VERTICAL LANDSCAPE STRUCTURE OF THE SOUTHERN PART OF VIS ISLAND, CROATIA

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Abstract
The paper presents some basic features of vertical landscape structure of the southern part of Vis Island, Croatia. Its aim is the determination of geocomplex types with a certain degree of stability and resistance to external influences, and confirmation or rejection of hypothesis that with the application of appropriate methods, the spatial relation between geocomplex types as well as the identification of specific dominant/stable and vulnerable/labile geocomplex types can be precisely determined. The results should serve as the basis for estimation of current status and future trends in the development of geocomplex types as well as the environmental changes.

Key words: vertical landscape structure, geocomplex types, geocomplexes, Adriatic, Vis Island

VERTIKALNA POKRAJINSKA STRUKTURA JUŽNEGA DELA OTOKA VIS, HRVAŠKA

Izvleček
V prispevku je predstavljena vertikalna pokrajinska struktura južnega dela otoka Vis, Hrvaška. Njegov namen je določitev tipov geokompleksov z določeno stopnjo stabilnosti in odpornosti proti zunanjim vplivom. Avtorji poskušajo potrditi ali zavrniti hipotezo, da je možno z uporabo ustreznih metod natančneje določiti prostorske odnose med tipi geokompleksov ter poiskati specifične dominantne/stabilne tipe geokompleksov. Rezultati se lahko uporabijo za ugotavljanje obstoječega statusa in prihodnjih trendov razvoja tipov geokompleksov in okoljskih sprememb.

Ključne besede: vertikalna struktura površja, tipi geokompleksov, geokompleksi, Jadran, Vis

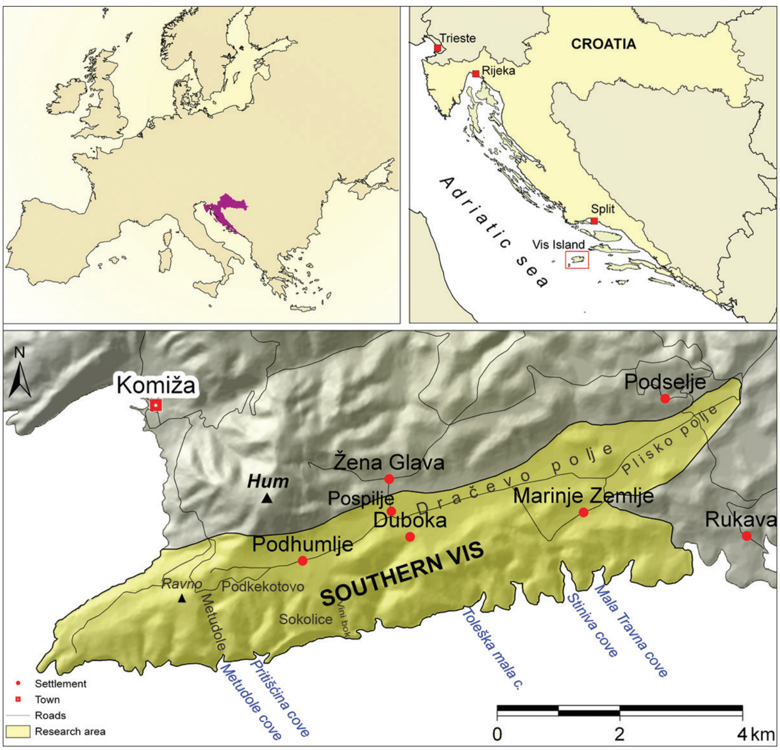
I. INTRODUCTION

In landscape element investigations, hierarchical approaches to classification are often used (Zonneveld, 1989). By measuring and analysing, based on pre-selected criteria, it is possible to identify homogeneous landscape elements to a greater or lesser extent (depending on the scale). The criteria are represented by different quantitative or qualitative environmental variables (geological, geomorphological, climatological, pedological and vegetational features as well as the agricultural/urban/transportation features of land use and the historical-geographical characteristics of the study environment), that will correspond to the demanding geoinformatic criteria in the further analysis (Forman and Godron, 1986; Zonneveld, 1989; Culotta and Barbera, 2010).

Karst systems all over the world are extremely fragile and susceptible to all kinds of external shocks that cause irreversible changes (Ford and Williams, 2007). Considering internal abiotic and biotic differences, karst areas of the Adriatic islands present a mosaic of different landscapes, which is particularly expressed in the area of Vis Island.

Investigated area includes the southern part of Vis Island (20.86 km²) (Figure 1) and it has been selected because of its exceptional bio/geodiversity of the natural environment.

Figure 1: Geographical position of investigated area
Slika 1: Geografski položaj preučevanega območja



Studied area can be divided in two morphostructurally distinctive parts: northern part dominated by poljes, and southern part which represents limestone mountainous area without significant recent agricultural production and almost unpopulated.

During the historical development and even today, geographical isolation of Vis Island has affected its socio-economic development. Demographic aging and depopulation, especially in the 20th century (Nejašmić and Mišetić, 2006) influenced the changes in landscape of the island (intensifying the process of vegetational succession and dry stonewalls degradation).

In this research, vertical landscape structure of landscape units (geocomplex types) was analysed. Landscape types have been determined on the basis of their abiotic (lithological and geomorphological features) and biotic elements (natural and cultivated vegetation), taking in consideration the human impact during the previous time (field cultures on cultivated land and in urbanised areas).

By using GIS tools, overlapping of three parameter layers related to abiotic and biotic features (lithology, slope inclination and vegetation types), 2556 basic units (geocomplexes) have been obtained. By generalization according to the similarity principle of the component features, 132 geocomplex types have been determined (2556 individual geocomplexes classified into 132 types). These types represent generalized homogeneous spatial units which remained basis to all further analyses.

In the next stage of investigation, vertical structure features have been determined by the relation between geocomponents (lithological structure, vegetation types and slope inclination) and analysed for each geocomplex type separately.

The final goal of this research is the confirmation or rejection of the hypothesis that by the application of the above mentioned procedures, it is possible to precisely determine the spatial relations between the geocomplex types as well as the existence of specific dominant/stable and vulnerable/labile geocomplex types. The results should serve as the basis for estimation of the current status and future trends of geocomplex types development as well as environmental change in general, in positive or negative direction, which can be applied in future planning and protection of the investigated area.

2. RESEARCH METHODS

For the analysis of the vertical structure of the landscape, three parameters were used: lithology, vegetation and slope inclination. Each parameter consists of several classes (slope – 5 classes, vegetation – 10 and geology – 5), and each class consists of elements of different sizes, which are present at various locations within study area.

By the overlapping of the parameters, new synthetic elements (geocomplexes), containing common attributes of parameters, were obtained. Due to a large number of elements (2556 combinations within parameters) and in order to manipulate data easily, in new overlapped layer the following actions were done:

- connecting of elements with identical attributes (132 synthetic classes (geocomplex types) were obtained), and

- reclassification (numeric value/code was added to the attributes within overlapped layer, e.g., to the 'Lower Cretaceous limestones/garrigue-macchia/12°–32°' geocomplex type value/code 33 was added).

Since at the landscape level the vertical structure cannot be displayed spatially, horizontal structure (spatial distribution of geocomplex types) served as a basis for analysis. That enabled the comparison and determination of hierarchy of connectivity strength of complete landscape. Connectivity strength index was used to determine the correlation between pairs of vertical structure elements (e.g., lithology – vegetation, lithology – slope, slope – vegetation) and served as an indicator of stability/instability of the parameters relationship within geocomplexes.

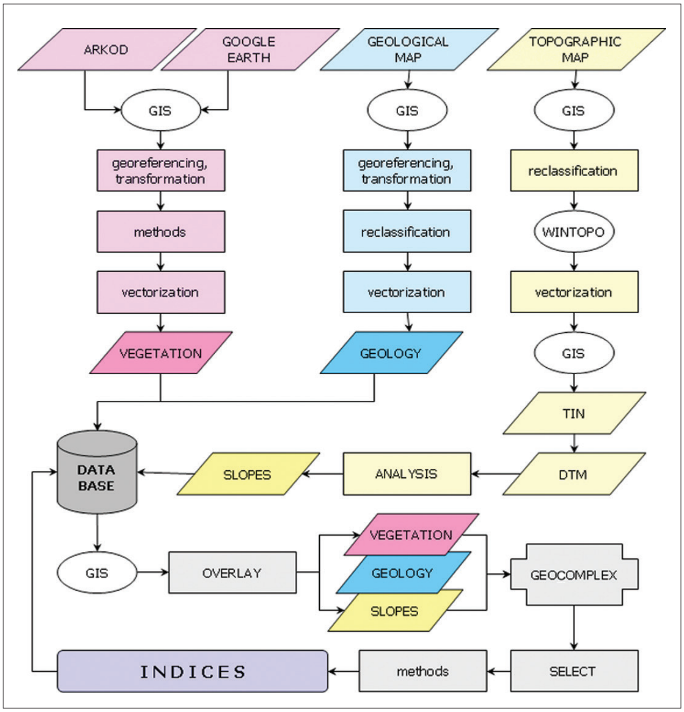
In most studies dealing with landscape, the vertical structure is ignored (and consequently, horizontal structure is preferred; Haines-Young and Chopping, 1996; Gustafson, 1998; McGarigal and McComb, 1999; Turner et al., 2001; Botequilha Leitão and Ahern, 2002; Botequilha Leitão et al., 2006; Johnson and Patil, 2007). Only few researches (Bezkowska, 1986; Kurnatowska, 1998; Richling, 1992; Kozłowska et al., 2006) are dealing with this issue which is of extreme importance because it allows determination of connection between parameters in a specific location (e.g., impact of slope inclination on vegetation distribution).

