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ASSESSMENT OF FIRE-PRONE AREAS USING MULTISPECTRAL SATELLITE DATA: A CASE STUDY FROM BREZNIK MUNICIPALITY (WESTERN BULGARIA)

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Abstract
The present study deals with the application of the Vegetation Condition Index (VCI). The main aim is to calculate it to distinguish fire-prone areas. The object of research is Breznik Municipality, located in the western parts of the country. Landsat 8 images were derived, and Corine Land Cover classes were used as a basic territorial unit for the analysis. The main focus was the month of June for the years of 1990, 1994, 1996, 2000, 2007, 2011 and 2021. The results of the study varied with VCI across the different years. Non-irrigated arable land stood out as the land cover type most under threat.

Introduction

Climate change is altering the environment. Drought and rising temperatures are among the consequences of it. This leads to the emergence of more susceptible areas to natural hazards. Fires are one of the types that are expected to have an increased occurrence. Nowadays, we possess more sophisticated technology that allows us to make better predictions. Landsat 8 and Landsat 9 possess the Operational Land Imager (OLI) optical sensor and Thermal Infrared Sensor (TIRS) [1–3]. An advantage of satellite images is that they contain a combination of bands with different wavelengths that can be used for imagery analysis, including ones on vegetation [4, 5]. The most notable among them is the Normalised Difference Vegetation Index (NDVI), which has its pros and cons. By studying its flaws, Kogan [6] created a modified NDVI, which he called the Vegetation Condition Index (VCI). The author offered a concept and technique for the elimination of NDVI's imperfections, using Advanced Very High Resolution Radiometer (AVHRR) data for the 1984–1987 seasons in Sudan. He began by studying the climate impact on different areas with non-homogeneous vegetation. The author noted that a problem stands out when it comes to considering differences between vegetation and other geographical features, such as climate, soil, topography, etc. So VCI offers better dynamics in terms of precipitation compared to NDVI and allows not only the description of vegetation, but also the assessment of spatial and temporal changes in it.

The Vegetation Condition Index compares the current NDVI to the range of values observed in the same period in previous years. The VCI is expressed in % and offers an idea of where the observed value is situated between the extreme values (minimum and maximum) in the previous years. Lower and higher values indicate bad and good vegetation state conditions, respectively. VCI varies from 0 for extremely unfavourable conditions to 100 for optimal.

Several scientific works have favoured the application of VCI since its introduction. They can be applied both to natural environments and to agricultural areas for studying drought, which can have different implications on the two given examples. Liu & Kogan [7] monitored soya bean production in Brazil (1985–1998). Domenikiotis et al. [8] applied the VCI for studying cotton crops in Greece. Quiring & Ganesh [9] conducted research in Texas, USA. The authors focused on the period between March and August (1982–1999) and concluded that VCI has to be used cautiously due to the presence of a number of ecological factors that affect it. Dutta et al. [10] evaluated droughts in the northern Indian state of Radjastan. Jiao et al. [11] applied the VCI for drought monitoring in the continental areas of the United States of America. Zambrano et al. [12] studied a 16-year period of the BioBio region, Chile. Qian et al. [13] studied agricultural areas in China between 1982 and 2010. Kamble et al. [14] evaluated the impact of drought on rice crops for the period of 1985–2015.

The analysis of the cited literature shows that VCI may be used in different geographical areas and for a prolonged period, and this is one of the aims of the present research, among others, which will focus on the investigation of fire hazard in Breznik Municipality, Western Bulgaria.

The VCI may successfully be adopted as a tool for the determination of fire-prone areas in Bulgaria, as proved by Avetisyan & Nedkov [15], who applied it for the assessment of hazard zones in forest landscapes in Simitli Municipality (Bulgaria). Avetisyan et al. [16] built upon the research idea using the index in the Lom River Upper Valley. VCI has also been applied in the country for satellite monitoring of winter crop status [17] and wheat yields [18] when it comes to agriculture. Other studies [19] and [20] have also made scientific contributions.

The object of the present research is Breznik Municipality. The authors chose a municipality as a territorial unit because it allows authorities to account for environmental management and territorial planning with its related decision-making.

