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Space Models of Oak Vegetation Dynamics in Protected Zone, Bulgaria

KEYWORDS
Quercus frainetto-cerris ecosystem, space distribution model, dynamics, satellite data, GIS

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ABSTRACT *The information for spatial and temporal variation in the distribution of forest ecosystems is essential for determining tendencies in alteration of the forest area size and structure under the conditions of climate changes and existing management of the forest. The paper presents spatial models of xerothermic oak ecosystems distribution in SCI "Zapadna Stara Planina i Predbalkan" in 1977, 1992 and 2007, as a result of the conducted simulation on the base of the studied forest vegetation reflective characteristics. The modification of occupied areas by altitude, exposure, slope, soil type and bedrocks has been analyzed. The climatic fluctuations are characterized by deviations of de Marton index. The ecological status of communities is determined by calculating of state vector and the output factors having the greatest weight to the established state are obtained. The comparative spatial analysis of ecological status presented in the paper and the dynamics of the forest vegetation is the result from the application of a combined investigation method – processing of satellites, aerial photo (orthophoto), GPS and overground data in the using of aerospace technologies and modeling in GIS environment. The created spatial models can be used in the monitoring of the forest ecosystems, for conservation of the forest flora and vegetation, for sustainable management of the forest areas, as well as and for investigation of xerothermic oak forest vegetation in other regions and protected zones.*

Introduction

The investigation of spatial and temporal state of the forest ecosystems will contribute for a better understanding the structure and the functional processes, occurring in them, and will make possible forecasting of future changes in the spatial variation of the woodlands (Manes et all., 1997). The joint use of aerospace technologies and modeling in GIS environment has been demonstrated in research works of many authors (Carleerand et al., 2004; Kuzera K. et al. 2005, Chen et Fraser 2009, Spruce et al. 2011, Saudani et al. 2012, Danilova et al., 2012 and others). Similar combined approach allowed a comparative spatial analysis of the ecological status and the dynamics of forest vegetation by years to be accomplish. The obtained spatial models give possibility not only for tracking changes in the areas and habitats of forest vegetation types, but also for monitoring the alteration in the structure of these areas according to the elements of the relief on the background of climatic factors variations, i.e. for a prediction of the common modification in the structure and distribution of forest vegetation in a particular geographical region (Roumenina et al. 2003; Lyubenova et al. 2002, 2011 and 2012 and others).

Although the use of remotely sensed data in forestry, forest ecology and monitoring of forest health has a long history (Reich and Price 1999, Bergen et al. 2000, Olson and Weber, 2000 and others) the application of these methods is not uniform. The application of aerospace information technologies is connected with the use of different type aerospace data with different spectral, spatial and temporal resolution. Due to the diverse conditions of aerospace data registration, there are some differences in the spectral reflectance characteristics on the same forest vegetation type. Therefore, the verification of aerospace data with the help of ground data is crucial for the adequacy of the obtained models.

The main purpose of the current research is the creation of spatial patterns of xerothermic oak ecosystems in SCI "Zapadna Stara Planina i Predbalkan", Bulgaria in 1977, 1992 and 2007 for comparative analysis of the distribution and the ecological status of these ecosystems and delineation of trends in alteration of the size and structure of the occupied areas.

The xerothermic oak ecosystems as part of the potential xerothermic forest vegetation of Bulgaria and Southeastern Europe (Bondev 1991) have expressed environmental, economic and social importance for their region of distribution. A large part from their territory of these forests has been destroyed in ancient times. Occupying altitudinal belt of rolling plains and foothills, i.e. near settlements, the oak forests are subjected to intensive exploitation that continues up to nowadays. The xerothermic oak forests in Bulgaria are mainly coppices and with degraded ecological and economic functions. The main task standing in front of forestry guild even back in the last century is the gradual transformation of these sprouts forests in seeds ones. For the time being, there are no results from the measures taken. Parts of the still preserved xerothermic oak forests in Bulgaria are included in the protected areas "Natura 2000" to ensure their preservation and improvement of the future perspectives. The national evaluation of the habitat area 91M0 Pannonian-Balkanic turkey oak-sessile oak forests in the protected zones of the country is 7.5 x 10^5 ha, as for the past 5 years this area has decreased by 20.9% (D-30-38/21.03.2011-2013 "Mapping and determining the conservation status of natural habitats and species - Phase I").

On the base of the reflection characteristics of the studied forest vegetation, the occupied areas by altitude, exposure, slope, soil type and bedrocks in three years are modeled. The characterization of communities' ecological status is also made by calculating the state vector and output factors that have the greatest weight to the established state are determined. The spatial patterns are obtained by processing satellite, aerial (orthophoto), GPS and ground data using aerospace technology and modeling in GIS environment. Through comparative analysis of the size of occupied areas, the spatial distribution of these areas according to the orographic and soil factors and ecological status of communities in the three years are outlined the trends of changes. The relationship between the observed trends in the distribution and the climatic fluctuations, characterized by variation of de Marton index is investigated.

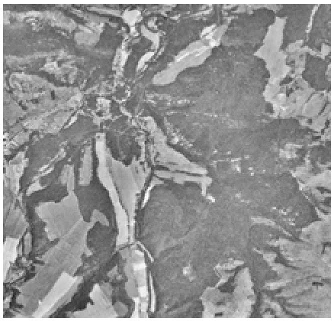
The created space models are applicable for the forest ecosystems monitoring, for the forest flora and vegetation conservation, for the forest areas sustainable management, as well as for the xerothermic oak forest in other regions and protected zones.