Slope inclination parameter was derived from a digital elevation model (DEM), which was created using semi-automatic and manual vectorization of contour lines of topographic maps (scale 1 : 25,000). WinTopo (tool for raster vectorization; WinTopo, 2012; Taie et al., 2011; Dharmaraj, 2005) was used for vectorization and this process consisted of several steps: (1) colours sampling, (2) noise removal, (3) skeletisation – Zhang Suen algorithm was used, (4) detection of edges, (5) connection of vector lines and (6) converting contour lines to shapefile. Attribute values (altitude) were added to converted layer. To obtain continuous surface with a series of z-values, contour lines were interpolated using triangulation irregular network (TIN) method (Mitas and Mitasova, 1999; Webster and Oliver, 2001; Isenburg et al., 2006; Jordan, 2007). Vector terrain model was produced and converted to raster for easier calculation of slope, exposition and elevation. GIS software calculates the slope inclination by using 3 x 3-squares method and calculates the maximum rate of altitude change of the central cell to the neighbouring cells (Burrough and McDonnell, 1998). Spatial resolution of the raster model was determined by cartographical rule method (Hengl, 2006), and was 12.5 meters.

Vegetation was manually vectorized (based on analysis of ARKOD, 2012, orthophoto maps in scale 1 : 5,000). According to species composition, ten vegetation classes were determined. During process of vectorization special attention was paid to the topological relations between classes (in order to avoid problems when overlapping with other parameters).

Geology layer was vectorized using Basic geological map (scale 1 : 100,000; Borović et al., 1977). Analogue map was scanned, georeferenced (using projection transformation with 10 reference points), colours were reclassified and coordinates were transformed.

Figure 2: Methodological scheme
Slika 2: Metodološka shema



3. GEOLOGICAL FEATURES

Structurally, Vis Island represents an anticline. The anticline core is formed of clastic sediments with gypsum and anhydrite in association with pyroclasts, as well as spilites and the diabases of Upper Ladinian – Upper Norian age, while the limbs are formed of carbonate sediments (limestones and dolomites) of Cretaceous age (Borović et al., 1977).

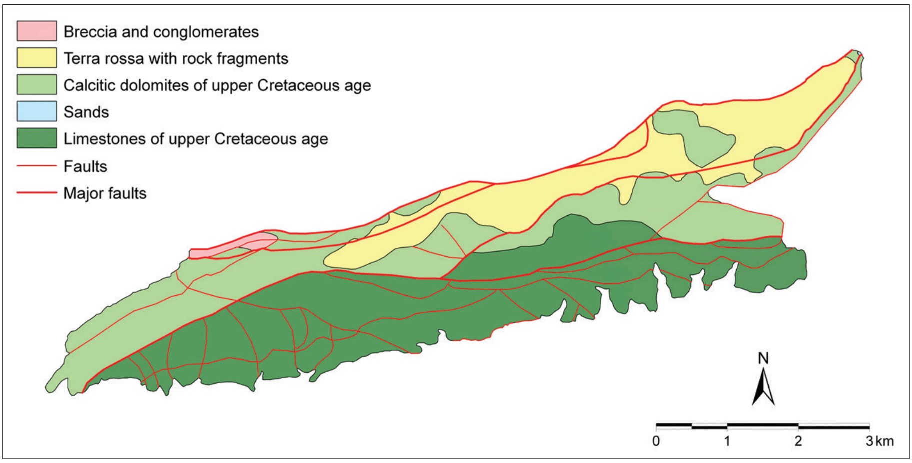
According to the hydrogeological properties, Terzić (2004) distinguishes several basic groups of rocks:

- Neocomian dolomites with low permeability and porosity covering relatively narrow zone around waterproof clastics and magmatites of Komiža Cove (the contact between these two units is tectonic) (Borović et al., 1977);
- carbonate rocks with medium permeability and cracking-dissolution porosity, calcareous dolomites, limestones of Cenomanian-Turonian age, limestones and dolomitic limestones of Berriasian age with marls and marly layers, and limestones of Aptian-Albian age which form the largest part of the area (Borović et al., 1977). They are partly karstified and porous enough to allow relatively rapid infiltration of rainwater into the ground;

- carbonate rocks of high permeability and cracking-dissolution porosity – white limestones of Senonian age, partly rudist limestones of Turonian age and karstified limestones of Cenomanian-Turonian age. Retention of the water in these fractured and karstified rocks is very limited, depending on the location;
- Quaternary rocks and sediments of alternating properties, interseed and cracking porosity – aeolian sands, terra rossa, colluvium breccias and conglomerates.

Geological mapping of the investigated area was conducted by Terzić (2004), but the authors made GIS analysis and calculated total areas (surfaces) for each lithological unit. Investigated area is formed of limestones (9.51 km², abbr. LUC) and calcitic dolomites of the Upper Cretaceous age (6.89 km², abbr. CD), while terra rossa with rock fragments (4.28 km², abbr. TRRF), breccias and conglomerates (0.18 km², abbr. BC) and sand (0.02 km², abbr. S) of the Quaternary age (Figure 3) can be found on the surface.

Figure 3: Geological map of the southern part of Vis Island (according to Terzić, 2004)
Slika 3: Geološka karta južnega dela otoka Vis (po Terzić, 2004)



4. GEOMORPHOLOGICAL FEATURES

Southern part of Vis island is dominated by altitudes up to 200 meters above sea level (Figure 4). Limestone mountain of Hum (587 m) dominates the northwestern part of the study area, while the negative relief forms (poljes) are formed on dolomites, mostly along the faults. The slope of southern coast is dissected by gullies and dry valleys.

Slope inclinations mostly reflect morphostructural relief features of the southern part of Vis Island. Five categories have been allocated. The largest part, 48.8% (10.191 km²), belongs to the category of 12 to 32 degrees, followed by inclinations of the category 5 to 12 degrees with 27.3% (5.698 km²), and inclinations of the category 2 to 5 degrees with the representation of 13.4% (2.785 km²). Slopes with inclinations higher than 20 degrees cover 9.1% (1.9 km²) of the observed area, while the smallest part belongs to the inclinations higher than 32 degrees with 1.4% (0.286 km²). Denudational processes become very active on the slopes steeper than 12 degrees (including the activation or increase of erosional processes, attrition and mass wasting).

Denudational processes are characteristic for the slopes over 12 degrees and are more intensive on the slopes more exposed to the sunshine during the day/year (S, SE, SW

Figure 4: The hypsometric map of the study area
Slika 4: Hipsometrična karta preučevanega območja

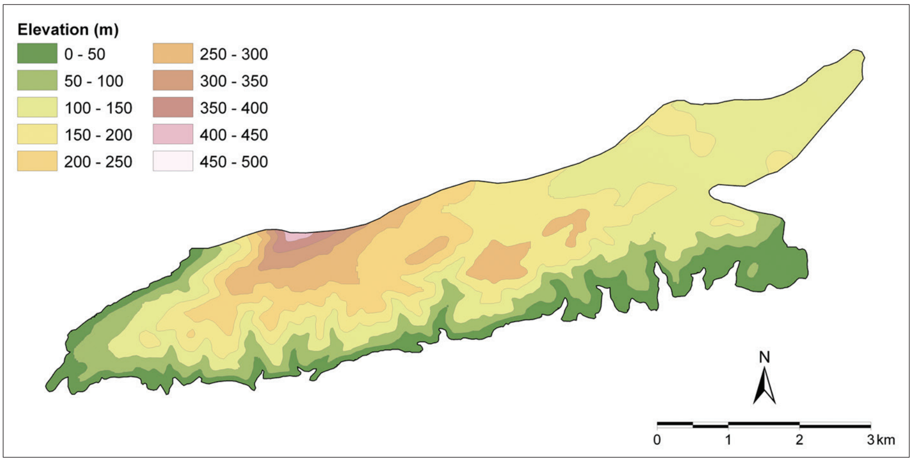
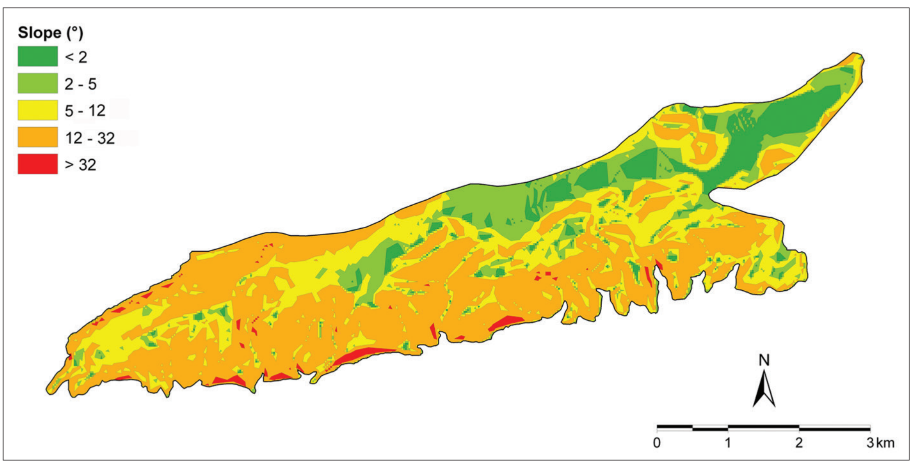
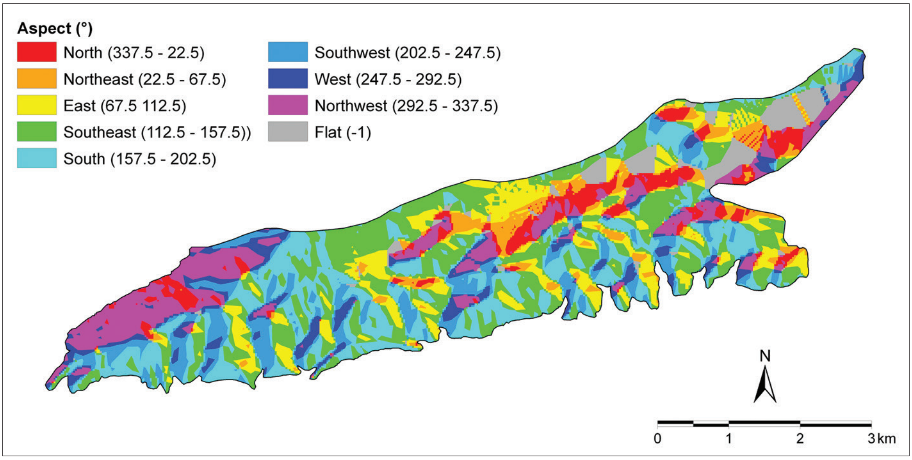


Figure 5: Slope inclination map of the study area
Slika 5: Karta naklonov površja preučevanega območja



expositions) because of the modification of solar radiation influences. That means increased temperature amplitudes which cause stronger mechanical weathering of the rock mass and soil drought (especially in summer) which have negative influence on vegetation cover.