Materials and methods

The study area – Breznik Municipality is situated in the western part of Bulgaria in the region of Kraishte (Fig. 1). The study area is located mainly within 600–1000 m a.s.l. It covers an area of over 400 km^2. It has ample natural diversity. The mountains of Zavalska, Lyubash, Viskyar, Erulska and Cherna Gora are situated here, as well as the Breznik Valley. The lithology includes conglomerates, sandstones, clays, marls, limestones, dolomitic limestones, dolomites, marls, shales and volcanics – hornblende andesites, trachyandesites, and andesitobasalts according to Zagorchev et al. [21]. Koynov et al. [22] studied the soils, which are mainly represented by Luvisols, Leptosols, and Fluvisols. Only a restricted part of the study area falls within the NATURA 2000 sites Lyubash BG0000624 and Rebro BG0000314 [23].

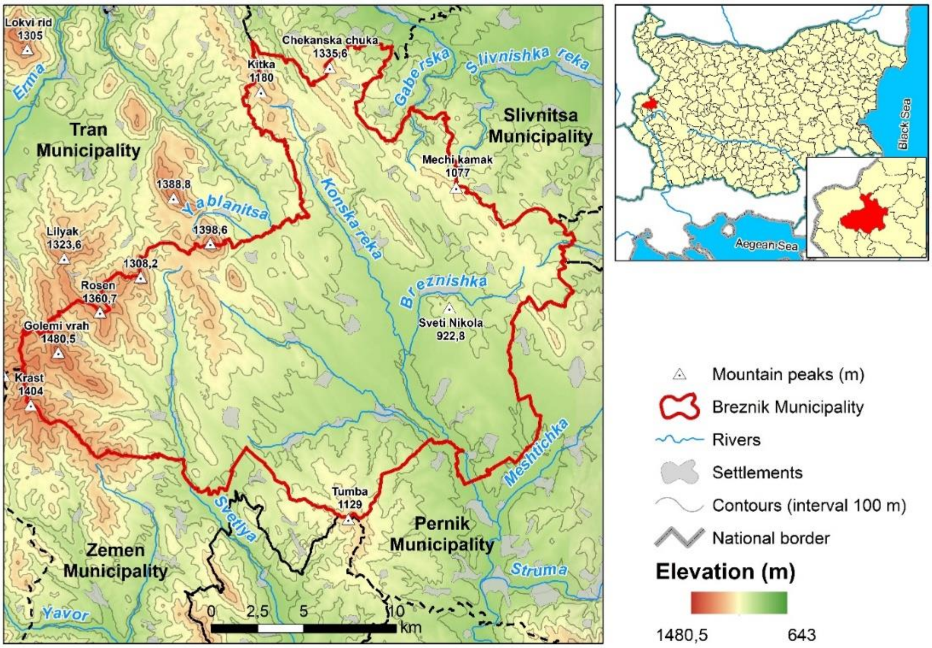

Fig. 1. Location of the study area

Images from Landsat 8 (Landsat Collection 2 Level-2, Landsat 8–9 OLI/TIRS C2 L2) were used for the calculation of VCI. Composite bands were created to get the VCI by using the Image analysis tool in ArcGIS 10.6.1. We used images only from the month of June, as follows: 25.06.1990, 20.06.1994, 09.06.1996, 04.06.2000, 24.06.2007, 19.06.2011, 30.06.2021 (Table 1). The month was chosen due to the fact that vegetation may be regarded as fully developed, still fresh and is expected to be in the same phenophase. Data regarding one month is easy to replicate, as well.

Table 1. List of used Landsat scenes

Landsat Scene Identifier	Date acquired (dd-mm-yy)	Path x Row	Cloud cover (%)
LT51840301990176FUI00	25.06.1990	184 x 30	7,00
LT51840301994171FUI00	20.06.1994	184 x 30	7,00
LT51840301996161FUI01	09.06.1996	184 x 30	0,00
LT51840302000156FUI00	04.06.2000	184 x 30	1,00
LT51840302007175MOR00	24.06.2007	184 x 30	3,00
LT51840302011170MOR01	19.06.2011	184 x 30	2,00
LC81840302021181LGN00	30.06.2021	184 x 30	0,02

VCI was calculated after the following steps:

Step 1: Maximum and minimum NDVIs were calculated (Spatial Analyst Tools – Local – Cell Statistics).

Step 2: VCI was calculated using maximum and minimum NDVI values (Spatial Analyst Tools – Map Algebra – Raster Calculator).

Step 3: The following formula was applied:
VCI = 100 * (NDVI – NDVI min) / (NDVI max – NDVI min) [6, 24].
NDVI max and NDVI min are the multiple-year maximum NDVI and minimum NDVI for a pixel with reference to a specific climatology.

