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APPLICATION OF REMOTE SENSING TECHNOLOGIES TO DETERMINE THE DIVERSITY OF STEPPE VEGETATION

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The aim of this study is to investigate the possibilities of using remote sensing techniques to assess the biological diversity of plant communities. Studies were carried out on the Donetsk Ridge steppe landscapes in the Ukraine. We found the significant correlation (0.9, Spearman rank correlation, $p<0.05$) between the steppe landscapes biodiversity and dinamics of normalized difference vegetation index (NDVI) from 1986 to 2011.

Key words: remote sensing, biodiversity, NDVI.

INTRODUCTION

At the stage of the modernization and optimization of existing ecological networks the problem of identification and inclusion to the network valuable landscapes is important. Since the vegetation is a major component of ecosystems, biodiversity, biomass and other quantitative indicators, which characterize the plant community – is one of the major criteria determining the value of the landscape and the importance of its conservation [1].

The study of quantitative indices of plant communities can be conducted by direct field studies, or at a distance, using the technology of remote sensing (RS). RS approach allows us to explore the remote area with a less time and money cost, but the results need to be comparing or combining with the data obtained during field studies. Therefore, these two approaches are not interchangeable and complementary [2].

The correlation between diversity and productivity is the subject of a regular debate in ecology. The productivity hypothesis predicts that when resources are abundant and reliable, species become more specialized, allowing more species per unit area [3]. However, empirical data shows that higher productivity can be either negatively or positively correlated with biodiversity. In fact, in many systems a unimodal pattern is found, with highest species richness at intermediate levels of productivity; above the point of central tendency species richness decreases as productivity increases, while below the point of central tendency species richness increases as productivity increases [4].

The sharp increase in the spectral reflectance of vegetation in the transition from red to near-infrared is a good indicator of the abundance of vegetation and its condition. This spectral signature is the basis of the widely used vegetation index NDVI (Normalized Difference Vegetation Index) [5]. Various studies have shown that NDVI integrates the influence of climatic variables and other environmental factors [6].

According to the Podolsky [7] interannual variation of the maximum NDVI can be used to assess whether vegetation cover over a number of years is actually stable in an area, or highly variable. For example, calculating the standard deviation for a number of years describes the variability of vegetation cover for an NDVI image pixel. Pixels with

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high standard deviations correspond to areas with large variations in vegetation composition and growth. Such areas are likely to have diverse habitats that may support richer assemblages of species. But in this case does not take into account the direction of change in NDVI, which in combination with the high standard deviation could hypothetically reflect the biodiversity more accurately.

Incomplete study and the relevance of this problem encouraged us to this investigation.

The aim of this work is to find a relationship between the direction and degree of NDVI change and biodiversity of steppe plant communities.

MATERIAL AND METODS

Field studies were conducted in the regional landscape park Zuevsky in the Donetsk region of Ukraine during the growing season in 2011. The landscape park total area is 1,024 hectares; the park is located between longitudes 48°02'–48°05' North and 38°07'–38°16' East.

Among the soil the typical black soil humus and ordinary humus in loess rocks prevail. According to the geobotanical zoning, studied area is located in the Donetsk region geobotanical district in the strip herb-fescue-feather grass steppes of the Azov-Black Seas steppe province, subprovince of the Euro-Asian steppe region.

The typical landscapes are petrophyte steppe and ravined forests. According to the floristic zoning, this area is in the sub-district of Donetsk region of East Black Sea subprovince as part of Don-Black sea province of Panonsko-Black sea-Caspian region of Holarctic kingdom [8]. This sub-area is characterized by steppe vegetation, with the participation of forest and petrophytic species and complexes of endemic and relict species which are often stenotopic.

Field Research included: a random selection of monitoring points, determining their geographic coordinates using GPS navigator, an assessment of biodiversity of plant communities. There were selected 20 points measuring 30 m × 30 m, disposed as shown in fig. 1.

In period of office data processing we studied the species composition of flora in the monitoring points (based on the collected herbarium material), performed a systematic and coenotic analysis of the flora on the test sites.