Object and Methods

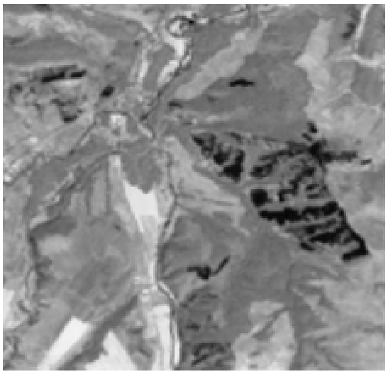
The xerothermic oak ecosystems are related to the habitat G1.768 Moesio-Danubiantermophilus oak forest according to the EUNIS classification (Davies et al. 2004) and 91M0 Pannonian-Balkanic Turkey oak-sessile oak forests according to Natura 2000 classification (Kavrakova et al. 2005). According to the assessment (D-30-38/21.03.2011 "Mapping and determining the conservation status of habitats and species - Phase I") - they participate with 2.8% in the area of the protected zone (SCI) "Zapadna Stara Planina and Predbalkan" (2,2* 10^{-5} ha). The vegetation in the protected zone refers to the Illyrian province of the European deciduous forests (Bondev 2002). The climate in the study region is characterized as moderate continental, with two dry periods - early spring and late autumn (Velev 2002). According to the divided into districts soil zones of Bulgaria the territory is a part of the Carpatho-Danuvian soil areas and the soils found are mainly Cambisols, Luvisols, Rendzinas (Ninov 2002). The studied territory is with a geographical coordinates of the northeast point N $43^0$45'22"; E $22^0$27'25"; low right soothes point N $42^0$57'02"; E $23^0$10'39" (Fig. 1).

Fig. 1. Object of investigations: A. Quercus frainetto-cerris forest; B. Orthophoto, 2011 C. Satellite data, 2007

(A)



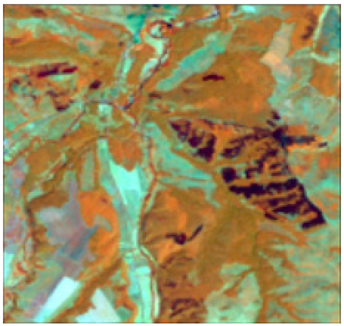
(B)



(C)

(A)

(B)



(C)

As an input data for the modeling of spatial distribution of the xerothermic oak ecosystems are used satellite composite images from different time periods - LandSat MSS 1977, LandSat 5TM 1992, LandSat 7ETM 2007; aerofoto images (recording 2011); terrestrial data (Forest Management Plan, FMP, of Forestry states "Govejda" and "Chuprene"); Vegetation Map of Bulgaria M 1:600 000; Map of the forests in Bulgaria M 1:1 000 000; CLC 2006; Soil map of Bulgaria M 1:400 000; Geological map of Bulgaria 1:100 000; DEM (step section 24 m); GPS data from communities field studies and data from climatic stations of the towns of Varshetz, Belogradchik and Iskrets. The used composite satellite images are in the following spectral bands: LandSat MSS, resolution 57 – 342 m (3VNIR – 0.7-0.8 μm, 4SWIR – 0.8-1.1 μm, 2VNIR-0.6-0.7 μm); LandSat 5TM, resolution 30 m and LandSat 7ETM, resolution 30 – 453 m (4VNIR- 0.78-0.9 μm, 5SWIR – 1.55-1.75 μm, 3VNIR – 0.63-0.69 μm) - Tab. 1 (NASA, 2013). The choice of these satellite data inputs is associated with the vegetation spectral characteristics -within these spectral diapasons a dominating role have the chlorophyll, the structure of the foliage leaf cells and the water content.

Tabl.1. Parameters of used composite satellite images

LandSat MSS 22.08.1977	GSD 57	3VNIR – 0.7-0.8 μm	4SWIR – 0.8-1.1 μm	2VNIR -0.6-0.7 μm
LandSat 5TM 01.08.1992	GSD 30	4VNIR - 0.78-0.9 μm	5SWIR – 1.55-1.75 μm	3VNIR – 0.63-0.69 μm
LandSat 7ETM 18.07.2007	GSD 30	4VNIR - 0.78-0.9 μm	5SWIR – 1.55-1.75 μm	3VNIR – 0.63-0.69 μm

The methodology, including a number of consecutive iterations, has been applied for the satellite data analysis. At first a controlled classification is realized using the maximum likelihood. The comparable (in size and location) areas with the polygons from FMP are used as training sets. These training sets are selected on those areas of the images, where the density distribution of the studied forest communities is highest and with a homogeneous distribution of the brightness in different spectral ranges. In this case, the probability for recognition is the highest, and the classification error is the lowest. Parallel to this was made visual photointerpretation and revision of the obtained results after classification. In case of errors the corrections in training classes are plotted. For achievement of high accuracy of the final results the several consecutive iterations of classification after visual photointerpretation and revision are realized. Each iteration is a comparative analysis of the results of the visual interpretation and manageable classification in order to minimize the errors. The classification is verified by travel over the studied field and capture of GPS coordinates, and also by comparing it with vectored polygons of Vegetation map of Bulgaria 1:600 000 (Bondev 1991) and Corine Land Cover (CLC'06). After verification a 95% accuracy for the xerothermic forest vegetation classifications in the zone has been achieved. In GIS environment the analysis and processing of the input data is made, using various operations that include: vectorization, converting vector data to raster and vice versa, for the area of polygons, exposure, slope, altitude, soil cover and foundation rock. The obtained results are used for quantitative and statistical analysis.