Figure 6: Slope aspect of the study area
Slika 6: Karta ekspozicij površja na preučevanem območju



5. VEGETATION FEATURES

Abiotic features of ecosystem along with the anthropogenic influence in the past and nowadays, have influenced the composition and distribution of characteristic vegetation species and associations of the southern part of Vis Island. The largest part of the area (78.3%) is covered by homogeneous or mixed areals of associations of evergreen forests, macchia, garrigue and bare rock with sparse grass vegetation. Very significant terraced agricultural areas in the past are nowadays in different overgrowth stages, along with the natural vegetation cover and form a mosaic structure in the largest part of the investigated area. It mainly refers to *Quercus ilex* forests, which have been, due to the long history of human presence on Vis Island, significantly changed (reclamation, fires and other negative factors).

Forest communities of the southern part of Vis Island can be classified into stenomediterranean vegetational zone of evergreen forests (*Querco ilicis-Pinetum halepensis*; Loisel, 1971), eumediterranean vegetation zone of evergreen forests (*Myrtle-Quercetum ilicis*; Trinajstić, 1985) and hemimediterranean vegetational zone of evergreen-deciduous forests (*Ostryo-Quercetum ilicis*; Trinajstić, 1985).

Aleppo pine forests with larger or smaller proportion of holm oak (*Querco ilicis-Pinetum halepensis*; Loisel, 1971) within the area with xerothermal climate, occupy microclimatically more humid habitats. Forest and holm oak macchia with myrtle (*Myrto-Quercetum ilicis*; Trinajstić, 1985) is the most thermophilic association, developed in areas with favourable ecological conditions, which primarily relate to the temperature range during winter (average minimum of the coldest month between 6 and 8 ºC) and sufficient precipitation (average around 1000 mm per year, with a maximum in the colder part of the year). In higher areas, where the conditions are colder and more humid, forests of holm oak and hop hornbeam (*Ostryo-Quercetum ilicis*) are widespread.

During the historical-geographical development, degradation of autochthonous forests occurred because of the excessive and irrational logging and grazing, often in areas where, due to drought and temperature, significant soil retention and vegetation regrowth was not possible. Destructive fires (spontaneous or caused intentionally to obtain new areas for cultivation of crops; Gams, 1991) need to be added to above mentioned factors. The degradation degree depended on the terrain morphology, soil characteristics and accessibility. The most degraded areas were located around the settlements on the upper parts of slopes surrounding poljes, where the original forests have almost completely disappeared due to logging and overexploitation. Nowadays, forest degradation is reduced to a minimum.

Macchia formed by forest degradation remained preserved (dense and almost completely impassable) in more isolated areas, often alternating with the holm oak or Aleppo pine forests.

Garrigue (further degradation stage) was dominantly created under influence of anthropogenic impact (grazing, logging and fires) or by natural progression of the former rocky pastures, in the areas with shallow soil and exposed to strong insolation and drought in summer. On the largest part of the area, garrigue is in association with other vegetation types, e.g., on abandoned agricultural land (mostly former vineyards) and is in association with the further degradation stage, which includes eumediterranean, stenomediterranean and rocky pastures. Today, large garrigue areas are mixed with holm oak macchia, or overgrown by Aleppo pine forests. In some areas, garrigue remains in the same degradation stage due to the unfavourable abiotic habitat conditions (e.g., very shallow and stony soil).

Rocky and bare ground areas prevail on the southern coastal slopes exposed to the wind influence (sirocco). On such surfaces, scarce shrub and grass vegetation are mostly present. Shrub vegetation occurs sporadically, mainly in less exposed areas (gullies), where the small part of soil remained, so these areas occasionally look like garrigue. Rarely and individually, Aleppo pine trees or smaller groups of other tree species occur.

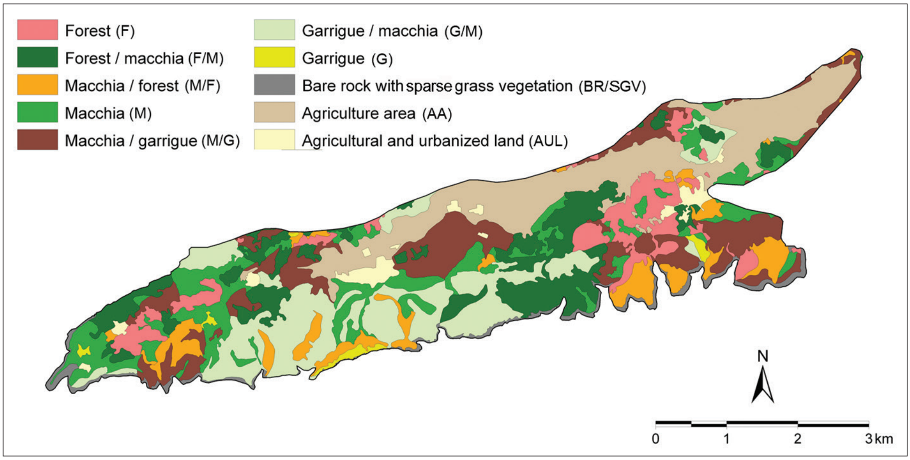
Still active agricultural areas are mostly in poljes and valleys near the settlements. The most extensive are in the Dračevo and Plisko polje and other smaller poljes, representing the mosaics of different crops, mostly vineyards. Abandoned agricultural lands are present almost everywhere. These areas, once under vineyards and orchards, are found mainly on terraces built on steeper slopes in whole investigated area.

By analysing satellite images of the study area (ARKOD, 2012), different vegetation areas (natural or anthropologically modified) have been allocated. Ten types of vegetation cover have been established (including the cultivated agricultural and agricultural/urbanized land categories) which occur homogeneous or in different interrelated combinations (Figure 7):

- forest (abbr. F);
- combination of forest and macchia (as in Figure 7 and elsewhere in text higher proportion of forest, abbr. F/M);

- combination of macchia and forest (higher proportion of macchia, abbr. M/F);
- macchia (abbr. M);
- combination of macchia and garrigue (higher proportion of macchia, abbr. M/G);
- combination of garrigue and macchia (higher proportion of garrigue, abbr. G/M);
- garrigue (abbr. G);
- bare rock and sparse grass vegetation (abbr. BR/SGV);
- cultivated agricultural land in poljes (abbr. AA);
- cultivated areas on the slopes and urbanized land (abbr. AUL).

Figure 7: Vegetation map of the southern part of Vis Island
Slika 7: Vegetacijska karta južnega dela otoka Vis



6. VERTICAL LANDSCAPE STRUCTURE

Vertical landscape structure analysis represents a method by which it is possible to determine relations between geocomponents contained in each geocomplex type (Kurnatowska, 1998) and can be expressed as connectivity strength index (W). This index is based on the relation between real surfaces with specific combinations of geocomponent features and theoretical, maximum surface on which these combinations can exist. Geocomponents analysed in this research include lithological characteristics, slope inclination and vegetation characteristics.

Determination of interaction features between geocomponents within each geocomplex type (vertical structure) is essential for understanding of dominance and stability within geoecosystem. Some combinations of geocomponents appear more frequently and cover larger areas (indicating a greater stability and resistance of geoecosystem to external influences), while some appear rarely or not appear at all (low stability degree and high sensitivity; Richling, 1992; Kurnatowska, 1998). Apart from frequencies, there are some other factors that can be used as indicators of stability/instability. These factors are mostly of anthropogenic nature (Geri et al., 2010; Bogaert et al., 2011). Some authors emphasized that landscape structure showing anthropogenic effects is characterized by fragmented natural land cover, simple patch geometry, and dominant proportions of anthropogenic geocomplexes. Landscape transformations associated with anthropogenic activities lead to a disintegration of natural geocomplex types and to a reinforcement of anthropogenic ones (Bogaert et al., 2011). This is the case of many geocomplex types of Vis Island (observed by terrain investigation and digital orthophoto maps analysis).

Based on the criteria of vertical structure connectivity index (and considering the anthropogenic influence too), the hierarchy of geocomplex types of different stability/instability and dominance/sensitivity features has been established. It served as the prerequisite of the final synthetic approach for the explanation of landscape features. Analysed combinations of geocomponent pairs include: vegetation/lithology, vegetation/slope inclination and slope inclination/lithology. Their connectivity indices were calculated according to the following terms:

1. $W = Pvl/Pl$, when $Pl < Pv$
   $W = Pvl/Pv$, when $Pv < Pl$
2. $W = Pvi/Pi$, when $Pi < Pv$
   $W = Pvi/Pv$, when $Pv < Pi$
3. $W = Pil/Pi$, when $Pl < Pi$
   $W = Pil/Pl$, when $Pi < Pl$

Where:
W = connectivity strength index
Pvl = area (surface) with specific vegetation (v) and lithology (l)
Pvi = area (surface) with specific vegetation type (v) and slope inclination (i)
Pil = area (surface) with specific slope inclination (i) and lithology (l)
Pv = total area with a specific type of vegetation (v)
Pl = total area with a specific type of lithology (l)
Pi = total area with a specific type of slope inclination (i)

The connectivity strength index reaches the maximum (W = 1.0) in areas where only certain combinations of geocomponent categories appear, while its minimum values (W = 0) are characteristic for areas where some combinations never appear together. High values of connectivity strength index indicate strong and stable relations that have a leading role in the landscape structure. The results of the analysis are grouped into several categories: a very strong relationship (W = 0.8–1.0); a strong relationship (W = 0.6–0.8); moderately strong relationship (W = 0.4–0.6); weak relationship (W = 0.2–0.4) and a very weak relationship (W = 0.0–0.2).