Step 4: The calculated VCI was reclassified to 5 classes (using Spatial Analyst Tools – Reclass – Reclassify). The following Break Values (%) were inserted: 10, 20, 35, 50, 100 (Table 2).

Table 2. Classification of VCI values

Value	**Drought_Severity**
< 10%	Extreme drought
10%–20%	Severe drought
20%–35%	Moderate drought
35%–50%	No drought
50%–100%	Wet

Corine Land Cover (CLC) [25] classes were applied to the territory of Breznik Municipality. They were the units upon which VCI analysis was applied.

Results and Discussion

The results are showing certain interconnections. The territories near the extreme drought category are more prone to fires than the ones in the wet category. CLC 2018 classes (Table 3, Fig. 2) were consistent with those of previous years, so this database was enough to get the outcomes.

Table 3. Corine Land Cover codes and nomenclature

CLC code	Level 1 nomenclature	Level 3 nomenclature	% of total area
112	Artificial surfaces	Discontinuous urban fabric	2,96
121		Industrial or commercial units	0,22
142		Sport and leisure facilities	0,08
211	Agricultural areas	Non-irrigated arable land	28,67
231		Pastures	3,17
242		Complex cultivation patterns	2,71
243		Land principally occupied by agriculture, with significant areas of natural vegetation	16,73
311	Forest and semi-natural areas	Broad-leaved forest	11,29
312		Coniferous forest	4,11
313		Mixed forest	6,92
321		Natural grasslands	10,27
324		Transitional woodland-shrub	12,46
333		Beaches, dunes, sands	0,23
512	Wetlands	Water bodies	0,17

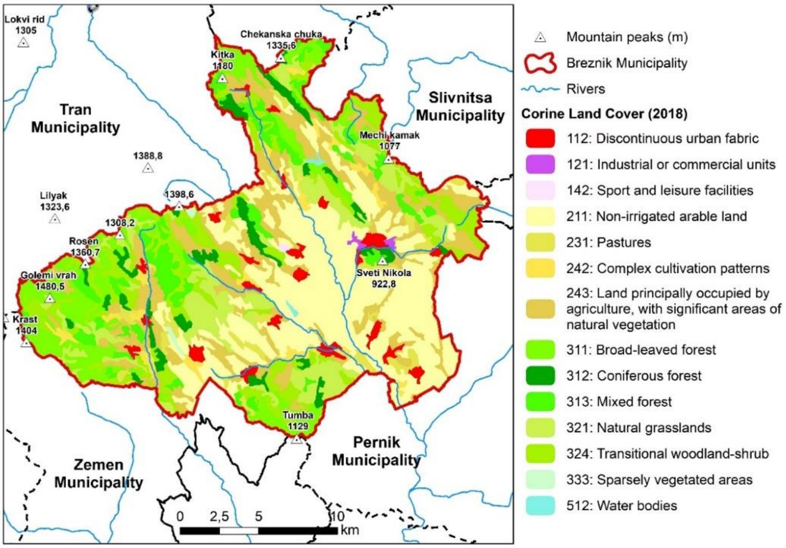

Fig. 2. Spatial distribution of Corine land cover classes within the area of interest

More than half of Breznik Municipality (51,28%) is occupied by arable land, while deciduous, coniferous and mixed forests cover about 22,32% of the administrative area. Grasslands, shrubs and areas with sparse vegetation canopy cover about 22,97% of the municipal area. Several small dams used for agricultural purposes (mainly irrigation) occupy an insignificant portion of the study area – less than 1%.

The spatial analysis will follow the presented data in Fig. 3. The first impression is that each year had its typical features. First in line will be 1990. Territories falling within the extreme drought category (red colour) this year are distributed mainly in the mountains of Zavalska and Viskyar to the north, as well as along the riverbed of Konska River. The territories with moderate drought are unevenly dispersed throughout the municipality. The areas falling within the wet category (green colour) may be discovered in Breznik Valley, but not to the full extent.

Next is the year 1994. Areas with extreme drought have moved from the north to the west and can be located in the mountains of Erulska and Lyubash. Such territories can still be discovered in Viskyar. Moderate drought locations are again unequally dispersed. Areas falling within the wet category are mainly situated in the central, southern and eastern parts of Breznik Municipality.

The year 1996 is the one with the least number of territories in the extreme drought category. They can be viewed mainly along the Konska River. Moderate drought areas are situated in the central and western parts predominantly, while the majority of the municipality's area falls within the wet category.