Index of drought of the climate de Marton have been calculated ($J = \frac{12P}{T+10}$, where P is the amount of precipitation in mm and T - temperature in C^0 (De Martonne 1926) and vegetation index of oak forests ($NDVI = \frac{DN_{NIR} - DN_{RED}}{DN_{NIR} + DN_{RED}}$, where DN_{NIR} is the numerical value of the brightness of pixels in the image in NIR [LandSat MSS, Band 3; LandSat 5TM/7ETM, Band 4], DN_{RED} - the numerical value of the brightness of the pixels in the image in the RED [LandSat MSS, Band 2; LandSat 5TM/7ETM, Band 3] (Rouse et al. 1974).

The ecological status of the studied vegetation is characterized by a state vector (VC). Formally, the state vector is represented by the equation:

$$VC = \{S, NDVI, J, Alt., Asp., Slope, Soil, Rock\},$$

where: S and NDVI are the components that reflect the parameters of the ecosystem, and the components - J, Alt., Asp., Slope, Soil, Rock are those, reflecting the factors of the environment.

The modulus of the state vector has the appearance:

$$\|VC\| = \sqrt{S^2 + NDVI^2 + J^2 + Alt.^2 + Asp.^2 + Slope^2 + Soil^2 + Rock^2},$$

where:

- S is the total area occupied by the oak forests of the corresponding year;
- NDVI – the average vegetation index for the given year;
- J – de Marton drought index (average per each year by months for the three meteorological stations);
- Alt. - the predominant altitude of the occupied area for the correspondent year;
- Asp. - the overall exposure of the occupied area for the correspondent year;
- Soil - the predominant soil type of the occupied areas for the correspondent year and Rock - the prevailing soil formed rocks of occupied areas for the corresponding year.

State vector expresses the condition of forest ecosystems at a given time. It includes the occupied area, NDVI, index deMarton as variables numeric values. The characteristics - altitude, exposure, slope, soil type and bedrock are presented as relative indices for each of the three years. These indices are calculated as the ratio between the area, occupied within the boundaries of the dominant characteristic of the parameter and the total area of the studied forests in the protected area. The determination of the dominant characteristics was performed in GIS environment as for each of them is entered numeric codes. And the varying of forest area within each of the dominant characteristics for the years of survey has been defined.

The used values of the quantities entering in the state vector are calculated by processing the satellite and terrestrial data in GIS environment. The real areas of the components were converted into relative units by their referring to the total occupied surface area in a particular year and thus way are obtained comparable values with a numerical value from 0 to 1. For example, instead of $S_{forest1977}$ – area of xerothermic oak ecosystems for 1977, the ratio: $0 \leq \frac{S_{forest1977}}{S_{SCI}} \leq 1$ is used, where S_{SCI} – the sum of the area in SCI „Zapadna Stara Planina i Predbalkan" for he studied years; instead of $S_{Alt.k1977}$ - an area of the oak forests at a certain altitude, Alt.k (k = 1-7) for 1977 year, the ratio $0 \leq \frac{S_{Alt.k1977}}{S_{forest1977}} \leq 1$ is used.

As components of the state vector from the indices of the environment, only those values that dominate for the whole territory are included (e.g. for a type of exposure is selected only the value of the predominant for the territory north exposure).

The factors with the greatest influence on the state vector in the studied years are derived by calculating the angle of their deviation from VC. The factors having greater divergence from VC are the most important for the values of VC. Also the component analyses have been made as the data were compared for each factor in the years with its absolute value. Tracking of quantitative changes in environmental factors and used oak ecosystems characteristics was done for a time interval of 30 years - 1977, 1992 and 2007.

By means of one-way ANOVA (variance analysis), the differences between arithmetic average values of the three years for all seven presented variables (altitude, exposure, slope, soil, rock type, area and NVDI index) were tested. Additionally the average values of air temperature and precipitation for each of the three years were compared by non-parametric Wilcoxon paired test. Finally the PCA including all above enumerated variables recorded from 37 localities of each year (a total of 111 samples for the three years) was carried out. All mentioned analyses were carried out by PAST statistical package according to Hammer et al. (2001).

Results

The performed spectral analysis of the composite satellite images - averaged spectral reflectance characteristics for the 10th polygons with the largest area of the xerothermic oak vegetation for the studied years, is shown in Fig. 2.