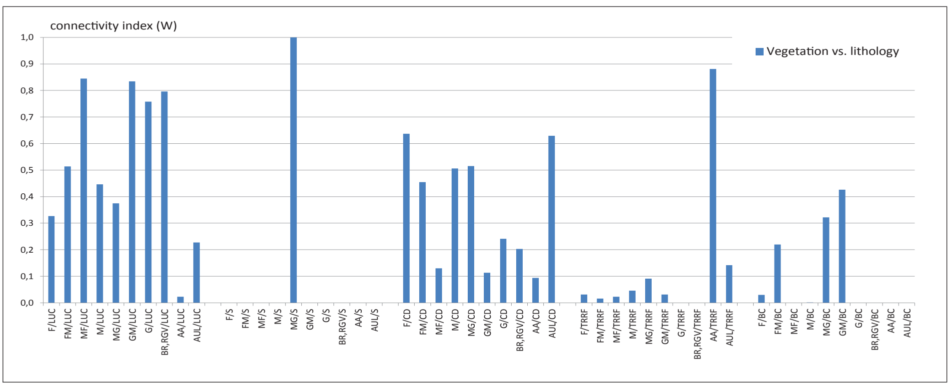
6.1. The relationship between vegetation cover and lithology

High and very high relationship (W = 0.6–1.0) is determined for following geocomponent pairs: MG-S (macchia and garrigue/Quaternary sands) (1.0), AA-TRRF (agricultural areas in poljes/terra rossa with rock fragments), MF-LUC (macchia and forest/Upper Cretaceous limestones), GM-LUC (garrigue and macchia/Upper Cretaceous limestones), BR/SGV-LUC (bare rock and sparse grass vegetation/Upper Cretaceous limestones), G-LUC (garrigue/Upper Cretaceous limestones), F-CD (forest/Upper Cretaceous calcitic dolomites) and AUL-CD (cultivated areas on the slopes and urbanized land/Upper Cretaceous calcitic dolomites; Table 1; Figure 8). Due to the fact that combinations of these geocomponents appear frequently and cover larger areas, we can assume that they indicate a greater stability and resistance of geoecosystem to external influences. This fact has been confirmed by some other investigations on other locations in Europe (Kurnatowska, 1998; Kozłowska et al., 2006).

Table 1: High and very high relationship of geocomponent pairs and associated geocomplex types (detailed explanation of geocomponent types numbers is in chapter 2)
Preglednica 1: Visoka in zelo visoka povezanost parov geokomponent in pripadajočih tipov geokompleksov (podrobnejša razlaga številk tipov geokomponent je v poglavju 2)

Pairs of geocomponents (vegetation cover/lithology)	Number of geocomplex types
MG-S (macchia and garrigue/Quaternary sands)	130, 131, 132
AA-TRRF (agricultural areas in poljes/terra rossa with rock fragments)	110, 111, 112, 113
MF-LUC (macchia and forest/Upper Cretaceous limestones)	18, 19, 20, 21, 22
GM-LUC (garrigue and macchia/Upper Cretaceous limestones)	33, 34, 35, 36, 37
BR/SGV-LUC (bare rock and sparse grass vegetation/Upper Cretaceous limestones)	43, 44, 45, 46, 47
G-LUC (garrigue/Upper Cretaceous limestones)	38, 39, 40, 41, 42
F-CD (forest/Upper Cretaceous calcitic dolomites)	53, 54, 55, 56
AUL-CD (cultivated areas on slopes and urbanized land/Upper Cretaceous calcitic dolomites)	57, 58, 59, 60

Figure 8: The strength of relationship (based on connectivity index) between vegetation cover and lithology
Slika 8: Stopnja povezanosti (na osnovi indeksa povezanosti) med rastlinskim pokrovom in kamninsko zgradbo



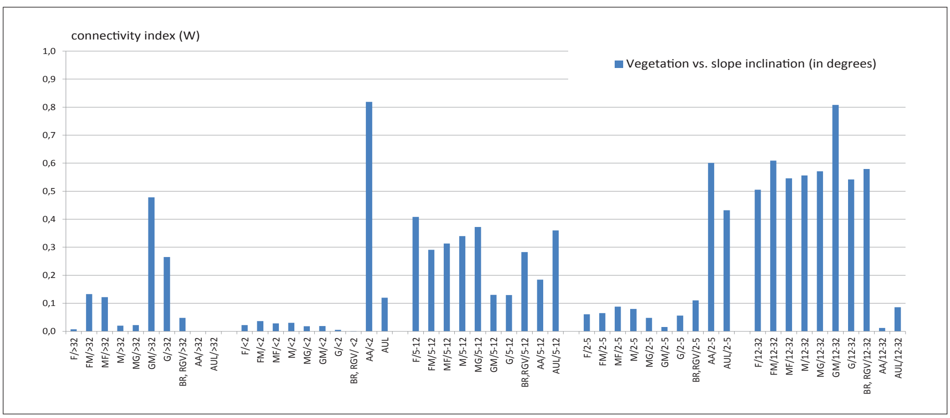
There is no relationship between the following geocomponent pairs: F (forest)-S (Quaternary sands), FM (forest and macchia)-S, MF (macchia and forest)-S, M (macchia)-S, GM (garrigue and macchia)-S, G (garrigue)-S, BR/SGV (bare rock and sparse rock vegetation)-S, AA (agricultural areas in poljes)-S, G-TRRF (terra rossa with rock fragments), BR/SGV-TRRF, MF-BC (breccias and conglomerates), G-BC, BR/SGV-BC, AA-BC, AUL (cultivated areas on slopes and urbanized land)-BC and M/BC. Very low relationship (W = 0.001–0.2) characterises following geocomponent pairs: FM-TRRF, AA-LUC, MF-TRRF, F-TRRF, F-BC, GM-TRRF, M-TRRF, MG-TRRF, AA-CD, GM-CD, MF-CD and AUL-TRRF (Figure 8). As we mentioned above, some combinations of geocomponents appear rarely or not appear at all, indicating basic inadequacy between certain kinds of vegetation cover and lithology, and thus, low stability degree and high sensitivity.

6.2. The relationship between vegetation cover and slope inclination

Some studies (e.g., Kurnatowska, 1998; Kozłowska et al., 2006) have shown clear links between vegetation cover and the type of morphodynamic surface (expressed through variations in the geomorphology of slopes). The majority of plant communities occur on a certain relief type and provide the natural boundaries for vegetation landscape units. Also, the different types of morphodynamic units are characterized by particular types of vegetation (Kozłowska et al., 2006).

High and very high relationship (W) is determined for following geocomponents pairs: AA (agricultural areas in poljes)/<2°, GM (garrigue and macchia)/12–32°, FM (forest and macchia)/12–32° and AA/2–5° (Figure 9). Pair AA/<2° includes geocomplex type No. 64; pair GM/12–32° types No. 33, 78 and 127; pair FM/12–32° types No. 1, 51 and 99; and pair AA/2–5° types No. 16, 62 and 112 (Figure 9).

Figure 9: The strength of relationship (based on connectivity index) between vegetation cover and slope inclination
Slika 9: Stopnja povezanosti (na osnovi indeksa povezanosti) med rastlinskim pokrovom in naklonom pobočij



There is no relationship between following geocomponent pairs: AA/>32° and AUL/>32°. Very low connection (W = 0.001–0.2) is determined between following geocomponent pairs: BR-SGV (bare rock and sparse grass vegetation)/<2°, G (garrigue)/<2°, F (forest)/>32°, AA /12–32°, MG (macchia and garrigue)/<2°, GM/2–5°, M (macchia)/>32°, MG/>32°, F/<2°, GM/<2°, M/<2°, MF (macchia and forest)/<2°, FM /<2°, MG/2–5°, BR-SGV/>32°, G/2–5°, F/2–5°, FM/2–5°, M/2–5°, AUL/12–32°, MF/2–5°, BR-SGV/2–5°, AUL/<2°, MF/>32°, G/5–12°, GM/5–12°, FM/>32° and AA/5–12° (Figure 9).

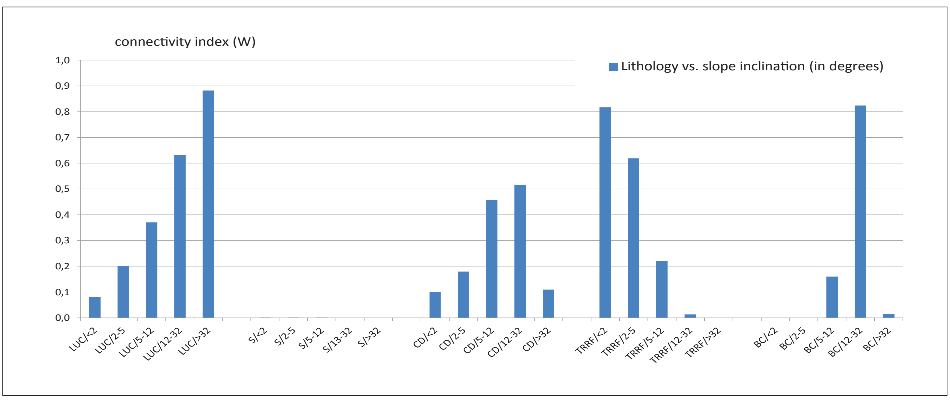
Based on above mentioned facts, we can conclude that certain types of vegetation cover appear more frequently on slopes of certain inclination. Example are crops that always occur on slopes with inclinations <2° or 2–5°. This is logical, because due to denudation processes, thicker soil layers could only be developed on slopes with low inclination. On steeper slopes (12–32°), due to more pronounced denudation processes, soil layer is thinner and consequently, only combinations of macchia and garrigue or forest and macchia appear.

6.3. The relationship between lithology and slope inclination

The nature and structural characteristics of the bedrock determine the hillslope morphology (Carson and Kirkby, 1972; Young, 1971; Parsons, 1988; Khanchoul and Altschul, 2008) and, consequently, characteristics of vegetation cover.