The situation changed in 2000. Extreme drought areas appear in the central parts and the mountains of Cherna gora to the south. More extensive moderate drought territories are located to the east. The mountains of Zavalska and Erulska may be given as examples of locations with territories falling within the wet category.

The extreme drought in 2007 was observed in the Cherna gora mountain and the Breznik Valley. There is unequal dispersal of moderate drought areas around the municipality. The mountains of Lyubash and Erulska may be given as examples of territories included in the wet category.

The year 2011 had extreme drought areas mainly in the Breznik Valley. They were accompanied by areas with moderate drought. Cherna gora mountain is in the wet category alongside the mountains of Erulska, Viskyar and Zavalska.

The last year that was in our scientific focus was 2021. The extreme drought areas were restricted back then mainly to the Breznik Valley. Moderate drought areas were mainly in the central and eastern areas of the municipality, while the territories in the wet category were prevailing, and the riverbeds of Konska and Breznishka Rivers stood out.

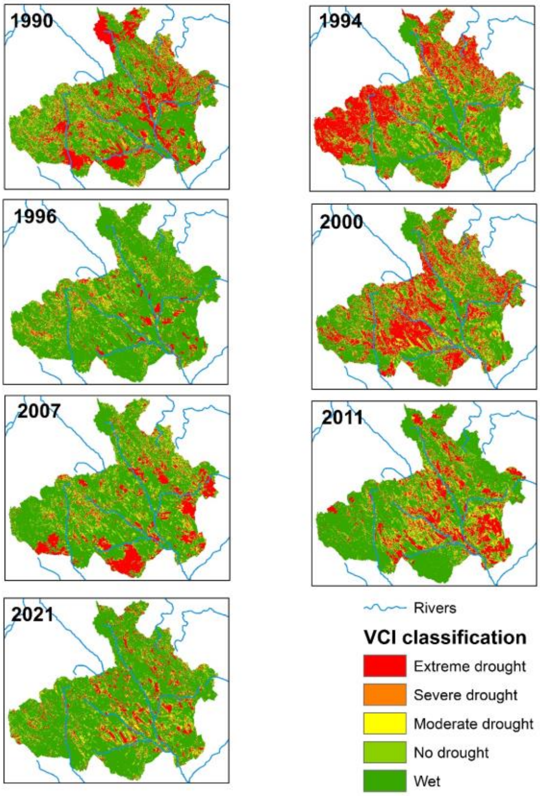

Fig. 3. Temporal changes in VCI of Breznik Municipality

The next lines consist of data regarding the drought severity, assigned to certain CLC classes. Territories that were more prone to fires will be in the focus. Forests, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation, non-irrigated arable land and transitional woodland and shrub were the classes that were under threat in 1990. Forest and semi-natural areas were under the greatest threat in 1994, with a focus on broad-leaved and mixed forests and transitional woodland and scrub. Non-irrigated arable land was the most fire-prone area in 1996. Natural grasslands, non-irrigated arable land, land principally occupied by agriculture with significant areas of natural vegetation and complex cultivation patterns were among those classes that were in greatest threat in 2000. The year 2007 had its own features. The most fire-prone areas were territories with transitional woodland-scrub, natural grasslands, non-irrigated arable land, pastures and broad-leaved forests. The non-irrigated arable land class was the most prone to fires in 2011, followed by broad-leaved forests and land principally occupied by agriculture with significant areas of natural vegetation and pastures to some extent. Non-irrigated arable land was the class that was under the biggest threat (extreme drought category) for the year 2021, followed by broadleaved forests, while the largest proportion of the other CLC classes was within the “wet” zone.

Overall, the class of the non-irrigated arable land has to be under special attention in the following years, because it is the one that was under the greatest threat according to the VCI. It is followed by broad-leaved forests, transitional woodland-scrub, land principally occupied by agriculture with significant areas of natural vegetation, complex cultivation patterns, natural grasslands and pastures. These results are consistent to some extent with those of Avetisyan & Nedkov [15] who point out that the riskiest areas are the ones that are in poor vegetation condition, represented by grasslands, shrublands and forests with *Pinus nigra* sp.