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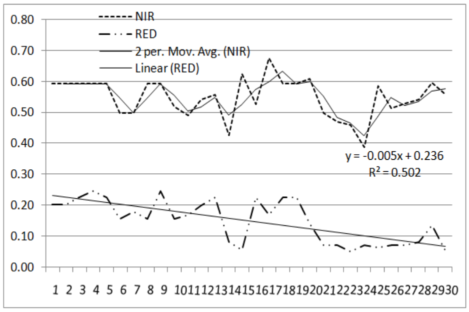
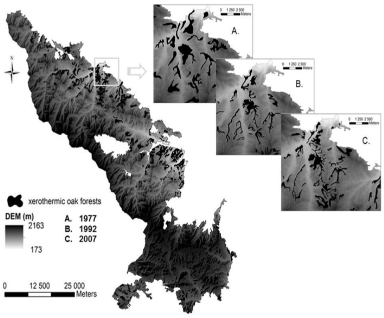
Fig. 2. Studied vegetation relative reflectance (%) at the ranges: RED (0.63-0.69 μm) and NIR (0.78-0.9 μm) for 1977 (x =1-10), 1992 (x=11-20) и 2007 (x=21-30)



The reflection of solar electromagnetic energy from the leaf surface of the xerothermic oak forests in RED range gradually decreased from 1977 to 2007, which can be described by a linear function. During 2007 year is observed the lowest reflection characteristics that are due to the higher quantity of pigments in the leaf bulk and the higher absorption of radiation. In NIR range the reflection ability of the vegetation in 1977 and 2007 years are relatively high and close by value which probably is a result of a higher content of water in the leaf cells.

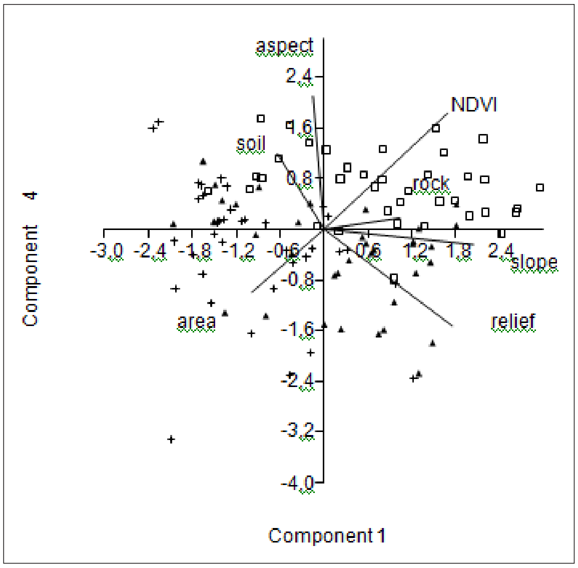
The obtained results for the vegetation classification by using the satellite image for 2007, are presented in Fig. 3.

Fig. 3. Spatial distribution of xerothermal oak forests in 2007 and observed changes for the part of territory in 1977 and 1992



The spatial distribution of the forests in the different years within a restricted area from the studied region are presented as large-scale samples. These samples demonstrate the change in location, size and contour of the forest polygons, as a result of the occurred alterations in structure and quality characteristics of the forest ecosystems (Table 2). The performed statistical analysis confirms the determine differences in the spatial distribution of the studied oak vegetation among the three years (Fig.4).

Fig.4. PCA biplot analysis between first and fourth main axes with data samples (total n=111) from year 1977 (n=37, +), year 1992 (n=37, ▲) year 2007 (n=37, □) and variables area, aspect, rock, relief, slope, NDVI and soil



The 1st axis on the Figure is composed mainly from vectors of slope and rock, while aspect and soil contribute to the formation of the fourth main axis. The variables relief and NDVI index contributed strongly and approximately equally to both axes. The biplot of 1st and 4th axes seems to separate samples of year 1977 from 2007 more clearly than the combination of 1st and 2nd axes while the year 1992 is a transitional between them.

The length of state vector varies during the different years as follows: 0.34, 0.28 and 0.36 respectively for 1977, 1992 and 2007. The alterations of the state vector by years are due to fluctuations in the values of the eight components, which are used for its calculation (Table 2 and Fig. 5 A).

Table 2. Average values alteration of the VC components

Year	Total area m2	NDVI	J	Area of prevailing habitat characteristics, m^2				
				Altitude, 251-350 m	Exposure, N	Slope, 0-5^0	Soil type (luvisols)	Rock (limestones)
1977	10226,3	0,44	53,1	1203,08	1134,57	1936,32	7288,58	3170,15
1992	5537,4	0,52	29,4	919,65	696,08	1298,67	4339,24	1882,72
2007	6445,7	0,71	48,2	1024,98	966,65	1562,34	4970,95	2707,19
%								
1977	0,47	0,44	0,53	0,12	0,11	0,19	0,71	0,31
1992	0,25	0,52	0,29	0,17	0,13	0,23	0,78	0,34
2007	0,29	0,71	0,48	0,16	0,15	0,24	0,77	0,42

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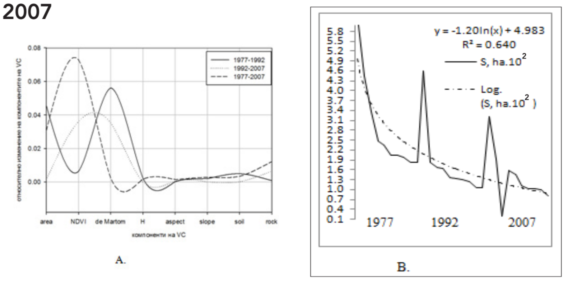
Fig. 5. Amendment of the differences of VC components relative average values (A) and of occupied territories (B) for 1977, 1992 and 2007