High and very high relationship (W) is determined for following geocomponent pairs (Figure 10): LUC (Upper Cretaceous limestones)/>32°, BC (breccias and conglomerates)/12–32°, TRRF (terra rossa with rock fragments)/<2°, LUC/12–32° and TRRF/2–5° (Figure 10). Pair LUC/>32° includes geocomplex types No. 4, 10, 22, 27, 32, 37, 42 and 47; pair BC/12–32° includes types No. 92, 93, 96 and 97; and pair TRRF/<2° includes types No. 102, 106, 107, 110, 114, 118, 122 and 126 (Figure 10).

Figure 10: The strength of relationship (based on connectivity index) between lithology and slope inclination
Slika 10: Stopnja povezanosti (na osnovi indeksa povezanosti) med kamninsko zgradbo in naklonom pobočij



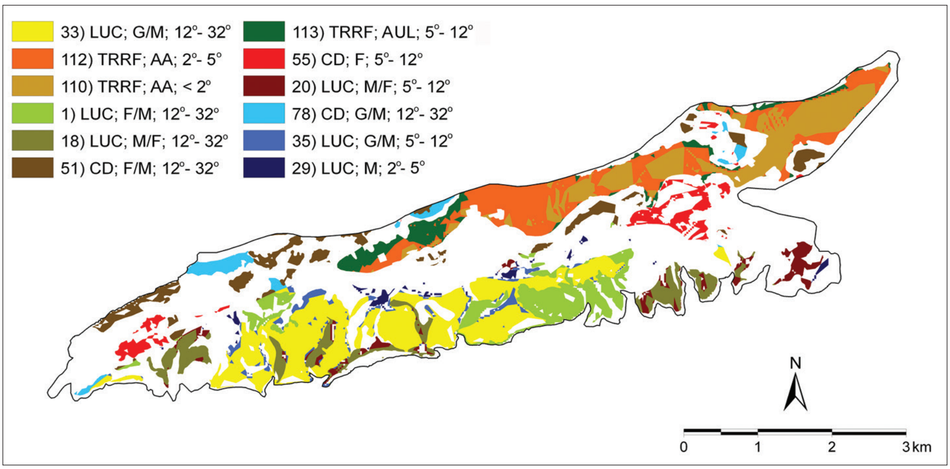
Minimal connection (0.0001–0.0003) is determined for following geocomponent pairs: S (Quaternary sands)/<2°, S/2–5° and S/5–12°; very low (0.01–0.2) for geocomponent pairs TRRF/12–32°, BC/>32°, LUC/<2°, CD/<2°, CD/>32°, BC/5–12° and CD/5–12°. There is no connection between pairs S/12–32°, S/>32°, TRRF/>32°, BC/<2° and BC/2–5° (Figure 10).

7. CONCLUSION

A detailed insight into the interrelation between the vertical landscape structure and the vertical connection of geocomponents of geocomplex types was provided by the comparative analysis and synthesis of vertical landscape structure parameters of the southern part of Vis Island. This approach allowed determination of the stability degree of each geocomplex type and the determination of the most stable and most dominant types, as well as the most unstable and the most sensitive ones.

Based on the strength of vertical connection of geocomponents, gained from connectivity index, twelve most stable and most dominant types (Figure 11) from all of 132 geocomplex types have been allocated.

Figure 11: Most stable and dominant geocomplex types in the investigated area (abbreviations are explained in text)
Slika 11: Najstabilnejši in dominantni tipi geokompleksov na preučevanem območju (okrajšave so pojasnjene v besedilu)



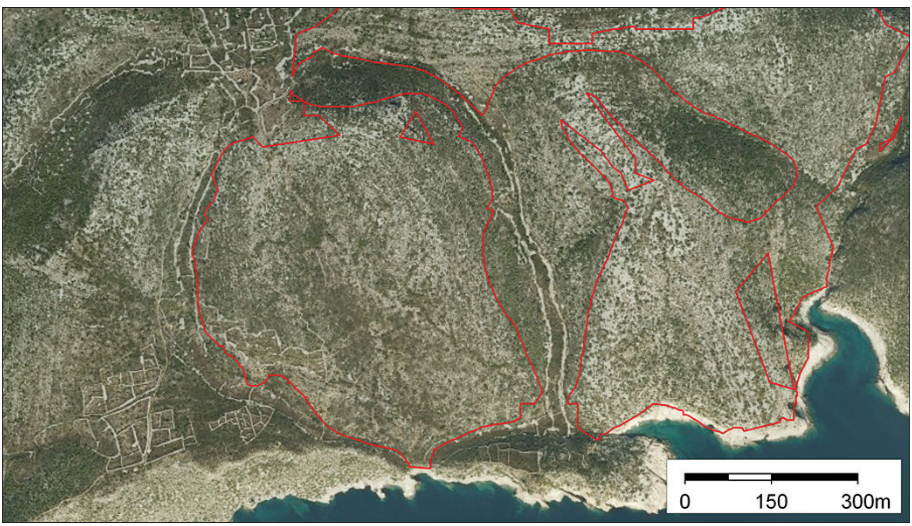
Some examples that have been further analysed during field investigations are shown here: geocomplex types No. 33 (Figures 11, 12), 112 (Figures 11, 12) and 110 (Figure 11).

The largest, most stable and most dominant geocomplex type (No. 33) prevails on large areas of the southern coastal slope. Considering the environmental factors, thin layer of soil has been developed in these areas. Elevation range is relatively large, ranging from 0 to 250 m, mostly on convex slope parts oriented towards south and southeast and, therefore, occasionally under significant wind (sirocco) and sea influence. There is a prevalence of garrigue association well adapted to habitat conditions, while macchia is present sporadically, in the microclimatically protected places, with a slightly thicker soil layer (e.g., gully bottoms).

Due to the relatively unfavourable physical-geographical conditions, these areas are uninhabited and human impact on the landscape is minimal. Expressed adaptive abilities (morpho-anatomic, subcell and physiological-biochemical adaptations to external conditions) of the existing vegetation and the absence of negative anthropogenic impact are the main reasons for preserving landscape balance. Because of the physical-geographical conditions, changes in ecosystems in terms of progressive succession of garrigue to macchia could not be expected to a significant extent.

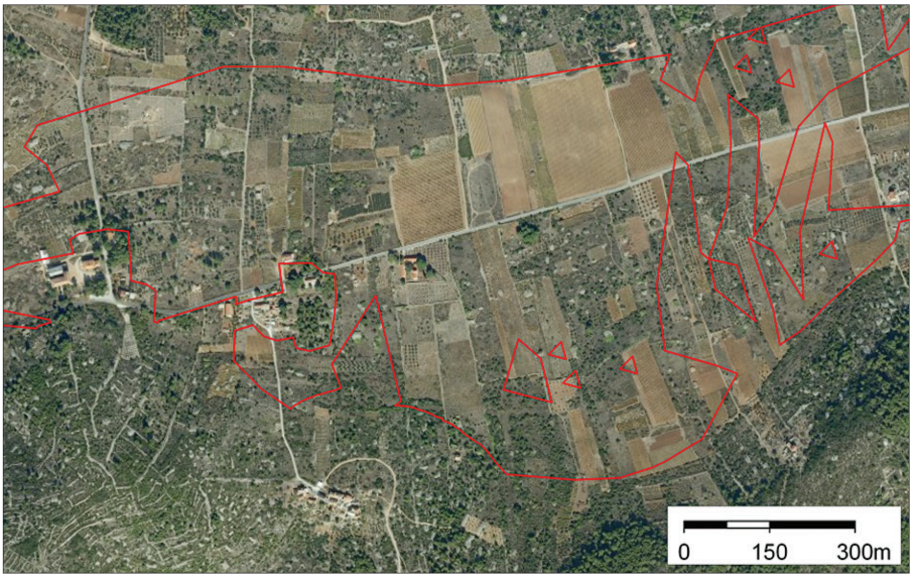
The second geocomplex type according to the size (No. 112) includes higher parts of Dračevo and Plisko polje, which have mainly anthropogenic soils with vineyards. There has been a long-term human impact on the natural landscape transformation, which partly reflects today's landscape appearance as well. Agriculture (especially viticulture) prevails and due to intensive agricultural use in the past these areas have not been urbanized. Based on the vertical structure indicators, as well as field researches, it can be concluded that there is a balance between geocomponents and anthropogenic impact. This means that the land use in the past respected the natural conditions, while nowadays large parts of the area are abandoned in terms of agricultural usage. It is left to natural process of renewal and succes-

Figure 12: Example of the part of the largest and dominant geocomplex type No. 33 (Sokolica–Vini bok–Duboka, south of Podhumlje) characterised by high connection between geocomponents (ARKOD, 2012)
Slika 12: Del največjega in dominantnega tipa geokompleksa št. 33 (Sokolica–Vini bok–Duboka; južno od Podhumlja) z značilno visoko stopnjo povezanosti med geokomponentami (ARKOD, 2012)



sion, which can further increase the stability of this geocomplex type. However, sometimes, it is not absolutely clear that the abandonment of agriculture increases the stability of system because natural factors (especially soil type) have a significant role in this process. This can be seen in areas where intensive soil erosion is present (e.g., soil erosion in flysch of Istria is still very strong after many decades; Zorn and Petan, 2008).

Figure 13: Dominant geocomplex type No. 112 located in western part of Dračevo polje (ARKOD, 2012)
Slika 13: Dominantni tip geokompleksa št. 12 v zahodnem delu Dračevskega polja (ARKOD, 2012)



Geocomplex type No. 110 is present in the lowest parts of Dračevo and Plisko polje. Height differences are small and the entire area is located at around 100 m above sea level. Anthropogenic soils prevail and because of the intensive agricultural use in the past and recent reduction of anthropogenic pressure, the area of this type is very similar to the type 112 by its characteristics.

For the most stable geocomplex types, a strong connection between vertical geocomponents (lithology, vegetation and slope inclination) is characteristic while indicating a high degree of internal cohesion (Kurnatowska, 1998; Kozłowska et al., 2006). This is of great importance because the internal cohesion directly affects the ecosystem resistance to negative external influences.

