Statistical assessment of vegetation dynamics within protected areas using remote sensing data

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Abstract

This study aimed to test the effectiveness of protected areas to preserve vegetation. The first step was to identify vegetation suitable areas, designed as areas with optimal morphological terrain features for a good photosynthetic activity. These areas were defined according to the following landscape factors: slope, altitude, aspect and land use. Enhanced vegetation index (EVI) was chosen as vegetation dynamics indicator. This method is based on a statistical approach using remote sensing data in a geographic information system (GIS) environment. The correlation between EVI and landscape factor was evaluated using the frequency ratio method. Classes of landscape factors that show good correlation with a high EVI were combined to obtain vegetation suitable areas. Once identified, these areas and their vegetation dynamics were analysed by comparing the results obtained whenever these areas are included or not included in protected areas. A second EVI dataset was used to verify the accuracy in identifying vegetation suitable areas and the influence of each landscape factor considered in their identification. This validation process showed that vegetation suitable areas are significant in identifying areas with good photosynthetic activity. The effects analysis showed a positive influence of all landscape factors in determining suitability. This methodology, applied to central regions of Italy, shows that the vegetation suitable areas located inside protected areas are *greener* than those outside protected areas. This suggests that the protective measures established by the institution of the parks have proved to be effective, at least as far as the status of vegetation development is concerned.

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Key words: areas suitable for vegetation, enhanced vegetation index, frequency ratio, open access data, geographic information system.

Received for publication: 28 January 2013.
Accepted for publication: 20 March 2013.

Journal of Agricultural Engineering 2013; XLIV:e5
doi:10.4081/jae.2013.e5

Introduction

Recently (United Nations, 1992; European Commission 1992; Council of Europe, 2000), when it comes to biodiversity and habitat protection, we generally refer to the concept of ecological network and its modalities of detection, protection and development (Fath *et al.,* 2007; Scotti *et al.,* 2007; Bazelet and Samways, 2011). The traditional forms of protected areas (PA) usually play a fundamental role inside the ecological network (Thompson *et al.,* 2007; Goetz *et al.,* 2009) and their long-established presence allows us to evaluate the degree of protection they have provided (Kharouba and Kerr, 2010; Ioja *et al.,* 2010; Marcer *et al.,* 2010).

The importance of monitoring PA has been confirmed internationally by the *Convention on Biological Diversity's Programme of Work* on PA in which each country was asked to conduct management effectiveness evaluations on at least 30% of its PA by 2010 (decision VI/26; Secretariat of the Convention on Biological Diversity, 2005). These studies have often shown the limitations of aesthetic and socio-economic criteria that have contributed to their determination (Scott *et al.,* 2001; Oldfield *et al.,* 2004), of the zoning and protective measures implemented (Sabatini *et al.,* 2007; Geneletti and Van Duren, 2008; Liu and Li, 2008), and the ever-growing influence of the surrounding urbanised areas (McDonald *et al.,* 2009; Borgstrom *et al.,* 2012). Despite these problems, PAs continue to play a key role in biodiversity conservation and it is imperative to verify their effectiveness.

Numerous methodologies and indicators have been developed to do this (Bertzky and Stoll-Kleemann, 2009; Stoll-Kleemann, 2010). In cases of terrestrial PA, the dynamics of vegetation are an important aspect in assessing the health of an environment (Saunders *et al.,* 1998).

Regional-scale studies of vegetation characteristics are typically carried out using remote sensing data (Trodd and Dougill, 1998; Caouette and DeGayner, 2005; Zerger *et al.,* 2009). Remote sensing spectral vegetation indexes are widely used in the assessment of biomass, water use, plant health and crop production. The launch of satellite platform Terra in 1999, with moderate resolution imaging spectroradiometer (MODIS) instrumentation on board, provided freely downloadable data from the data centre of the National Aeronautics and Space Administration (NASA), with excellent temporal and spatial resolutions (Reeves *et al.,* 2001; Li and Fox, 2012).

The purpose of this study is to produce a versatile and low-cost model for large-scale spatial data analysis that can rapidly identify vegetation suitable areas from the point of view of morphological terrain features (VSAM). Therefore, VSAM are areas with optimal morphological terrain features for a good photosynthetic activity. The VSAM have been identified using a frequency ratio method. Although frequency ratio is one of the simplest and easiest statistical methods, it offers a level of accuracy comparable to more complex approaches, such as analytical hierarchy process, logistical regression analysis, and artificial neural network approaches (Pradhan and Lee, 2010; Park *et al.,* 2011). In addition, frequency ratio has already been used successfully in other studies to identify susceptible/suitable areas (Lee and Talib, 2005; Park *et al.,* 2011).