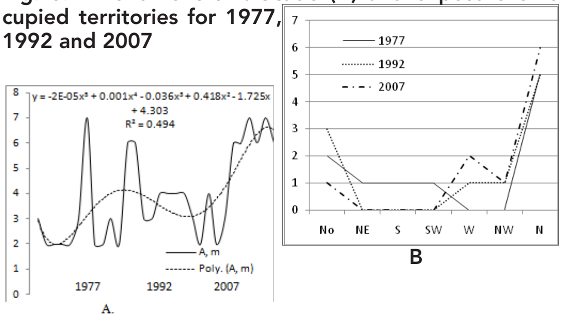
The components with the highest impact on the VC and therefore the greatest angle of divergence from the vector are as follows: the area of the polygons of the oak forests (for 1977 - 40^0, for 1992 - 8^0, for 2007 - 33^0), NDVI index (1977 -15^0, 1992-43^0, 2007-49^0) and the de Marton drought index (1977-44^0, 1992-42^0, 2007-9^0).

The total area of the forest polygons of the xerothermic oak ecosystems is greatest for 1977 and lowest for 1992 as for 2007 about 0.5% increase in the areas were observed. A general trend observed for the all three studied years is the decrease of the areas of the oak vegetation in the zone, described by a logarithmic function (Fig. 5 B).

For all the three years the change in the structure of this area in relation to the factors of relief are also observed.

The altitudinal distribution range of oak forests in the zone is 170-550 m. The change in spreading of the forest polygons according to altitude is estimated by polygons with the greatest area in the zone and altitude range to which they fall. The alteration by years on that index is negligible and it is in within the scope of a dominant altitude class (251-300 m). In 1992, when the area of the habitat in the zone is the lowest, the predominant altitude class is retained. The percentage distribution of the areas in the other high-altitude classes are slightly amended in 1992 year – the areas occurring in the higher-class from 300-351 m are increasing, while for 1977 and 2007 the polygons are uniformly distributed around the average height class and values of the areas at 300-351 m are comparable to those at 200-251 m. The alteration of the spatial distribution of the areas in altitude over the three years can be described by a polynomial of the fifth degree

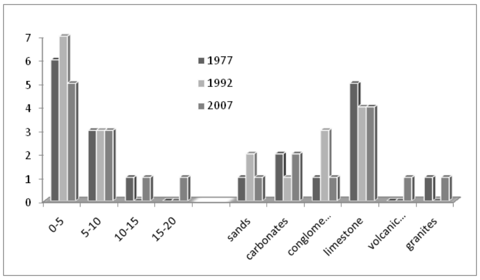
Fig. 6. Amendment of altitude (A) and exposure of occupied territories for 1977, 1992 and 2007



(Fig. 6 A). There is also observed a slight shift of vegetation from the lowland, the northeastern, southern and southwestern exposures in comparison with 1977 and increasing in the areas of west, northwest and north exposures (Fig. 6 B).

The amendment in the forest areas structure according to the exposure is less in 2007 in comparison to 1977. The areas located on 0-5^0 slopes are reduced and those on the larger slope 15-20^0 are increased (Fig. 7). In 1992 was observed increasing of polygons occupying more gentle slopes and appear polygons with alluvial soils that are not typical for the distribution of xerothermal oak forests in investigated region. The predominant soil type is gray forest soils. In 1977 is larger the percentage of the polygons located on brown soils (15%) in comparison to 1992 (8%) and in 2007 (4%), it reduces by half compared to the previous year considered. In 2007 the reduction of areas located on sand and limestone as bedrocks and increase of those on volcanic rocks is also established (Fig. 7).

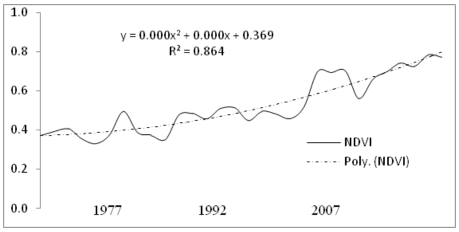
Fig. 7. Amendment of slope and rocks of occupied territories for 1977, 1992 and 2007



The settle peculiarities in the areas structure of the investigated vegetation could be due to the great extend to the special features in regional forest management and the anthropogenic loading on the territory.

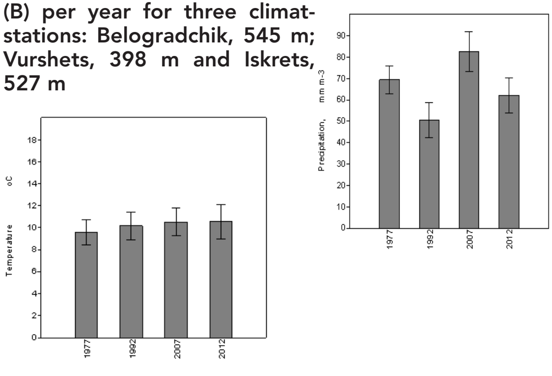
The average values of NDVI for 1977 ranged in the limits 0.39-0.65; in 1992 the lower and upper boundary of variation is increased - 0.62 and 0.80 and in 2007 they are 0.33 to 0.55. The alteration of the averages of NDVI for the studied 10 polygons in 1977, 1992 and 2007 years quite clearly reflect the observed trend in reflectance ability of the vegetation for the period, namely the gradually increase in the values of the index from 1977 to 2007. The amendment of NDVI for the three inspected years is well described by a second order polynomial (Fig. 8).