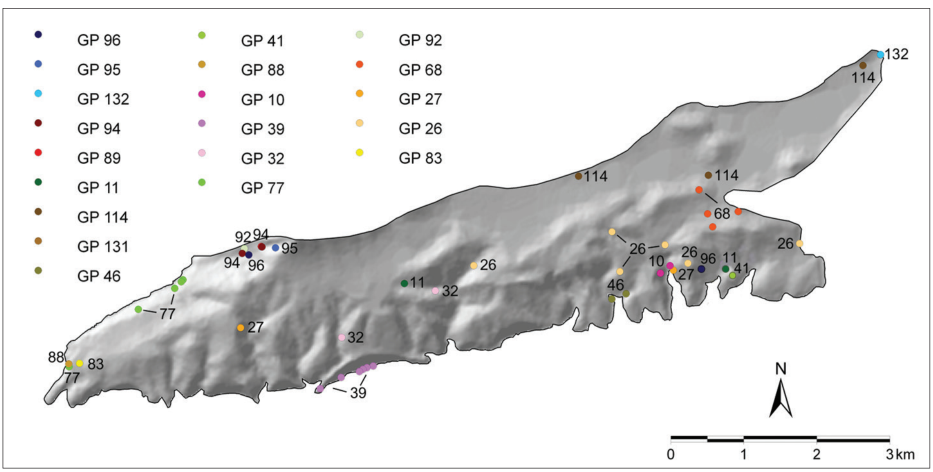
The allocation of geocomplex types with low stability and high sensitivity degree is very important, because it enables more efficient current and future protection of their geoecosystems. When the changes occur within these geocomplex types (due to the negative impact of natural and anthropogenic environmental factors), they are often irreversible and, if it comes to regeneration, a long period of recurrence time (in most cases, the system cannot return to previous state) is usually required. The reasons to that are mostly significant losses of pedological and/or vegetation cover.

By application of the comparative analysis and synthesis parameters of the vertical landscape structure (very weak vertical correlation of one or more geocomponent pairs), twenty most unstable and most endangered geocomplex types (Figure 14) have been determined. Several examples analysed in detail during the field research are shown in figures 15 and 16.

Parts of the geocomplex types No. 96, 11 and 41 (shown in Figure 15) are situated near Mala Travna cove on the south coast. The bedrock is Upper Cretaceous limestone, covered with a thin layer of terra rossa or lithosols. All three areas are located on the slopes of a gully which leads to cove, with a low altitude (50 m) and a large range of slope inclination (5–32°). They are exposed to the south, southwest and southeast, and therefore exposed to a strong negative sea and wind (sirocco) influence. Related to this, in these areas, continuous sediment erosion and denudation processes are present, along with the strong anthropogenic influence expressed through apartment building construction and infrastructure (roads).

Nowadays, maintenance of terraces has been abandoned, resulting in intensification of the mentioned geomorphological processes which strongly restrict natural succession of vegetation. All this enhances a continuous destabilization and increased vulnerability of this geocomplex types.

Figure 14: The most sensitive and endangered geocomplex types (GP 96 = MG – BC – 12–32°; GP 95 = MG – BK – >32°; GP 132 = MG – S – 2–5°; GP 94 = MG – BC – 12–32°; GP 89 = FM – BC – 5–12°; GP 11 = AUL – LUC – 12–32°; GP 114 = MF – TRRF – <2°; GP 131 = MG – S – <2°; GP 46 = BR/RGV – BC – <2°; GP 41 = BR/RGV – LUC – <2°; GP 88 = BR/RGV – CD – >32°; GP 10 = F – LUC – >32°; GP 39 = G – LUC – 2–5°; GP 32 = M – LUC – >32°; GP 77 = M – CD – >32°; GP 92 = F – BC – 5–12°; GP 68 = MF – CD – <2°; GP 27 = MG – LUC – >32°; GP 26 = MG – LUC – <2°; GP 83 = G – CD – 2–5°)
Slika 14: Najobčutljivejši in najbolj ogroženi tipi geokompleksov



Geocomplex type No. 27 (Figure 16) is located on the coastal part of Stiniva cove. It has been formed in Upper Cretaceous limestones covered with a thin layer of terra rossa and lithosols. Considering high inclination (12–32°) and the constant sea and wind influence, the existing soil layer is exposed to continuous denudation which does not allow the development of more dense vegetation cover.

These examples show that the main factors of influence on these geocomplex types were negative anthropogenic impacts (deforestation, construction, excessive agricultural use, etc.) and abiotic habitat conditions (expressed mainly through erosion and denudation processes). If taking in consideration, along with the mentioned impacts, their spatial dispersion and the pressure of the neighbouring, more stable and more dominant geocomplex types, we can expect that over time the existing vegetation will change and adjust to environmental conditions. As a result of these processes, it could come to the transformation of these geocomplex types into more stable ones, or, in the worst scenario, to a complete disappearance of vegetation cover and strong activation of erosion and denudation processes. According to some authors (Reice, 1994; Marston, 2010), consequences of these processes are not necessarily negative. Namely, the active erosion and denudation processes on the slopes in certain circumstances, could create positive conditions for recolonisation of species and increase landscape heterogeneity.

Landscape structure is exposed to continuous change due to various activities related to spatial planning and management. The landscape represents an interface between natural and social processes in the environment, while planning and decision-making related

Figure 15: Examples of the smallest and most sensitive geocomplex types (No. 96, 11 and 41) near Mala Travna cove (ARKOD, 2012)
Slika 15: Primer najmanjših in najobčutljivejših tipov geokompleksov (št. 96, 11 in 41) blizu zaliva Mala Travna (ARKOD, 2012)

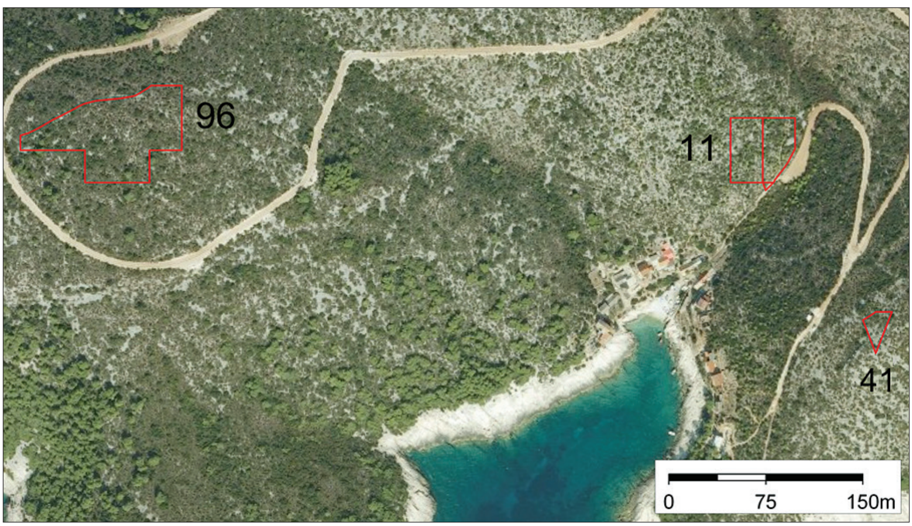
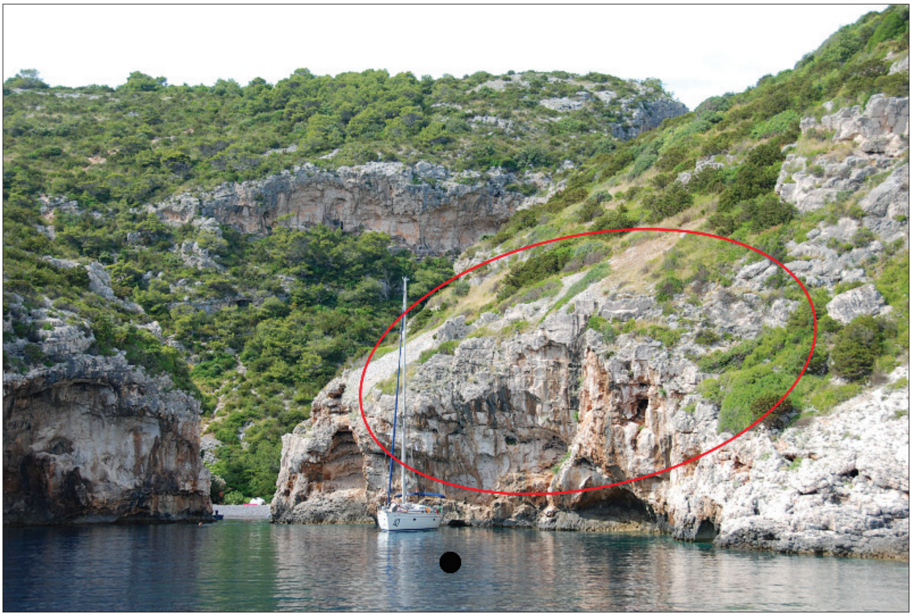


Figure 16: Part of geocomplex type No. 27 (Upper Cretaceous limestones – macchia/garrigue – >32°), Stiniva cove
Slika 16: Del tipa geokompleksa št. 27 (zgornjekredni apnenec – makija/gariga – >32°) v zalivu Stiniva



to sustainable development should certainly take in consideration the spatial relations of landscape elements (Turner, 1989). This is particularly important for karst areas, which are very sensitive to external influences due to their specific abiotic and biotic characteristics. Estimation of the negative anthropogenic impact on these areas is a difficult task. For that reason, there is a need for development of multidisciplinary methods and techniques, by which the changes in the environment of karst areas could be more efficiently determined (De Waele, 2009).

Natural balance disturbances have strong impact on geoecosystems and landscape as a whole; therefore many ecological processes depend on the current dynamics of abiotic and biotic elements, considering the anthropogenic influence as well. The nature of these relations is essential and often the result of periodic or episodic changes of landscape features, that consequently affects bio/geodiversity. Environmental management strategies should take into account these changes in the dynamics of landscape elements.