For remote sensing studies, we used remote sensing data obtained by the Landsat-5 (sensor Thematic Mapper, TM) and Landsat-7 (sensor Enhanced Thematic Mapper Plus, ETM +) satellites, captured in July of 1986–2011 years and having no interference in the form of haze and cloud cover.

We have analyzed the trend of temporal change of NDVI in the study area for each pixel used satellite images (pixel size is equivalent to the square of 30 m × 30 m area). We used the value of linear angle tangents which approximates NDVI changes. For its calculation we used the method of least squares. Positive values correspond to increasing NDVI trends in the period of 1986–2011 years. And negative corresponds to decreasing. The value of tg(x) proportional to the rate of change. The reliability of the approximation is calculated by determining the rank correlation coefficient between the values of time and NDVI. The correlation coefficients were calculated between the rows with a confidence level β = 0.95. Those pixels where this ratio was less than 0.8 were not used in the study.

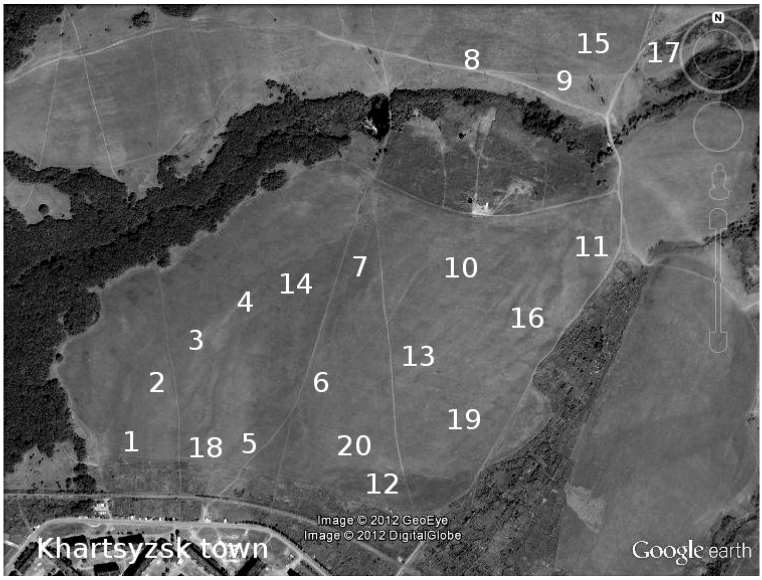

Fig. 1. Location of the study area (numbers indicated the localization of the monitoring points)

RESULTS AND DISCUSSION

At all monitoring points have been founded 105 species of flowering plants belonging to 79 genera and members of the 25 families.The dominant families in the flora of all monitoring points are Asteraceae (21 species), Poaceae (14 species) and Fabaceae (10 species). The ratio of classes Liliopsida and Magnoliopsida is 1:6.4, which is typical for the modern stage florogenesis [9]. The richest in species of genera are *Viola* (3), *Veronica* (3), and *Plantago* (3).

Based on the investigations results we have made a map (fig. 2) which shows the spatial distribution of the values of tangent of the line which approximates the change in NDVI.

According to the maps, the increasing of NDVI in the study area is characterized by heterogeneity. The smallest increase in this figure corresponds to the areas regularly exposed to burnout.

According to the results of studies, the largest number of species is a characteristic of the test area number 5, the least – for the test area number 8. Monitoring point number 5 is also characterized by the largest relative increase of NDVI. The smallest percentage of ruderal species is on the test area number 5, the highest – № 8.

Set of values of the number of species, genera, families and the relative increase in NDVI is not characterized by a normal distribution, therefore, to assess the relationship between them, we chose the Spearman rank correlation index.