The VSAM have been used to assess PA effectiveness on vegetation protection by comparing the results between vegetation performances in VSAM inside PA and in those outside PA. This paper represents a first screening of the suitability of an area for vegetation development, from the point of view of morphological terrain features. Inside the VSAM, the analysis should be focussed on other factors related with vegetation to obtain an exhaustive indication of vegetation suitable areas. The identification of these areas may also help decision-making regarding changes to the boundaries of existing PA and their expansion.

Materials and methods

To develop the geographic information system (GIS) database, all spatial data have been projected to the WGS84 UTM zone 33N co-ordinates system. The resolution chosen for this work is 250×250 m as this is the resolution of the less detailed data used (MODIS data).

Study area

The study area has the following characteristics: i) a size that can be represented by a statistically significant number of pixels (Lee and Talib, 2005) using MODIS Terra imagery, *i.e.* 250×250 m; ii) characteristics that are similar from a climatic, socio-economic and historical viewpoint so as to reduce the influence of these factors in the interpretation of changes in vegetation dynamics.

The developed method has been applied to regions in central Italy. These regions form a well-defined territorial context (41°12'N, 44°28'N latitude, 9°30'E, 14°47'E longitude) covering a total area of 70,000 km^2 distributed as shown in Table 1.

Choice of vegetation index

In satellite remote sensing applications, the most common vegetation indexes are of an intrinsic nature that analyse the activity of vegetation based only on measured spectral reflectance. These include: ratio vegetation index (Jordan, 1969) and the normalised difference vegetation index (Rouse *et al.,* 1974). More recently, Liu and Huete (1995) have proposed a vegetation index called enhanced vegetation index (EVI). The EVI is able to detect the response of vegetation through a de-coupling of canopy background signal and a reduction in atmospheric influences (Huete *et al.,* 2002; Napolitano *et al.,* 2005) according to the equation:

$$EVI = G * \left(\frac{(\rho_{nir} - \rho_r)}{(L + \rho_{nir} + C_1 * \rho_r - C_2 * \rho_b)} \right) \qquad (1)$$

where
G is the gain factor, r_{nir}, r_r, r_b are the surface reflectances of near-infrared, red and blue bands, L is the canopy background adjustment that addresses non-linear differential NIR and red radiant transfer through a canopy, C_1 and C_2 are the co-efficients of the aerosol resistance term which uses the blue band to correct for aerosol influences in the red band.

In this study, we chose to use the EVI (MOD 13 data products) detected by the MODIS sensor aboard the Terra satellite (freely downloadable at: http://modis.gsfc.nasa.gov).

The files are segmented into tiles with an area of 10°×10° and contain information relating to 12 different bands.

EVI measures the amount of green biomass and occupies one band of the following product: MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN grid V005; one of the available spatial resolution is 250 m and the temporal resolution is 16 days. EVI values are calculated using the maximum values for a period of 16 days (maximum composite value) in order to compensate for the possible presence of null values caused by the persistence of cloud formations on the areas of recovery. Several studies have shown that EVI is strongly linked to many ecosystem variables such as leaf area index, biomass, canopy cover and fraction of absorbed photosynthetically active radiation (Huete *et al.,* 2002; Portillo-Quintero *et al.,* 2012). EVI is characterised by a theoretical range of linear values between –1 and 1; for bare soil it assumes values slightly above zero, reaching higher values the denser the vegetation (Huete *et al.,* 2002).

A total of 48 data containing EVI band for 2010 were downloaded from the NASA website; for 2010, for each granule 24 files are available, and 2 granules are needed to cover the entire spatial extent of analysis for the study area. The EVI performance trend analysis on these data showed that the period of most intense vegetation vigour for the study area in 2010 is between 10th and 25th June. This period was, therefore, chosen for study.

EVI values were grouped into 4 classes of variability where class 1 (EVI1) represents low photosynthetic activity and class 4 (EVI4) high photosynthetic activity.

Choice of landscape factors

There are many and important factors related to vegetation dynamics: vegetation types, morphological terrain features (*e.g.* altitude, aspect, slope), climate (precipitation, wind), hydrological profile (distance from river, groundwater depth), ground condition (soil type, soil drainage). Since this study is a first screening of the suitability of an area for vegetation development, and to ensure simplicity and cost-free data acquisition, it was decided to use standard sets available nationally, such as the Corine Land Cover (CLC) and the Digital Terrain Model (DTM), from which to derive altitude ranges, aspect and slope.