Conclusion

The present study dealt with the application of the Vegetation Condition Index (VCI). It was calculated on the basis of Landsat 8 (Landsat Collection 2 Level-2, Landsat 8–9 OLI/TIRS C2 L2) images. The VCI was calculated for the month of June, as a representative month for the years of 1990, 1994, 1996, 2000, 2007, 2011 and 2021. Territories that were under threat of fire were distinguished by the use of the Corine Land Cover classification. The analysis showed that among them are Breznik Valley and the mountains of Viskyar and Cherna gora Mountains. Non-irrigated arable land was the class that stood out the most, so it has to be a main focus of policymakers when it comes to this type of natural hazard. The results of the study showed promise and may serve as a basis for extending this type of research to neighbouring administrative units and adjacent territories.

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References

1. Rogan, J., D. Chen. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. *Progress in Planning*, vol. 61, iss. 4, pp. 301–325. https://doi.org/10.1016/S0305-9006(03)00066-7
2. Hemati, M., M. Hasanlou, M. Mahdianpari, F. Mohammadimanesh. (2021). A systematic review of landsat data for change detection applications: 50 years of monitoring the earth. *Remote Sensing*, vol. 13, iss. 15. https://doi.org/10.3390/rs13152869
3. Radočaj, D, Plaščak, I., Jurišić, M., Majić, I., Ozimec, S., Sarajlić, A. & Rožac ,V. (2024). Phenology analysis for detection of vegetation changes based on Landsat 8 images in Nature Park Kopački rit, Croatia. *Geographica Pannonica*, vol. 28, iss. 4, pp. 238–249. https://doi.org/10.5937/gp28-50802

4. Touminen, J., T. Lipping, V. Kuosmanen, R. Haapanen. (2009). Remote Sensing of Forest Health. In: P. Gee, P. Ho (Eds.). *Geoscience and Remote Sensing*, INTECH, 29–52. https://doi.org/10.5772/8283
5. Huang, S., L. Tang, J. Hupy, Y. Wang, G. Shao. (2021). A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. *Journal of Forestry Research*, vol. 32, iss. 1, pp. 1–6. https://doi.org/10.1007/s11676-020-01155-1
6. Kogan, F. (1990). Remote sensing of weather impacts on vegetation in non-homogeneous areas. *International Journal of Remote Sensing*, vol. 11, iss. 8, pp. 1405–1419. DOI: 10.1080/01431169008955102
7. Liu, W., F. Kogan. (2002). Monitoring Brazilian soybean production using NOAA/AVHRR based vegetation condition indices. *International Journal of Remote Sensing*, vol. 23, iss. 6, pp. 1161–1179. DOI: 10.1080/01431160110076126
8. Domenikiotis, C., M. Spiliotopoulos, E. Tsiros, N. Dalezios. (2004). Early cotton yield assessment by the use of the NOAA/AVHRR derived Vegetation Condition Index (VCI) in Greece. *International Journal of Remote Sensing*, *25*, 14, 2807–2819. DOI: 10.1080/01431160310001632729
9. Quiring, S., S. Ganesh. (2010). Evaluating the utility of the Vegetation Condition Index (VCI) for monitoring meteorological drought in Texas. *Agricultural and Forest Meteorology*, vol. 150, iss. 3, pp. 330–339. https://doi.org/10.1016/j.agrformet.2009.11.015
10. Dutta, D., A. Kundu, N. Patel, S. Saha, A. Siddiqui. (2015). Assessment of agricultural drought in Rajasthan (India) using remote sensing derived Vegetation Condition Index (VCI) and Standardized Precipitation Index (SPI). *The Egyptian Journal of Remote Sensing and Space Science*, vol. 18, iss. 1, pp. 53–63. https://doi.org/10.1016/j.ejrs.2015.03.006
11. Jiao, W., L. Zhang, Q. Chang, D. Fu, Y. Cen, Q. Tong. (2016). Evaluating an Enhanced Vegetation Condition Index (VCI) Based on VIUPD for Drought Monitoring in the Continental United States. *Remote Sensing*, vol. 8, iss. 224. doi:10.3390/rs8030224
12. Zambrano, F., M. Lillo-Saavedra, K. Verbist, O. Lagos. (2016). Sixteen Years of Agricultural Drought Assessment of the BioBío Region in Chile Using a 250 m Resolution Vegetation Condition Index (VCI). *Remote Sens.*, vol. 8, iss. 530. https://doi.org/10.3390/rs8060530
13. Qian, X., L. Liang, Q. Shen et al. (2016). Drought trends based on the VCI and its correlation with climate factors in the agricultural areas of China from 1982 to 2010. *Environ Monit Assess*, vol. 188, iss. 639. https://doi.org/10.1007/s10661-016-5657-9
14. Kamble, D., S. Gautam, H. Bisht, S. Rawat, A. Kundu. (2019). Drought assessment for kharif rice using standardized precipitation index (SPI) and vegetation condition index (VCI). *Journal of Agrometeorology*, vol. 21, iss. 2, pp. 182–187. https://doi.org/10.54386/jam.v21i2.230
15. Avetisyan, D., R. Nedkov. (2015). Assessment of Fire Hazard Zones in the Forest Landscapes in Simitli Municipality (Bulgaria). *Journal of Environment Protection and Sustainable Development*, vol. 1, iss. 4, 225–233.
16. Avetisyan, D., B. Borisova, R. Nedkov. (2016). Determination of the Landscapes Regulation Capacity and Their Role in the Prevention of Catastrophic Events: A Case Study from the Lom River Upper Valley, Bulgaria. In: Koulov, B., G. Zhelezov (Eds.). *Sustainable*