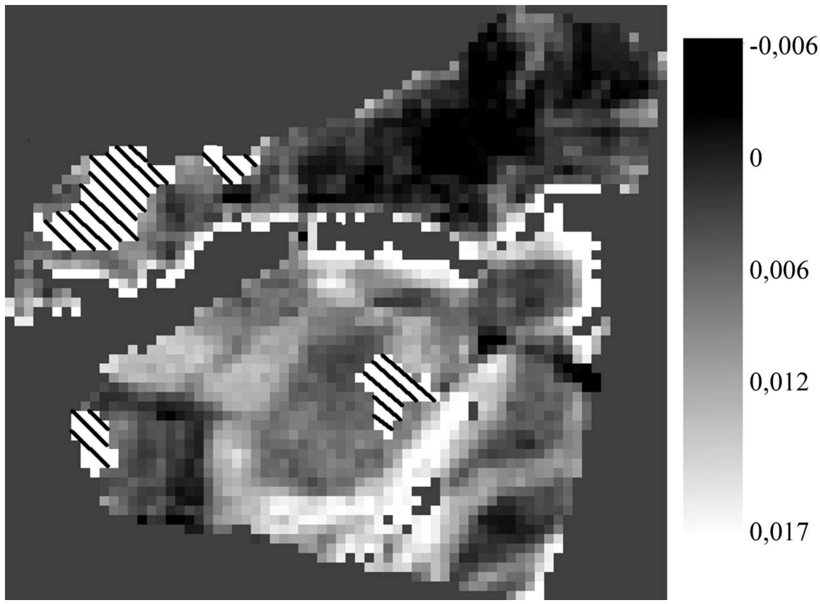

Fig. 2. A schematic map of the spatial distribution of the degree of increase of NDVI (the tangent of the angle of the straight line approximating the change of NDVI) in the study area

Hatching marked areas for which the correlation coefficient between time and NDVI index was less than 0.8.

Coefficients of Spearman rank correlation between the indices derived from floristic analysis (number of species, genera, families) and relative growth rates NDVI, have values greater than 0.8 (table 1, fig 3), indicating that there is a significant relation between the relevant parameters.

In most papers, results are based on the correlation between biodiversity and the NDVI index, defined at a particular time [4]. In this paper the author tried to move away from the traditional approach, and used indicator of the dynamics of NDVI to find the correlation with biodiversity. Studies have shown that the long-term dynamics of the NDVI can be the predictor of species richness.

We then explored the relationship between growth NDVI rates and count of species in steppe flora and uncovered a positive curvilinear relationship. The dependence is reliable for the species and genera.

However, it should be noted that similar results, except the relationship between biodiversity and productivity dynamics, can explain the discrepancies during the observations. For example, this work does not take into account the spectral characteristics of the soil cover in the choice of monitoring points. It can affects for the indication of plants productivity by NDVI index [10]. In addition, the author believes that the number of control points is insufficient. This is the reason that these studies will be continued.

Thus, the rate of increase in the relative NDVI can be used to determine the floristic values of individual sections of landscapes and to identify areas with different degree of digression. But, the indicator of NDVI dynamics is an integral indicator; it has not relation with any individual parameter which characterizes the state of the plant community.

Table 1

Diversity of vegetation on test sites, percentage of ruderal vegetation and relative increase of NDVI index

№ of test site	Species	Genera	Families	The percentage of ruderal vegetation,%	The relative increase of NDVI, tg(x)
1	16	14	12	82	0
2	17	15	12	79	0
3	24	20	15	69	0,002
4	26	22	17	75	0,002
5	42	32	20	45	0,0038
6	27	20	15	71	0,0015
7	26	20	16	70	0,0008
8	14	14	11	85	−0,002
9	15	14	12	81	−0,002
10	33	22	16	56	0,0025
11	24	21	15	64	0,0001
12	40	30	20	55	0,0031
13	32	24	17	50	0,0031
14	22	17	12	62	0,0008
15	30	24	18	55	0,0031
16	18	17	15	80	−0,003
17	16	14	11	80	−0,002
18	20	17	13	76	−0,002
19	20	16	13	82	−0,002
20	33	25	19	52	0,004
Spearman rank correlation with a relative growth of NDVI	0,91	0,89	0,89	−0,89	

CONCLUSIONS

Flora of the study area is diverse, representative for the floristic analysis. Indicators obtained as a result of floristic analysis (number of species, genera, families, and the percentage of ruderal vegetation in the flora), and indicators of the relative increase in NDVI are characterized by significant positive rank correlation coefficient.

