDVI (Fig. 7). The coefficient of determination was improved by 4% (from 0.65 to 0.69) and both $B$ variables were significant and negative (-0.62; -0.26). In accordance with the above-mentioned, this result may imply that the herd takes into consideration the environmental conditions and uses more frequently, areas that are more convenient to travel. The relatively small additional percentage to the coefficient of determination could be related to other environmental factors that might affect the movement of the herd i.e. rugged terrain and presence of terraces. The later were beyond the scope of this research and could not be calculated using the digital elevation model.

**Conclusions**

Human intervention within the context of a number of successional stages in a Mediterranean landscape could be identified by means of satellite images of small-scale features such as a local slope unit (~10 ha). The scale used here provided more details than previous studies that
utilized LANDSAT TM images to characterize rangelands in this heterogeneous region. The temporal approach presented here, using different algorithms has demonstrated the possibility of monitoring recovery rates of woody Mediterranean vegetation, under various human impacts. It was found that units subjected to more intensive use (and consequently having less vegetation cover) demonstrated a high recovery rate within a 5-year period compared to areas subjected to less intensive use where cover is changing only slightly over time. Human intervention, which affects successional processes in the studied area, is characterized by preventing shrubland formations from replacing formations of lower vegetation. However, human activities seem to delay the succession process only as long as the activity continues, after which, the landscape recovers rapidly to its expected status of closed shrubland (Di Castri 1981; Shoshany, 2002). The closed shrubland is not expected to add a significant amount of vegetative cover over the short run. Consequently, the human activity is expected to prevent or, at least to delay the development of the landscape to the subsequent formation: Mediterranean woodland.

Acknowledgment

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