Mountain Regions: Challenges and Perspectives in Southeastern Europe. Springer, Cham. https://doi.org/10.1007/978-3-319-27905-3_13
17. Roumenina, E., L. Filchev, V. Naydenova, G. Jelev, P. Dimitrov, V. Vassilev, L. Kraleva. (2014). Monitoring of winter crop status in Bulgaria using a series of NOAA AVHRR NDVI images. *Canadian Journal of Remote Sensing*, vol. 36 (sup2), 224–230. https://doi.org/10.5589/m10-057
18. Chanev, M., L. Filchev. (2021). Satellite monitoring of wheat yields in Bulgaria. – *Journal of Mountain Agriculture on the Balkans*, vol. 24, iss. 5, pp. 373–395.
19. Dimitrov, Z. (2022). Polarimetric analysis of Alos Palsar Data (Pol-Sar) over test areas in North-West Bulgaria – Polarimetric descriptors, decompositions and classifications. *Aerospace Research in Bulgaria*. vol. 34, pp. 29–54. https://doi.org/10.3897/arb.v34.e03
20. Moni, D., D. Avetisyan. (2024). Comparative analysis of secondary ecological succession following widlfires in three distinct forest types. A study case from Moguer, Spain. *Aerospace Research in Bulgaria*. vol. 36, pp. 94–105. https://doi.org/10.3897/arb.v36.e08
21. Zagorchev, I., V. Kostadinov, D. Chunev, R. Dimitrova, I. Sapunov, P. Chumachenko, S. Yanev. (1991). *Geological map of the Republic of Bulgaria, Scale 1:100 000. Vlasonitse and Breznik Map sheet*. Sofia, Committee of Geology and Mineral Resources (in Bulgarian).
22. Koynov, V., H. Trashliev, M. Yolevski, T. Andonov, N. Ninov, A. Hadjijanakiev, E. Angelov, T. Boyagiev, E. Fotakieva, S. Krastanov, I. Stainkov. (1968). *Soil Map of Bulgaria, Scale 1:400 000*. Sofia, General Administration of Geodesy and Cartography.
23. 23 Council Directive 92/43/EEC (1992) on the conservation of natural habitats and of wild fauna and flora. http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
24. Kogan, F. (1995). Droughts of the Late 1980s in the United States as Derived from NOAA Polar – Orbiting Sattelite Data. *Bulletin of the American Meteorological Society*.
25. CORINE Land Cover (2018) https://land.copernicus.eu/pan-european/corine-land-cover (Accessed 2024-8-9)

ОЦЕНКА НА ПОДАТЛИВИ КЪМ ПОЖАРИ РАЙОНИ ЧРЕЗ ИЗПОЛЗВАНЕ НА САТЕЛИТНИ ДАННИ: ОБЩИНА БРЕЗНИК (ЗАПАДНА БЪЛГАРИЯ)

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Резюме

Настоящото изследване е насочено към прилагането на вегетационния индекс VCI. Целта е да бъдат открити райони, податливи на пожари. Обектът на изследване е община Брезник. Използвани са данни от Landsat 8, като са приложени и класове Corine Land Cover с цел анализ. Основен фокус е месец юни през годините: 1990, 1994, 1996, 2000, 2007, 2011 и 2021. Резултатите варират за различните години. Ненапояваните обработваеми земи излизат на преден план, като класът, който е най-застрашен.