CLC 2006 (version 13 February 2010, raster data. Freely available from: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster) is used for covering land use. The classification used in this study for land use is the third level of CLC which includes 44 different types of land use. In the study area, the following 4 land cover types are not present: glacier and perpetual snow, peat bog, intertidal flats, estuaries, so the number of classes used in the subsequent statistical analysis has been reduced to 40.

The DTM data source used in this analysis is the Web Map Service provided by the Italian National Cartographic Portal (available from: http://www.pcn.minambiente.it/PCNDYN/catalogowms.jsp?lan=it).

A product with a resolution of 75×75 m was downloaded and was then re-sampled to the work resolution. Starting from the DTM, slope and aspect of the study area can easily be obtained using a common GIS tool. The study area was then split into 8 elevation classes: lowland (0-200 m asl), low hills (200-400 m asl), hill (400-600 m asl), high hills

Table 1. Study area: size and location (data source: http://www.istat.it).

Region		Area (km^2)	Area (%)
Abruzzi		10,789.50	33.28
Latium		17,200.21	12.22
Marches		9708.23	14.03
Tuscany		23,021.09	24.87
Umbria		8455.85	15.60
	Study area	69,174.88	100

(600-800 m asl), low mountains (800-1000 m asl), mountains (1000-1500 m asl), medium-high mountains (1500-2000 m asl), high mountains (above 2000 m asl), 7 homogeneous slope classes with steps of 5°, and 9 aspect classes.

Relationship between enhanced vegetation index and the degree of correlation between two georeferenced variables: frequency ratio method

Frequency ratio is a simple statistical method that evaluates the degree of correlation between two georeferenced variables (EVI-LF). The EVI is a response variable in relation to a set of *state* variables representative of the area analysed: land use, altitude, slope, aspect. A statistical analysis approach is appropriate when it is assumed that those physical and morphological characteristics of the study area that have EVI higher values (EVIhv: EVI class 3 and 4) will allow EVIhv to be maintained in the future as well. The correlation between EVI variability and classes of land use has been analysed in different contexts (Zerger *et al.,* 2006; Mondal, 2011) and has always been significant, whereas for the relationship between EVI and topographic characteristics of soil, the research has shown that it is correct to analyse this on a planning scale, but not at spatial resolutions of great detail, because this index is influenced by the roughness of terrain (Matsushita *et al.,* 2007). The frequency ratio calculations are shown in Table 2 where x_i indicates the EVI_i class and y_{kj} the class *j* of the LF *k*. The counter variable *i* assumes values from 1 to I, where I is the number of EVI classes, the counter variable *j* from 1 to J, where J is the number, variable for each LF, of the classes in which the values are grouped. Finally, the variable counter *k* assumes values from 1 to K, where K is the number of LF analysed. X_i, is the total number of cells of the study area falling in i^{th} class of EVI and Y is the total number of cells analysed:

$$Y=\Sigma_i X_i \tag{2}$$

The total number of frequency ratios calculated is given by the total number of classes into which the LF are divided, multiplied by the number of EVI classes (I), as shown in Eq. (3).

$$n.FR=\Sigma_k j*I \tag{3}$$

In the present study, the counter variables assume the following values: I=4 and K=4; for *k* equal to 1 (CLC) J assumes the value of 40; for *k* equal to 2 (altitude) J assumes the value of 8; for *k* equal to 3 (slope) J assumes the value of 7; for *k* equal to 4 (aspect) J assumes the value of 9. According to Eq. (3), the total number of frequency ratios is 256.

View of morphological terrain features and protected areas

Classes of LF that show a good correlation with high EVI are combined to obtain VSAM according to Eq. (4):

$$VSAM=\cap_{ikj}(p*FR) \tag{4}$$

where the variable frequency ratio is the correlation value of the i^{th} class of EVI and the j^{th} class of k-th LF and p represents the weight assigned to every frequency ratio calculated; p assumes value 1 with a frequency ratio greater or equal to unity, 0 in all other cases.

VSAM were then classified as internal and external to PA, and EVI performances in the two classes were compared. It has been decided to apply this methodology only to those PA classified as parks, since these are the areas with the most significant extensions. Parks cover approximately 10% of the whole national territory and are approximately 90% of all the terrestrial protected areas nationally (Table 3). In addition, parks are particularly important to monitor because their historic institution has meant that financial resources will continue to be allocated for their conservation.