Fig. 8. Variation of xerothermal oak forests NDVI values for studied years



The amendments of the averages annual temperatures among the examined years: 1977, 1992, 2007 and 2012 showed common tendency of temperatures increase that is preserved up to this day. However, only two statistically significant differences were proven by Wilcoxon paired test, i.e. 2007>1977 and 2012>1977 (Fig. 9A).

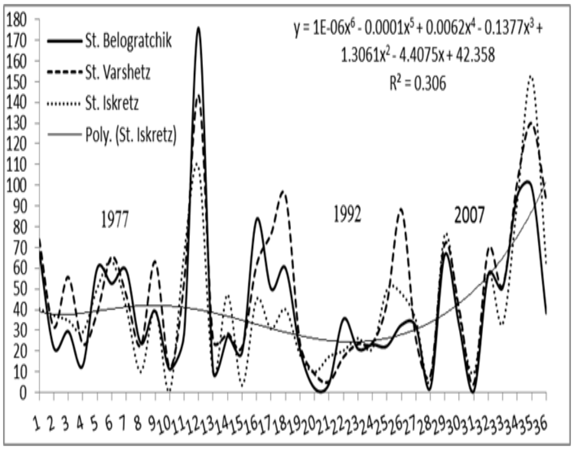
Fig.9. Average values and standard errors of temperatures (B) per year for three climatic stations: Belogradchik, 545 m; Vurshets, 398 m and Iskrets, 527 m



A B

The alteration in precipitations is much more dynamic (Fig. 9B).
Statistically significant difference in the values quantities is proven between 1977, 1992 and 2007, as in 1992 the precipitations were lowest (Fig. 9A). It is interesting to analyze the combined influence of the both regimes, in the conditions that the existence of the examined forest vegetation is realized through the index. The variation in drought index values de Marton is quite similar in the separate years for the three meteorological stations (Fig. 10).

Fig. 10. Seasonal variation of the de Marton index studied for climatic stations: Belogradchik, 545 m; Varshetz, 398 m; Iskretz, 527 m



Between the three years, however, there are differences in the seasonal dynamics of the index, which indicates pronounced fluctuation of climatic parameters. In 1992, the average index values were lowest for the three stations, as increasing the number of months with J <20 (severe drought) and J <30 (drought) - Table 3, Alexandrov (2005). In 2007 the average index values in most cases are increased and the number of the months with drought reduced, but the seasonal dynamics of the index sharply differs from that in 1977 and 1992.

Table 3. Values of the de Marton index for the three station in 1977, 1992 and 2007

Year/Station	J<20		J<30		J av.
	J av.	months, n	J av.	months, n	
1977					
Belogradchik	12.1	2	27.2	4	45.1
Varshetz	12.3	1	23.1	2	52.6
Iskrets	1.5	2	29.2	1	43.5
1992					
Belogradchik	9.0	4	23.1	4	29.8
Varshetz	10.5	3	24.5	6	34.2
Iskrets	11.7	5	22.5	3	24.1
2007					
Belogradchik	1.5	2	22.4	1	44.1
Varshetz	6.2	2	26.0	1	60.5
Iskrets	7.4	2	0.0	0	54.8

Discussion

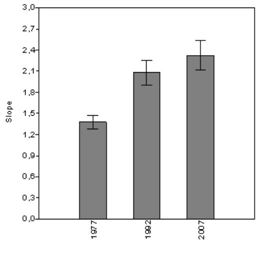
In the rationalization of the established reflection characteristics of the oak vegetation and the absorption of the sun radiation many parameters should be taken into account such as the volume of leaf bulk as well as and its moment condition – the content of chlorophyll and water, also the length of vegetation season, the tree age and probably the number of rotations of those sprout forests.

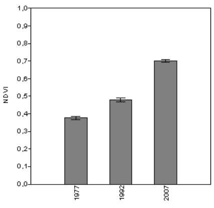
The values of the state vector are close for 1977 and 2007, but they are significantly higher from the value in 1992, which is demonstrated and from the alterations of the components of VC. The curves for 1977 and 2007 have one and the same character, but because of changes in area and the structure of polygons the three curves are shifted from one another (Fig. 4 A).

The area of the oak forest polygons, NDVI index and the de Marton drought index reflect the vegetation peculiarities and the complex of the influencing climatic factors in the region, i.e. by their alteration can be judged for the quick and significant for the forest ecosystems changes. Those are also the components that have determined the highest influence on VC. The established general trend of reducing the occupied area of the studied forests is not statistically proven, i.e. no statistically significant differences between years (One-way ANOVA variance analysis: F=1.992, p=0.14). The identified changes in the area are most likely due to anthropogenic impacts associated with logging part of the forest communities' polygons and subsequent regeneration or reforestation. According to the FMP data of Forestry state "Govejda" and "Chuprene" from previous periods (1985 and 2007) *Q. frainetto* in the research area has decreased from 4.1% to 2.7%, and *Q. cerris* marks a slight increase in the area from 1.2% to 1.5%. The reason for this is also the observed withered of Turky oak trees in the early 90s, which led to the implementation of clear cutting in some of the polygons. According to the assessment for 5 years the area of the habitat in the zone has decreased by 13.8% (D-30-38/21.03.2011 "Mapping and determining the conservation status of habitats and species - Phase I").