In the study area, a better understanding of characteristics of vertical landscape structure should allow more efficient detection of changes related to the natural landscape dynamic and anthropogenically caused disturbances, which can lead to transition of geocomplex types from the natural balance state to an imbalance state and to the increase of their vulnerability as well.

The primary task of this research was the establishment of appropriate methodology with an objective of exact analysis and synthesis of vertical landscape structure, which should improve the understanding of geoecological context of the current landscape state as well as the predictions of future development trends. Determination of the dominant, stable and resistant geocomplex types, and moreover the unstable, sensitive and non-resistant ones, could be a useful reference during the planning process and decision-making related to planning purposes and sustainable land-use in the southern part of Vis Island. This primarily refers to the preventing of excessive exploitation of natural resources (vegetation cover devastation, quarrying and mining activity), inappropriate planning in urbanized zones, industrial and transport infrastructure, inadequate agricultural use and environmental pollution.

(Translated by Mijo Župić)

References

ARKOD – Land parcel identification system. Ministry of Agriculture, Fisheries and Rural Development, Croatia. URL: http://www.arkod.hr (Cited 20. 2. 2012).

Bezkowska, G., 1986. Structure and types of geocomplexes in the central part of the Southern Poland Lowland. Acta Geographica Lodziensia, 54, pp. 1–130 (in Polish).

Bogaert, J., Sabas S. Barima, Y., Jian, J., Jiang, H., Bamba, I., Iyongo Waya Mongo, L., Mama, A., Nyssen, E., Dahdouh-Guebas, F., Koedam, N., 2011. A methodological framework to quantify anthropogenic effects on landscape patterns. In: Landscape ecology in Asian cultures. Ecological research monographs, 2. New York, pp. 141–167.

Borović, I., Marinčić, S., Majcen, Ž., Magaš, N., 1977. Basic geological map of Yugoslavia in scale 1 : 100,000, Geology of the Vis K 33–33, Jelsa K 33–34, Biševo K 33–45 sheets. Geological Research Institute Zagreb, Federal Geological Institute Belgrade (in Croatian). Belgrade.

Botequilha Leitão, A., Ahern, J., 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and urban planning, 59, pp. 65–93.

Botequilha Leitão, A., Miller, J. N., Ahern, J., McGarigal, K., 2006. Measuring landscapes. A planner's handbook. Washington, Island Press, 272 pp.

Burrough, P. A., 1986. Principles of geographical information systems for land resources assessment. Oxford, Clarendon Press, 193 pp.

Burrough, P. A., McDonnell, R. A., 1998. Principles of geographical information systems. Oxford University Press, 333 pp.

Carson, M. A., Kirkby, M. J., 1972. Hillslope form and process. Cambridge, Cambridge University Press, 484 pp.

Culotta, S., Barbera, G., 2010. Mapping traditional cultural landscapes in the Mediterranean area using a combined multidisciplinary approach: Method and application to Mount Etna (Sicily, Italy). Landscape and urban planning, 100, pp. 98–108.

De Waele, J., 2009. Evaluating disturbance on Mediterranean karst areas: The example of Sardinia (Italy). Environmental geology, 58, 2, pp. 239–255.

Dharmaraj, G., 2005. Algorithms for automatic vectorization of scanned maps. Master thesis. Calgary, University of Calgary, 148 pp. URL: http://www.ucalgary.ca/engo_webdocs/DM/05.20226.Girija-Dharmaraj.pdf (Cited 20. 2. 2012).

Flora Croatica Database, 2004. Department of Botany, Faculty of Science, University of Zagreb. Zagreb.

Ford, D., Williams, P., 2007. Karst hydrogeology and geomorphology. Chichester, John Wiley & Sons, 562 pp.

Forman, R. T. T., Godron, M., 1986. Landscape ecology. New York, John Wiley & Sons, 619 pp.

Gams, I., 1991. Systems of adapting the littoral Dinaric Karst to agrarian land use. Acta geographica, 31, pp. 5–106.

Geri, F., Amici, V., Rocchini, D., 2010. Human activity impact on the heterogeneity of a Mediterranean landscape. Applied geography, 30, 3, pp. 370–379.

Gustafson, E. J., 1998. Quantifying landscape spatial pattern: What is the state of the art? Ecosystems, 1, 2, pp. 143–156.

Haines-Young, R., Chopping, M., 1996. Quantifying landscape structure: A review of landscape indices and their application to forested landscapes. Progress in physical geography, 20, 4, pp. 418–445.

Hengl, T., 2006. Finding the right pixel size. Computers & geosciences, 32, 9, pp. 1283–1298.

Hooper, D. U., Chapin, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J. H., Lodge, D. M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A. J., Vandermeer, J., Wardle, D. A., 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. Ecological monographs, 75, 1, pp. 3–35.

Isenburg, M., Liu, Y., Shewchuk, J., Snoeyink, J., Thirion, T., 2006. Generating raster DEM from mass points via TIN streaming. GIScience'06 Conference proceedings. Münster.

Jordan, G., 2007. Adaptive smoothing of valleys in DEMs using TIN interpolation from ridgeline elevations: An application to morphotectonic aspect analysis. Computers & geosciences, 33, 4, pp. 573–585.

Johnson, G. D., Patil, G. P., 2007. Landscape pattern analysis for assessing ecosystem condition. Environmental and ecological statistics, 1. New York, Springer, 130 pp.

Khanchoul, K., Altschul, R., 2008. The relationship between lithology and slope morphology in the Tucson Mountains, Arizona. Anuário do Instituto de Geociências, 31, 1, pp. 30–42.

Kozłowska, A., Rączkowska, Z., Zagajewski, B., 2006. Links between vegetation and morphodynamics of high-mountain slopes in the Tatra Mountains. Geographia Polonica, 79, 1, pp. 27–39.

Kurnatowska, A., 1998. GIS for the analysis of structure and change in mountain environments. In: Craglia, M. and Onsrud, H. (Eds.) Geographic information research: Transatlantic perspectives. London, Taylor & Francis, pp. 227–256.

Loisel, R., 1971. Séries de végétations propres en Provence aux massifs des Maures et de l'Estérel. Bulletin de la Société Botanique de France, 118, 3–4, pp. 203–236.

Marston, R. A., 2010. Geomorphology and vegetation on hillslopes: Interactions, dependencies, and feedback loops. Geomorphology, 116, 3–4, pp. 206–217.

Nejašmić, I., Mišetić, R., 2006. Depopulation of Vis Island, Croatia. Geoadria, 11, 2, pp. 283–309.

McGarigal, K., McComb, W. C., 1999. Forest fragmentation effects on breeding birds in the Oregon Coast Range. In: Rochelle, J. A., Lehman, L. A., Wisniewski, J. (Eds.). Forest fragmentation: Wildlife and management implications. Leiden, pp. 223–246.

Mitas, L., Mitasova, H., 1999. Spatial interpolation. In: Geographical information systems: Principles, techniques, management and applications. GeoInformation International. Chicester. URL: http://www.colorado.edu/geography/class_homepages/geog_4203_s08/readings/mitas_mitasova_1999_2005.pdf (Cited 20. 2. 2012).

Parsons, A. J., 1988. Hillslope form. London, Taylor & Francis, 228 pp.

Reice, S. R., 1994. Nonequilibrium determinants of biological community structure. American scientist, 82, 5, pp. 424–435.

Richling, A., 1992. Comprehensive physical geography. Wydawnictwo Naukowe PWN (in Polish). Warszawa, 376 pp.

Taie, S. A., ElDeeb, H. E., Atiya, D. M., 2011. A new model for automatic raster-to-vector conversion. International journal of engineering and technology, 3, 3, pp. 182–190.

Terzić, J., 2004. Hydrogeological relations on karstified islands – the island of Vis case study. Rudarsko-geološko-naftni zbornik, 16, pp. 47–58 (in Croatian).

Trinajstić, I., 1985. Fitogeografsko-sintaksonomski pregled vazdazelene šumske vegetacije razreda *Quercetea ilicis* Br.-Bl. u jadranskom primorju Jugoslavije. Poljoprivreda i šumarstvo, 31, pp. 71–96 (in Croatian).

Turner, M. G., 1989. Landscape ecology: The effect of pattern on process. Annual review of ecology and systematics, 20, pp. 171–197.

Turner, M. G., Gardner, R. H., O'Neill, R. V., 2001. Landscape ecology in theory and practice. New York, Springer, 401 pp.

Webster, R., Oliver, M., 2001. Geostatistics for environmental scientists. Chichester, John Wiley & Sons, 271 pp.

WinTopo raster to vector converter. URL: http://www.wintopo.com (Cited 23. 01. 2012).

Young, A., 1971. Slope profile analysis: The system of best units. In: D. Brunsden (Ed.). Slopes form and process. Institute of British Geographers Special Publication, 3. London, pp. 1–13.

Zonneveld, I. S., 1989. The land unit – a fundamental concept in landscape ecology, and its applications. Landscape ecology, 3, 2, pp. 67–86.

Zorn, M., Petan, S., 2008. Interrill soil erosion on flysch soil under different types of land use in Slovenian Istria. XXIVth Conference of the Danubian countries on the hydrological forecasting and hydrological bases of water management. IOP Conference Series: Earth and environmental science, 4. Bristol. URL: http://iopscience.iop.org/1755-1315/4/1/012045/pdf/1755-1315_4_1_012045.pdf (Cited 20. 2. 2012).

VERTIKALNA POKRAJINSKA STRUKTURA JUŽNEGA DELA OTOKA VIS, HRVAŠKA

Povzetek

Kraški sistemi po vsem svetu so izjemno občutljivi in dovzetni za vse vrste zunanjih šokov, ki povzročajo nepopravljive spremembe (Ford, Williams, 2007). Glede na notranje abiotske in biotske razlike predstavlja kraško površje jadranskih otokov mozaik različnih pokrajin, kar je še posebej izrazito na otoku Vis. Preučevano območje zajema južni del otoka (20,86 km^2) in je bilo izbrano zaradi izjemne bio/geodiverzitete naravnega okolja.