Results

Data analysis

In the study area, EVI values mostly fall within two intermediate classes (class 2 and 3) (Table 4); EVIhv mostly correspond to the Apennine ridge (Figure 1).

As far as land use is concerned, the most representative classes are Broad-leaved forest (code 311, 28.5%) and non-irrigated arable land (code 211, 27%), which together cover more than 50% of the total surface.

From a morphological standpoint, the Apennine ridge that crosses central Italy from north to south has a relatively low average altitude, as mountain areas (>1000 m asl) cover approximately 10% of the study area and the most represented class is lowland (approx. 30%). The slopes are gentle (approx. 75%<15°, approx. 25%<5°) except in some areas of the Apennines. Exposures are evenly distributed; flat areas are less than 1%.

In the study area, there are 8 National Parks and 30 Regional Parks, altogether covering 9.36% of the total area, slightly below the national average (Figure 2).

The most recent park was established in 1999 (*Parco Naturale Regionale di Bracciano*), while the oldest were established by Royal Decree in 1923 (*Parco Nazionale dell'Abruzzo, Lazio e Molise*; *Parco Nazionale del Gran Sasso e Monti della Laga*).

Table 2. Equation for frequency ratio calculation: enhanced vegetation index classes/degree of correlation between two georeferenced variables classes.

	$n.x_i$	A	$n.y_{kj}$	B	FR_{ikj}
y_{kj}	No. of events ith EVI class falling into j^{th} class of kth LF	Percentage of x_i events falling into y_{kj} ($n.x_i*100/X_i$)	No. of cells of study area falling into y_{kj} class	% cells falling into y_{kj} class ($n.y_{kj}*100/Y$)	Correlation level between j^{th} class of i^{th} LF (y_{kj}) and i^{th} EVI class (x_i) $FR_{ikj}=A/B$
Total	X_i	-	Y	-	-

FR, frequency ratio; EVI, enhanced vegetation index; LF, the degree of correlation between two georeferenced variables.

Relationship between enhanced vegetation index and the degree of correlation between two georeferenced variables: results of frequency ratio method

Results of frequency ratio method are discussed for every LF; Table 5 shows frequency ratio calculations for class 3 of EVI as an example.

Where frequency ratio is greater than 1, there is a good correlation between jth class of LF$_k$ and EVI3; in order to avoid statistically not significant results, as performed on a negligible number of pixels, frequency ratio results for those values of A or B below 1 were not considered.

Relationship between enhanced vegetation index and Corine Land Cover

The class with the best correlation with EVI4 is Broad-leaved forest (Corine code 3.1.1). Classes that have a good correlation with the EVI3 are, in descending order, broad-leaved forest (Corine code 3.1.1.), mixed forest (Corine code 3.1.3.), transitional woodland-shrub (Corine code 3.2.4.). Land mainly occupied by agriculture with significant areas of natural vegetation (Corine code 2.4.3.), pastures (Corine code 2.3.1.) and natural grassland (Corine code 3.2.1.).

This means that the most vegetative growth occurs for broad-leaved forest and mixed forest, involving 61.24% of the study area with EVIhv.

Relationship between enhanced vegetation index and morphological terrain features

As regards morphological terrain features, the elevation classes showing good correlation with EVIhv go from high hills to high mountains, where the forest areas are concentrated. With regard to the slope classes, it seems that they do not have any particular influence on EVI performance, except for extreme values. For very steep slopes, the good correlation is not significant because of the low number of pixels analysed; for flat areas with slopes of less than 5°, the lack of correlation may be due to the fact that these areas are usually characterised by a strong anthropic use (urban areas and intensive agriculture).

With regards to aspect, moving clockwise, a good correlation can be observed of the areas exposed from north-west to north-east with the EVI3 class and from east to south with EVI4. This could be due to the fact that, as the altitude increases, the thermophilic species tend to colonise the warmer slopes.

Effect analysis and validation

The results of Eq. 4 in the study area show that VSAM cover 18.62% of the total area and are distributed mainly along the Apennine ridge (Figure 2). An effect analysis has been performed to verify which LF have the greatest effect in determining the VSAM, re-calculating 4 new VSAM, each without one LF. Inside the 5 generated VSAM (VSAM, VSAM except slope, VSAM except aspect, VSAM except altitude, VSAM except CLC) and inside the whole study area, the EVI performance have been analysed with the work data (10th-25th June) (Table 6).