The observed differences between the three years in the structure of the occupied areas on their altitude (F = 2.204, p = 0.11), exposition (F = 2.70, p = 0.07), soil type (F = 0.263, p = 0.77) and underground scale (F = 0.342, p = 0.71) were not statistically significant according to a one-way variance analysis. On the other hand the changes between years of the slope of the monitored territories of forest assemblages showed that the most common degree range (0-50) revealed statistically significant increase from 1997 towards the years 1992 and 2007 (Fig. 11 A).

Fig.11. One-way ANOVA (variance) analysis of the slope of occupied territories (A) and of the NDVI variation (B) between studied years





A B

A tendency of NDVI index increase from 1977 to 2007 was statistically significantly proven for all of the compared three years (one way ANOVA, Fig.11B).

The amendment in the vegetation index is indicative for the environmental condition of the forests for a given year, as it is better in 2007 than in 1977. NDVI values for 2007 are close to the seasonal dynamics of the index quoted by other authors, which further again confirms the correctness of the performed classification of xerothermal oak forests (Benedetti et al, 1994; Bauer et al., 1994; Achard and Estraguil, 1995; Stagakis, 2007).

Conclusion

The conditions of the xerothermic oak ecosystems are amended over the years, as this alterations is most strongly expressed between 1977 and 2007, and 1992 occupies an intermediate position. In 1977, the VC has the highest value that decreases in 1992 and manifest a trend of improving for 2007. The fluctuations in the VC over the years are mainly due to the oak forests ecological status, estimated by the values of NDVI index, the climatic conditions expressed by the de Marton drought index, and the occupied forest area. There was established a trend of increasing of NDVI index from 1977 to 2007, which is statistically proven. The study of climatic factors showed a gradual increase in the temperatures for the period and the precipitations increase in 2007 compared to 1992, as well as the drought periods increasing in 1992, which changes follow the trend of alteration of the VC. According to the estimated assessments the occupied area of the studied oak forests decreased in this period, but the differences in the area during the three years are not statistically proven.

For the period under review, the changes in the spatial distribution of forest communities according to the orographic factors, soil ground covering and bedrock base were observed, that are however not statistically proven with exception of the spread toward slope of terrene. Therefore, in assessing the gravity of the factors for the values of the VC can be concluded that they practically do not affect the status of oak ecosystems in the studied area.

The identified changes in the occupied areas of oak ecosystems and their spatial distribution are probably due to the drier climate in 1992, but the parallel anthropogenic impacts modified the natural influences and lowered their statistical reliability.

The identified spectral peculiarities of the studied vegetation, the demonstration of the applied integrated approach to study the changes in the structure and the quality of the forest areas, as well as the obtained results can be used in next investigations and monitoring of oak ecosystems and forest vegetation with similar ecological specificities.