These data suggest the possibility of using maps, showing the relative increase in NDVI, to determine the floristic values of individual areas.

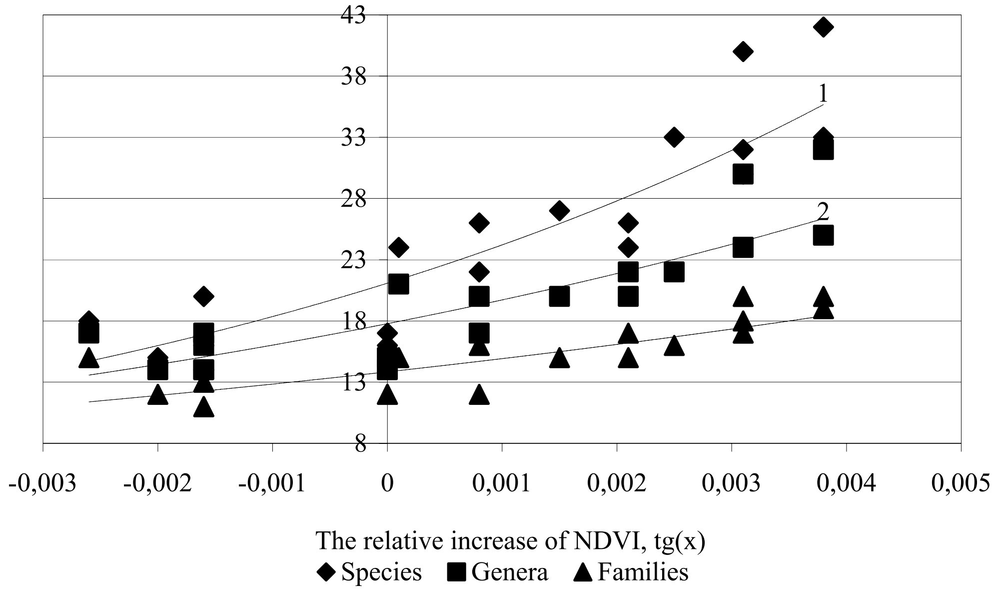

Fig. 3. Relationship between the number of species, genera, families
and the index of the relative increase of NDVI

Relationship between growth rates NDVI and count of species, genera and families in steppe flora is a positive curvilinear relationship (1) $y = 21{,}07e^{138{,}4x}$, $R^2 = 0{,}795$; (2) $y = 17{,}77e^{103{,}7x}$, $R^2 = 0{,}750$; (3) $y = 13{,}83e^{75{,}04x}$, $R^2 = 0{,}665$. $P<0.05$.

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Колесников С. В. Застосування технологій дистанційного зондування землі для визначення біологічного різноманіття рослинних угруповань // Екосистеми, їх оптимізація та охорона. Сімферополь: ТНУ, 2012. Вип. 6. С. 235–241.

Метою даного дослідження є вивчення можливості використання методів дистанційного зондування для оцінки біологічного різноманіття рослинних угруповань. Дослідження проводилися на території РЛП «Зуївський» Донецької області. Була визначена значима кореляція (0.9, рангова кореляція Спірмена, $p<0,05$) між біорізноманіттям степових ландшафтів та динамікою вегетаційного індексу NDVI в період з 1986 по 2011 рік.

Ключові слова: дистанційне зондування, біорізноманіття, NDVI.

Колесников С. В. Применение технологий дистанционного зондирования земли для определения биологического разнообразия растительных сообществ // Экосистемы, их оптимизация и охрана. Симферополь: ТНУ, 2012. Вып. 6. С. 235–241.

Целью данного исследования является изучение возможности использования методов дистанционного зондирования для оценки биологического разнообразия растительных сообществ. Исследования проводились на территории РЛП «Зуевский» Донецкой области. Была определена значимая корреляция (0.9, ранговая корреляция Спирмена, $p<0,05$) между биоразнообразием степных ландшафтов и динамикой вегетационного индекса NDVI в период с 1986 по 2011 год.

Ключевые слова: дистанционное зондирование, биоразнообразие, NDVI.

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