These results were then validated with a second EVI dataset related to the period just preceding that used in the study (May 25th-10th June: validation value) (Table 7). From the analysis of the trends, it can be observed how in both cases the EVI values tend to be higher inside the VSAM than in the rest of the study area (Tables 6 and 7). CLC, with both study and validation data, is the LF with the greatest influence on EVI variations. This can be observed from the lowering of the mean and median values in the VSAM where Corine classes have been taken into account. The LF with the lowest influence is slope. However, even if only slightly, the values of the mean and median in the VSAM without

Table 3. Distribution of protected areas types on a national level (data source: official list of natural protected areas, 6th update 2010, Ministerial Decree of 27 April 2010) (Italian Regulation, 2010).

PA type	No.	Surface (ha)	Relative frequency of the surface occupied by PA	Percentage on national territory
National park	24	1,465,681.01	0.46	4.86
Marine protected areas	27	0	0.00	0.00
Nature state reserve	147	122,775.90	0.04	0.41
Other national protected areas	3	0	0.00	0.00
Regional parks	134	1,294,655.87	0.41	4.30
Nature regional reserve	365	230,240.21	0.07	0.76
Other regional protected areas	171	50,237.72	0.02	0.17
Total	871	3,163,590.71	1	10.50

PA, protected area.

Table 4. Performance of the 4 classes enhanced vegetation index inside study area.

EVI class	EVI variation range	No. cells	Percentage of the whole study area
1	0-0.25	61,415	4.76
2	0.25-0.50	696,944	54.07
3	0.50-0.75	517,266	40.13
4	0.75-1	13,416	1.04
Total	1,289,041	100	

EVI, enhanced vegetation index.

slope are lower than those of the VSAM, so it can be concluded that all the considered LF have a positive influence on VSAM. Therefore, with this methodology, even if there are some LF which are less significant, this would lead, at worst, to missing some of the areas and not identifying false suitability.

Relationship between view of morphological terrain features and protected area within the study area

Around 35% of the VSAM are located within PA (Figure 2). The spatial pattern of the EVI were then re-analysed within VSAM, differentiating the results between inside PA and outside PA. Observing the variations in EVI variability, it appears that the areas contained in EVIhv increased from 83.3% (outside PA) to 88.8% (inside PA). This confirms that there is a greater concentration of EVIhv in VSAM that are located within the PA (Table 8). An immediate way to test the strength of the dependence between EVIhv and PA is the Chi-Square (χ^2) Pearson's test. There are numerous non-parametric frequency validation tests that have found wide application, like the Kolmogorov-Smirnov test (Smirnov, 1948) and Fisher's exact test (Fisher, 1922), but it was decided to proceed using the Pearson's χ^2 test (Plackett, 1983) for the nominal nature of the variables involved and for its reliability even in the presence of a limited number of samples (Greenwood, 1996). The result is χ^2=779.36, with odds ratio of 1.59. These values show a good association between EVIhv and PA.

Discussion and conclusions

The study has developed an easily reproducible, inexpensive method (using only freely downloadable georeferenced data) for rapid identification of VSAM. The effect analysis has shown that all the LF considered have a positive influence on determining such vegetation suitable areas, also validated using EVI data from a different period (May). An interesting development could be to use, inside VSAM, other suitability indexes based on the intersection or the weighted sum of other LF in order to grade the assignment of value in the analysed area. As with all studies developed on a regional scale, the VSAM represent those areas where further investigation in greater detail and with other indicators is required. In all cases, VSAM can support decision making by identifying those zones where existing PA should be extended or new ones created. The study showed that there is a good association between EVIhv and PA. Therefore, we can conclude that PA play an active role in protecting vegetation and do not only serve a purely formal function, despite different results obtained outside the European context (Fuller *et al.,* 2010). This hypothesis has contributed to the evaluation of the protective capacity of PA. Where a good monitoring modality has been implemented, it has been possible to identify mistakes and to find the best management strategies (Verburg *et al.,* 2006; McDonald and Boucher, 2011). This result, if inserted in a broader context of the analysis of other vegetation indexes, the monitoring of species, and the