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REFERENCE

Achard, F., and C. Estreguil, 1995. Forest classification of southeast Asia using NOAA AVHRR data, Remote Sensing of Environment, 54:198–208. | Alexandrov, V. 2005. On the Soil Drought in Bulgaria. Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, Sofia, 56 pp. | Bauer, M.E., T.E. Burk, A.R. Ek, P.R. Coppin, S.D. Lime, T.A. Walsh, D.K. Walters, W. Befort, and D.F. Heinzen, 1994. Satellite inventory of Minnesota forest resources, Photogrammetric Engineering Remote Sensing, 60(3):287–298. | Benedetti, R., P. Rossini, and R. Taddei, 1994. Vegetation classification in the middle Mediterranean area by satellite data, International Journal of Remote Sensing, 15(3):583–596. | Bergen, K., J. Colwell, and F. Sapio, 2000. Remote sensing and forestry: Collaborative implementation for a new century of forest information solutions, Journal of Forestry, 98(6):5–9. | Bondev I., 1991 – Vegetation og Bulgaria. Map M1:600 000 with explanatory text, "St. Kliment Ohridski" Uni. Press, Sofia. | Bondev, I., 2002 – Geobotanical regioning. In: Kopralev I. (ed.). Geography of Bulgaria. Physical geography, ForCom, Sofia: 336-351. | Carleerand A., E. Wolff, 2004 -Exploitation of Very High Resolution Satellite Data for Tree Species Identification-Photogrammetric engineering & remote sensing | Chen X. , R. Fraser. 2009. Quantifying Impacts of Land Ownership on Regional Forest NDVI Dynamics: A Case Study at Bankhead National Forest in Alabama, USA. Photogrammetric Engineering & Remote Sensing, Vol. 75, No. 8, 997–1003. | Corine Land Cover Bulgaria, 2006. | D-30-38/21.03.2011 "Mapping and determine the conservation status of habitats and species - Phase I", 25.03.2011 - 25.03.2013. European Regional Development Fund, State Budget of the Republic of Bulgaria / Operational Programme "Environment 2007 - 2013 г. | Danilova I., V. Ryzhkova, K. Michaelorets, 2012 – Recognizing vegetation chronosequence in Landsat imagery, BOSQUE 33(3): 359-362 | Davies, C., D. Moss, M. Hill, 2004. EUNIS habitat classification revised. Final report to EA and ETC on Nature Protection and Biodiversity | De Martonne, E. (1926). Aréisme et indice artidite. Comptes Rendus de L'Acad Sci, Paris, 182,1395–1398. | FMP Chuprene, 1985, 2007, 2011 | FMP Govejda, 2003, 2011 | Geological map of Bulgaria M1: 100 000, 1992 - Committee for Geology and Mineral Resources, Geology and Geography AD, Sofia | Hammer Ø., Harper D. A. T. and P. D. Ryan. 2001. Palaeontologia Electronica 4 No1, 9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm | Kavrakova, V., D. Dimova, M. Dimitrov, R. Tzonev, T. Belev (ed.), 2005 - Guidance for identifying habitats of European importance in Bulgaria, WWF, Green Balkans, MoEW. | Kuzera K., J. Rogan , J. Eastman. 2005. Monitoring Vegetation Regeneration and Deforestation Using Change Vector Analysis: Mt. St. Helens Study Area. ASPRS 2005 Annual Conference, Baltimore, Maryland, March 7-11, 2005. | Lyubenova, M., R. Nedkov, I. Ivanova, A. Chikalanov, N. Georgieva, E. Ivanova, V. Lyubenova. 2012. Ecological Space Modeling as a Pattern for Forest Vegetation Investigations (Example with Belasitsa Mts., BG). Comptes rendus de l'Académie Bulgare des Sciences. Biologie, ecologie, 65, N 4, 481 - 488. | Lyubenova, M., R. Nedkov, I. Ivanova, A. Shikalanov, N. Georgieva, M. Zaharinova, M. Dimitrova, E. Ivanova, V. Yanchev, K. Radeva, N. Stankova, R. Tsoneva 2011: Study of ecological dynamics of forest vegetation in the region of East Rhodope on the base of satellites and terrestrial data – "Ecological engineering and environment protection", 1/2011, Sofia, 45-50. | Lyubenova, M., E. Rumenina, V. Dimitrov, E. Ivanov. 2002. Study of ecosystems of the biosphere reserve "Chuprene" with fitoecological methods and spatial modeling.-In:Proc. Scientific conference with international participation, in memory of prof. Dimitat Yaranov, Varna, Vol. 1, 260-269. | Manes, F., A. Grignetti, A. Tinelli, R. Lenz and P. Ciccioli (1997): General features of the Castelporziano test site, Atmos. Environ., 31, 19-25. | Map of Forests in Bulgaria M 1:1 000 000 1961 - Main Forestry Council of MC, Kartproekt, Sofia | NASA, 2013 – The Landsat Programm (http://landsat.gsfc.nasa.gov/about/landsat7.html). | Ninov, N., 2002 – Soils. In: Kopralev I., (ed.) Geography of Bulgaria. Physical-geography, ForCom, Sofia: 277-311. | Olson, C.E., Jr., and F.P. Weber, 2000. Foresters' roles in remote sensing, Journal of Forestry, 98(6):11–12 | Reich, R.W., and R. Price, 1999. Detection and classification of forest damage caused by tomentosus root rot using an airborne multispectral imager (CASI), Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry (D.A. Hill and D.G. Leckie, editors), Canadian Government Publishing Centre, Ottawa, Ontario, Canada, pp. 179–185. | Roumenina, E., M. Lyubenova, V. Dimitrov. 2003. Ecological risk assessment of spruce vegetation in biosphere reserve "Chuprene" with space mould in GIS.- In: Proceeding «International Scientific Conference" – 75 years Institute of Forestry, Bulgarian Academy of Sciences», 1-5 October, 2003 y., volume I, 61-64. | Rouse, J., J. Haas, J. Schell and D. Deering (1974): Monitoring vegetation systems in the Great Plains with ERTS, in Proceedings of the Third Earth Resource Technology Satellite-1 Symposium, Goddard Space Flight Center, Science and Technical Information Office, NASA, Washington, D.C, NASA SP-351, 309-317. | Soil Map of HP Bulgaria M 1:400 000, 1965 - General Department of Geodesy and Cartography, Maps factory Sofia | Soudani K., G. Hmimina, N. Delpierre, J.-Y. Pontailler, M. Aubinet , D. Bonal, B. Caquet , de Grandcourt, B. Burban, C. Flechard, D. Guyon , A. Granier, P. Gross, B. Heinesh, B. Longdoz, D. Loustau , C. Moureaux , J.-M. Ourcival, S. Rambal, L. Saint André, E. Dufrêne. 2012. Ground-based Network of NDVI measurements for tracking temporal dynamics of canopy structure and vegetation phenology in different biomes. Remote Sensing of Environment, 123, Elsevier , 234–245. | Spruce J., S. Sader, R. Ryanc, J. Smoot, Ph. Kuper, K. Ross, D. Prados, J. Russell, G. Gasser, R. McKellip, W. Hargrove. 2011. Assessment of MODIS NDVI time series data products for detecting forest defoliation by gypsy moth outbreaks. Remote Sensing of Environment 115 (2011),427–437. | Stagakis St., N. Markos, E. Levizou, A. Kyparissis, 2007 - Forest ecosystem dynamics using spot and modis satellite images, Proc. 'Envisat Symposium 2007', Montreux, Switzerland 23–27 April 2007 (ESA SP-636, July 2007). | Velev, St., 2002 – Climatic regioning. In: Kopralev I. (ed.). Geography of Bulgaria. Physical geography, ForCom, Sofia: 155-157. |