Analiza vertikalne strukture pokrajine temelji na uporabi treh parametrov: kamninske zgradbe (litologije), vegetacije in naklona pobočij. Vsak parameter je razdeljen na več razredov (naklon – 5, rastje – 10 in litologija – 5), in vsak razred je sestavljen iz elementov različnih velikosti, ki so prisotni na različnih lokacijah znotraj preučevanega območja.

S prekrivanjem parametrov smo pridobili nove sintezne elemente (geokomplekse), ki vsebujejo skupne značilnosti parametrov. Zaradi velikega števila elementov (2556 kombinacij znotraj parametrov) in zaradi enostavnejšega obvladovanja podatkov smo na novi podatkovni plasti naredili naslednje: (1) povezali smo elemente z enakimi značilnostmi in dobili 132 združenih razredov (tipov geokompleksov) in (2) preklasificirali novo dobljene elemente (atributom v tej plasti smo pripisali številčne vrednosti/kode, npr. geokompleks 'spodnjekredni apnenec/gariga/makija/12–32°' je dobil novo vrednost/kodo 33).

Ker na pokrajinskem nivoju vertikalne strukture ni mogoče prostorsko prikazati, smo kot podlago za analizo uporabili horizontalno strukturo (prostorsko razporeditev tipov geokompleksov). To je omogočilo primerjavo in določitev hierarhije intenzivnosti povezanosti v celotni pokrajini. Za določitev korelacij med pari vertikalnih strukturnih elementov (npr. litologija – vegetacija, litologija – naklon, naklon – vegetacija) smo uporabili indeks povezanosti (angl. connectivity strength index) in ta nam je služil kot pokazatelj stabilnosti/nestabilnosti odnosov med parametri znotraj geokompleksov.

Večina študij ne upošteva vertikalne pokrajinske strukture (in posledično daje prednost horizontalni strukturi: Haines-Young, Chopping, 1996; Gustafson, 1998; McGarigal, McComb, 1999; Turner in sod., 2001; Botequilha Leitão, Ahern, 2002; Botequilha Leitão in sod., 2006; Johnson, Patil, 2007). Le nekaj raziskav (Bezkowska, 1986; Kurnatowska, 1998; Richling, 1992; Kozłowska in sod., 2006) se je lotilo tega vprašanja, čeprav je izjemno pomembno, saj omogoča ugotavljanje povezanosti med parametri na določenem mestu (npr. vpliv naklona na značilnosti vegetacije).

Analiza vertikalne pokrajinske strukture je metoda, s katero je mogoče določiti razmerja med geokomponentami v vsakem tipu geokompleksa (Kurnatowska, 1998) in ta lahko izrazimo z indeksom povezanosti (W). Ta indeks temelji na razmerju med dejanskimi površinami s specifičnimi kombinacijami značilnosti geokompleksa in teoretično, največjo možno površino, na kateri lahko ta kombinacija obstaja. V tej raziskavi smo analizirali litološke in vegetacijske značilnosti ter naklon pobočij.

Ugotavljanje interakcij med značilnostmi geokomponent v vsakem tipu geokompleksov (vertikalna struktura) je ključnega pomena za razumevanje dominantnosti in stabilnosti znotraj geoekosistema. Nekatere kombinacije geokomponent se pojavljajo pogosteje in na večjih površinah (to kaže na večjo stabilnost in odpornost geoekosistema na zunanje vplive), medtem ko se nekatere kombinacije pojavljajo redko ali sploh ne (nizka stopnja stabilnosti in visoka občutljivost; Richling, 1992; Kurnatowska, 1998). Poleg pogostnosti pojavljanja obstajajo še nekateri drugi dejavniki, ki jih je moč uporabiti kot kazalnike stabilnosti/nestabilnosti. Ti dejavniki so večinoma antropogenega izvora (Geri in sod., 2010; Bogaert in sod., 2011). Nekateri avtorji so poudarjali, da so za pokrajinsko strukturo, ki kaže učinke antropogenih vplivov, značilni razdrobljenost naravne vegetacije, enostavni geometrični vzorci in prevladujoči deleži antropogenih geokompleksov. Pokrajinske spremembe, povezane s človekovimi dejavnostmi, vodijo k razpadanju naravnih tipov geokompleksov in krepitvi antropogenih (Bogaert in sod., 2011). To velja tudi za številne tipe geokompleksov na otoku Vis (ugotovljeno med terenskim preučevanjem in z analizo digitalnih ortofotokart).

Na podlagi indeksa povezanosti vertikalne strukture (in ob upoštevanju antropogenega vpliva) je bila določena hierarhija tipov geokompleksov z različno stopnjo stabilnosti/nestabilnosti ter dominantnosti/občutljivosti. To smo uporabili kot izhodišče za končni sintezni pristop k pojasnjevanju pokrajinskih značilnosti. Analizirane kombinacije parov geokomponent so: vegetacija/litologija, vegetacija/naklon površja in naklon/litologija. Za te pare smo izračunali indekse povezanosti. Ta doseže največjo vrednost (W = 1,0) na območjih, kjer se pojavijo le nekatere kombinacije kategorij geokomponent, njegova minimalna vrednost (W = 0) pa je značilna za območja, kjer se nekatere kombinacije nikoli ne pojavljajo skupaj. Visoke vrednosti indeksa povezanosti kažejo močne in stabilne odnose, ki imajo vodilno vlogo v pokrajinski strukturi. Rezultate analize smo razvrstili v več kategorij: zelo močna povezanost (W = 0,8–1,0), močna povezanost (W = 0,6–0,8), srednje močna povezanost (W = 0,4–0,6), šibka povezanost (W = 0,2–0,4) in zelo šibka povezanost (W = 0,0–0,2).

Glede na jakost vertikalne povezanosti geokomponent, pridobljeno iz indeksa povezanosti, smo opredelili in lokalizirali dvanajst najbolj stabilnih in dominantnih tipov geokompleksov izmed vseh 132 ugotovljenih. Nekatere teh primerov smo v nadaljevanju še dodatno preučili na terenu in so predstavljeni v prispevku. Zelo pomembna je tudi določitev tipov geokompleksov z nizko stopnjo stabilnosti in visoko stopnjo občutljivosti, saj omogoča učinkovitejše sedanje in prihodnje varovanje teh geoekosistemov. Ko pride do sprememb v teh tipih geokompleksov (zaradi negativnega vpliva naravnih ali antropogenih okoljskih dejavnikov), so pogosto nepopravljive, če pa gre za regeneracijo, je zanjo običajno potrebno zelo veliko časa, v večini primerov pa se sistem ne more vrniti v prejšnje stanje. Najpogostejša razloga sta občutnejša izguba prsti in/ali vegetacijske odeje.

S primerjalno analizo in sinteznimi parametri vertikalne pokrajinske strukture (zelo šibka vertikalna korelacija enega ali več parov geokomponent) smo določili tudi 20 najbolj nestabilnih in najbolj ogroženih tipov geokompleksov. Ti primeri kažejo, da so glavni dejavniki vpliva nanje negativni antropogeni vplivi (krčenje gozda, gradnja, pretirana kmetijska raba idr.) in abiotske razmere v habitatu (najpogosteje se kažejo kot erozijski in denudacijski procesi). Če hkrati z omenjenimi negativnimi vplivi upoštevamo še njihovo prostorsko razpršenost in pritiske sosednjih, stabilnejših in bolj dominantnih tipov geokompleksov, lahko pričakujemo, da se bo obstoječa vegetacija s časom spremenila in prilagodila okoljskim razmeram. Kot posledica teh procesov lahko pride do preoblikovanja teh tipov geokompleksov v stabilnejše, v najslabšem primeru pa tudi do popolnega izginotja rastlinske odeje in močnega aktiviranja erozijskih in denudacijskih procesov. Po mnenju nekaterih avtorjev (Reice, 1994; Marston, 2010) posledice teh procesov niso nujno negativne. Aktivni erozijski in denudacijski procesi na pobočjih lahko v določenih okoliščinah ustvarijo ugodne pogoje za ponovno naselitev vrst in povečanje pokrajinske raznolikosti.

Naravne motnje ravnovesja močno vplivajo na geoekosisteme in pokrajino v celoti, zato je veliko okoljskih procesov odvisnih od trenutne dinamike abiotskih in biotskih elementov, vključno z antropogenimi vplivi. Narava teh odnosov je ključnega pomena in pogosto posledica periodičnih ali občasnih sprememb pokrajinskih značilnosti, ki vplivajo na bio/geodiverziteto. Strategije upravljanja z okoljem bi morale upoštevati te spremembe v dinamiki pokrajinskih elementov.

Na preučevanem območju bi boljše razumevanje vertikalne pokrajinske strukture omogočalo učinkovitejše odkrivanje sprememb, povezanih z naravno pokrajinsko dinamiko, in s človekovimi posegi povezane motnje, ki lahko pripeljejo do prehoda tipa geokompleksa iz naravnega uravnoteženega stanja v neravnovesno stanje in s tem do povečanja njegove ranljivosti.

Glavni namen te raziskave je bil vzpostavitev ustrezne metodologije za natančno analizo in sintezo vertikalne pokrajinske strukture, s čimer bi izboljšali naše razumevanje geoekološkega konteksta trenutnega stanja pokrajine kot tudi možnosti napovedovanja prihodnjih trendov razvoja. Določitev dominantnih, stabilnih in odpornih tipov geokompleksov je lahko, poleg ugotavljanja nestabilnih, občutljivih in neodpornih tipov, zelo koristno v procesu prostorskega načrtovanja za trajnostno rabo prostora v južnem delu otoka Vis. Predvsem se to nanaša na preprečevanje prekomernega izkoriščanja naravnih virov (uničevanje rastlinske odeje, pridobivanje kamna in rudarstvo), neustrezno načrtovanje v urbaniziranih območjih, gradnjo industrijske in prometne infrastrukture, neustrezno kmetijsko rabo ter onesnaževanje okolja.

(Prevedel Karel Natek)