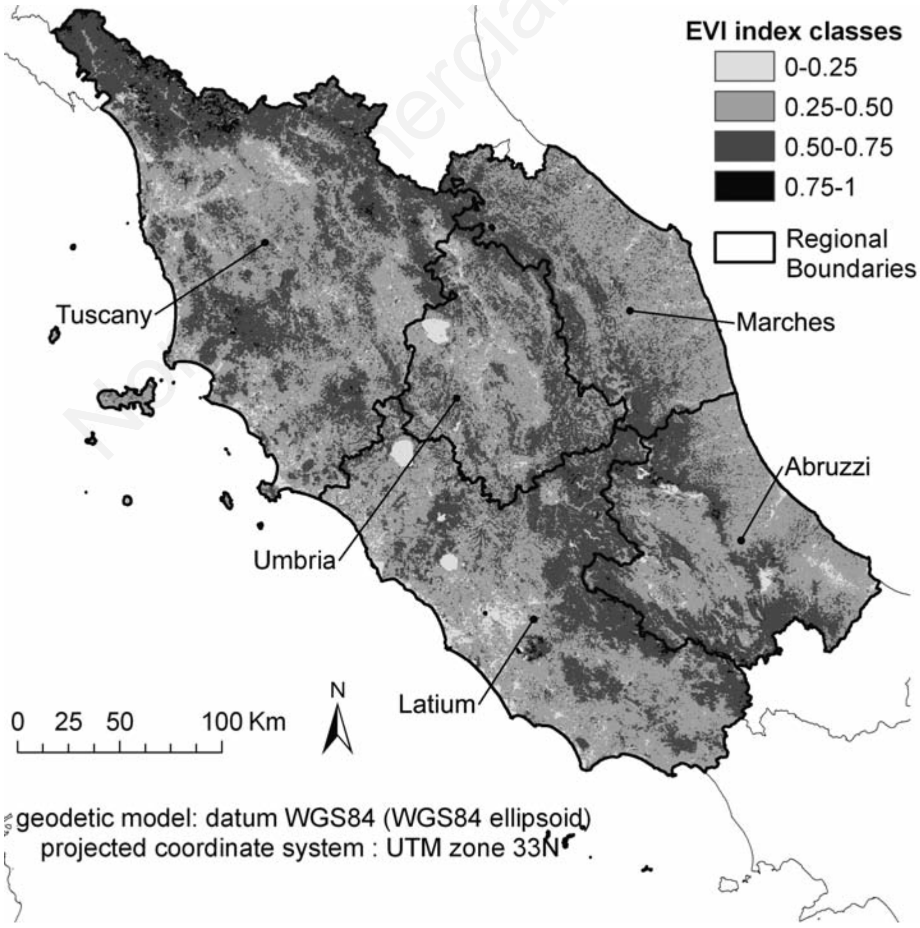

Figure 1. Boundaries of study area with information about enhanced vegetation index (EVI) variability.

Table 5. Example of frequency ratio calculation table for enhanced vegetation index class 3.

$i=3$: x_i=Evi3 (0.5-0.75) CLC code ($k=1$; j:1…40)	x_i	$A = \frac{x_i * 100}{X_i}$	y_{kj}	$B = \frac{y_{kj} * 100}{Y}$	FR
111	36	0.0070	4201	0.3259	0.0214
112	1535	0.2968	34,085	2.6442	0.1122
121	203	0.0392	11,164	0.8661	0.0453
122	21	0.0041	825	0.0640	0.0634
123	0	0.0000	208	0.0161	0.0000
124	8	0.0015	861	0.0668	0.0232
131	267	0.0516	2389	0.1853	0.0000
132	0	0.0000	28	0.0022	0.0000
133	11	0.0021	264	0.0205	0.1038
141	52	0.0101	611	0.0474	0.2121
142	232	0.0449	1401	0.1087	0.4127
211	48,967	9.4665	350,361	27.1800	0.3483
212	458	0.0885	2632	0.2042	0.4336
213	3	0.0006	75	0.0058	0.0997
221	1597	0.3087	16,774	1.3013	0.2373
222	3417	0.6606	6346	0.4923	1.3418
223	7416	1.4337	47,323	3.6712	0.3905
231	9961	1.9257	21,250	1.6485	1.1681
241	388	0.0750	4175	0.3239	0.2316
242	20,248	3.9144	126,083	9.7811	0.4002
243	41,480	8.0191	88,157	6.8390	1.1726
244	12	0.0023	12	0.0009	2.4920
311	292,992	56.6424	366,906	28.4635	1.9900
312	4295	0.8303	14,996	1.1633	0.7137
313	19,952	3.8572	32,979	2.5584	1.5077
321	20,650	3.9921	48,642	3.7735	1.0579
322	66	0.0128	777	0.0603	0.2117
323	3553	0.6869	11,092	0.8605	0.7982
324	35,615	6.8852	64,306	4.9887	1.3802
331	127	0.0246	1308	0.1015	0.2420
332	400	0.0773	3269	0.2536	0.3049
333	2891	0.5589	13,918	1.0797	0.5176
334	4	0.0008	4	0.0003	2.4920
411	177	0.0342	1207	0.0936	0.3654
421	11	0.0021	169	0.0131	0.1622
422	0	0.0000	20	0.0016	0.0000
511	91	0.0176	1128	0.0875	0.2010
512	125	0.0242	8027	0.6227	0.0388
521	0	0.0000	548	0.0425	0.0000
523	5	0.0010	520	0.0403	0.0240
Total	517,047	100%	1,289,041	100%	-
Altitude ($k=2$; j:1…8)					
0-200 m	60,234	11.649	391,924	30.404	0.3832
200-400 m	102,068	19.740	342,994	26.608	0.7419
400-600 m	111,245	21.515	201,550	15.635	1.3761
600-800 m	86,365	16.703	123,572	9.586	1.7424
800-1000 m	65,060	12.583	87,215	6.765	1.8598
1000-1500 m	75,037	14.512	104,466	8.104	1.7908
1500-2000 m	16,946	3.277	32,903	2.552	1.2840
Over 2000 m	92	0.017	4417	0.342	0.0519
Total	517,047	100%	1,289,041	100%	-

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Table 5. Continued from previous page.

i=3: x_i=Evi3 (0.5-0.75) Aspect (k=3, j:1…9)	x_i	$A = \frac{x_i * 100}{X_i}$	y_{kj}	$B = \frac{y_{kj} * 100}{Y}$	FR
Flat	2017	0.390	25,511	1.979	0.1971
North	59,347	11.478	68,134	5.285	2.1716
North east	73,389	14.193	159,666	12.386	1.1459
East	69,329	13.408	159,889	12.403	1.0810
South east	61,798	11.952	155,223	12.041	0.9926
South	57,985	11.214	158,148	12.268	0.9141
South west	67,921	13.136	183,641	14.246	0.9221
West	66,335	12.829	170,017	13.189	0.9727
North west	58,926	11.396	142,460	11.051	1.0312
Total	517,047	100%	1,289,041	100%	-
Slope (k=4; j:1…7)					
0-5°	125,592	24.290	598,881	46.459	0.5228
6-10°	155,788	30.130	334,875	25.978	1.1598
11-15°	114,416	22.128	180,029	13.966	1.5845
16-20°	63,598	12.300	91,156	7.071	1.7394
21-25°	34,056	6.586	48,649	3.774	1.7452
26-30°	16,270	3.146	23,780	1.844	1.7057
Over 30°	7327	1.417	11,671	0.905	1.5651
Total	517,047	100%	1,289,041	100%	-

Evi, enhanced vegetation index; FR, frequency ratio; CLC, Corine Land Cover.

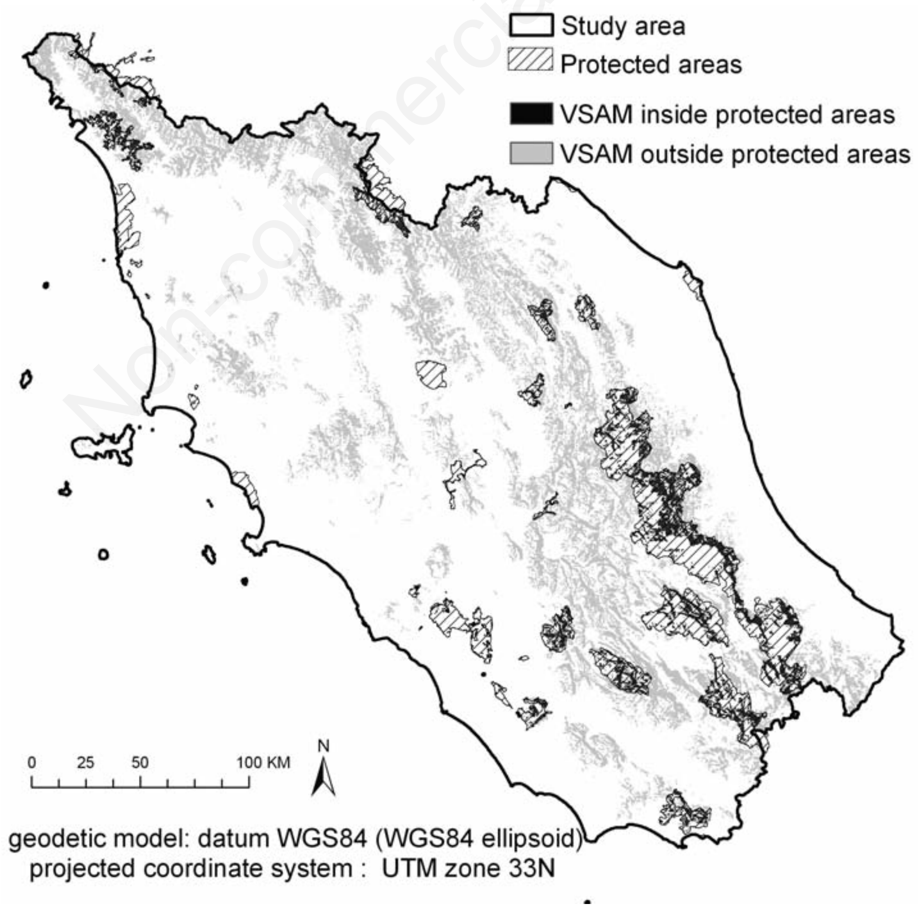

Figure 2. View of morphological terrain features (VSAM) and protected areas identification in the study area.

Table 6. Statistics concerning enhanced vegetation index (Evi_value) performance in view of morphological terrain features varying the degree of correlation between two georeferenced variables in the two periods: 10th-25th June and 25th May-10th June.

Evi_value	Minimum value	Maximum value	Range	Mean value	Standard deviation	Median
VSAM except alt.	0.00	1.00	1.00	0.5746	0.0971	0.5759
VSAM except slope	0.04	1.00	0.96	0.5880	0.0937	0.5898
VSAM except aspect	0.00	1.00	1.00	0.5862	0.0939	0.5871
VSAM except corine	0.00	1.00	1.00	0.5633	0.1054	0.5675
VSAM	0.06	1.00	0.94	0.5920	0.0930	0.5937
Study area	0.00	1.00	1.00	0.4690	0.1310	0.4690

Evi, enhanced vegetation index; VSAM, view of morphological terrain features; alt., altitude.

Table 7. Statistics concerning enhanced vegetation index (Evi_ validation value) performance in view of morphological terrain features varying the degree of correlation between two georeferenced variables in the two periods: 10th-25th June and 25th May-10th June.

Evi_validation value	Minimum value	Maximum value	Range	Mean value	Standard deviation	Median
VSAM except alt.	0.07	0.99	0.92	0.5904	0.0886	0.5911
VSAM except slope	0.01	0.99	0.98	0.6015	0.0874	0.6033
VSAM except aspect	0.07	0.99	0.92	0.5991	0.0881	0.6011
VSAM except corine	0.01	0.99	0.98	0.5785	0.1003	0.5828
VSAM	0.07	0.99	0.92	0.6039	0.0877	0.6060
Study area	0.00	0.99	0.99	0.5053	0.1211	0.5121

Evi, enhanced vegetation index; VSAM, view of morphological terrain features; alt., altitude.

Table 8. Strength of the correlation between higher values of enhanced vegetation index and protected areas: contingency table.

	Observed values				Expected values			
	EVIhv	EVI1_2	Total	%EVIhv	EVIhv	EVI1_2	Total	%EVIhv
Inside PA	37,276	4716	41,992	88.8	35,394.12	6597.88	41,992	84.3
Outside PA	156,242	31,358	187,600	83.3	158,123.88	29,476.12	187,600	84.3
Total	193,518	36,074	229,592	84.3	193,518	36,074	229,592	84.3
	χ^2=779.36				Odds ratio=1.59			

EVIhv, higher values of enhanced vegetation index.

examination of social and economic factors conditioning the performance of the different PA analysed, would provide in-depth evaluation of the PA and guide optimal PA management (Thackway *et al.,* 2007; Yapp *et al.,* 2010). The parks studied have, over time, finalised heterogeneous measures of protection, both internally and between different parks (Peano and Mausello 1997; Boatti and Papa, 1995). It would be interesting to re-apply the defined methodology by differentiating the results according to the measures implemented (Pressey *et al.,* 1996), to assess which have been the most effective.

The methodology developed is transferable to other contextes, is flexible and can be reproduced using other vegetation indicators and other land factors.

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