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Spatial analysis of wildfire occurrence in the Emerald Network sites of Volyn and Zhytomyr Polissia (2012-2024)

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SUMMARY

The paper analyzes the spatial and temporal distribution of wildfires over a 13-year period in 36 sites of the Emerald Network located within the Ukrainian Polissia region. Materials of remotely sensed data from MODIS satellites provided by the European Forest Fire Information System (EFFIS) were used. The number of hotspots in each of the Emerald Network sites was calculated, and the density of fires was determined both in individual sites and for the entire territory. The temporal distribution of wildfires occurrence was analyzed, and the years and seasons of the maximum and minimum number of fires were identified. The area of burned land was estimated. The Emerald Network sites were ranked according to the obtained quantitative indicators. The locations and types of ecosystems most and least affected by fires were identified. It was established that most of the studied Emerald Network sites are characterized by a lower frequency of wildfires occurrence compared to the average values for the region.

Introduction

Wildfires are significant threats to ecosystems and require continuous detailed monitoring. Today, remote sensing methods greatly assist in fire monitoring. Thermal infrared channels from various satellites can detect thermal anomalies that can most often be correlated with wildfires (Soshenskyi et al., 2021, Kussul et al., 2023). Current climate changes in the Ukrainian Polissia region significantly contribute to the increased fire risk (Karamushka, et al., 2023, Zibtsev et al., 2019). For example, the dry winter of 2019-2020 caused a series of large-scale fires in March-April 2020, which destroyed thousands of hectares of natural ecosystems (Sydorenko et al., 2024) and significantly worsened air quality (Savenets et al., 2020). Several large fires in September 2024 also occurred after a prolonged dry period with high temperatures and high evaporation.
Protected areas require special monitoring, as they often represent the most valuable parts of the region's ecosystems. On the one hand, the protected status should contribute to less anthropogenic impact and, consequently, a lower risk of fires. On the other hand, when fires occur, it is often more difficult to extinguish them in protected areas due to their remoteness and lack of appropriate infrastructure.
Volyn and Zhytomyr Polissia are located in the north and northwest of Ukraine and cover most of the Volyn, Rivne, and Zhytomyr regions. For comparison purposes, this study also covers a few sites within these administrative units, but outside the Polissia natural region.
Several previous studies examined fires in the Volyn region (Fesyuk et al., 2020, Kovalchuk et al., 2024), Rivne region (Zibtsev et al., 2019), and Zhytomyr region (Humenyuk et al., 2021). In our study, we want to analyze relevant data primarily for Emerald Network sites in these regions.

Method and Theory

To obtain the initial data, the European Forest Fire Information System (EFFIS) service was used, from where the dataset of thermal anomalies recorded by MODIS Aqua and MODIS Terra satellites for the period from February 2012 to December 2024 was downloaded. This dataset contains data on the location, time and tools for recording thermal points and their individual quantitative characteristics (frp – fire radiation power, brightness, etc.) (San-Miguel- Ayanz, et al., 2012). Not all detected hotspots correspond to wildfires, but the dataset can be filtered by frp and confidence.
Data was sampled for the territory of Volyn, Rivne and Zhytomyr regions of Ukraine. According to the confidence index, data with a value of less than 40% were excluded (13.2% of them were found to be so). The main statistical indicators of fire occurrence for this period were calculated. A corresponding vector data layer was created in QGIS.
The next step was to create a layer of contours of Emerald Network objects in the area of interest, according to the Emerald portal Network by European Environment Agency (emerald.eea.europa.eu)
Then, using QGIS spatial analysis tools, the number of hotspots within each of the Emerald Network objects was calculated. The area of burned areas for the period 2020-2024 was also estimated according to the EFFIS Burnt Area product. The objects were compared based on the obtained results.

Results

Over the specified period 2012-2024, more than 30 thousand thermal anomalies that can be associated with wildfires were recorded by remote sensing methods in the region. After filtering out cases with a value of less than 40% confidence, this number amounted to about 27.5 thousand.
Figure 1 shows the distribution of wildfire density by region and by year.
As we can see, the highest rates were more often observed in Rivne region, the lowest in Volyn region (except for 2012 and 2017). In 2020, 2022 and 2023, the highest fire density was in Zhytomyr region.
In general, the average annual fire density across the territory was 0.035 per 1 square kilometer, but in different years it ranged from 0.0032 to 0.124 (or from 3.2 to 124 per 1 thousand sq. km). The average density for the entire period under review was 0.4/ sq. km.

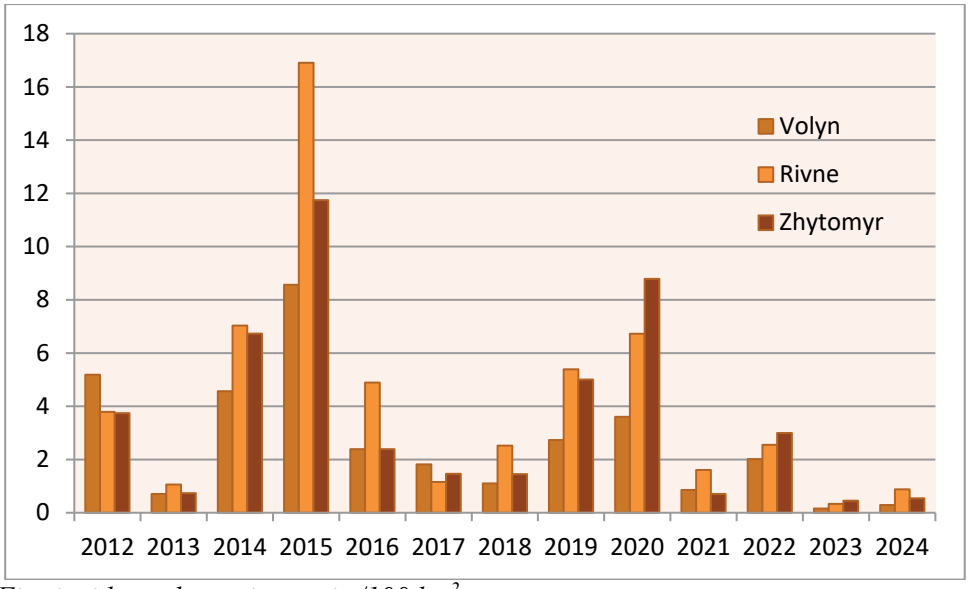


Figure 1 *Fire incidence by region, units/100 km^2.*

The maximum number of fires was recorded in 2015, 2020, 2014 and 2019, and the minimum number - in 2013, 2023 and 2024. Almost all of these cases are closely related to the corresponding weather conditions. In terms of seasons, March and April are clearly distinguished by the maximum number of fires (more than half of the total number), as well as August-September, and partly October. In other periods, there are few fires, with the exception of individual cases (November 2014, July 2015, May 2022).

As for the Emerald Network sites themselves, a total of about 2.5 thousand thermal anomalies were recorded within their boundaries during the period 2012-2022, which, in terms of area, gives a fire density of 0.212 per 1 sq. km. This is almost half the average fire density for the territory of these regions.

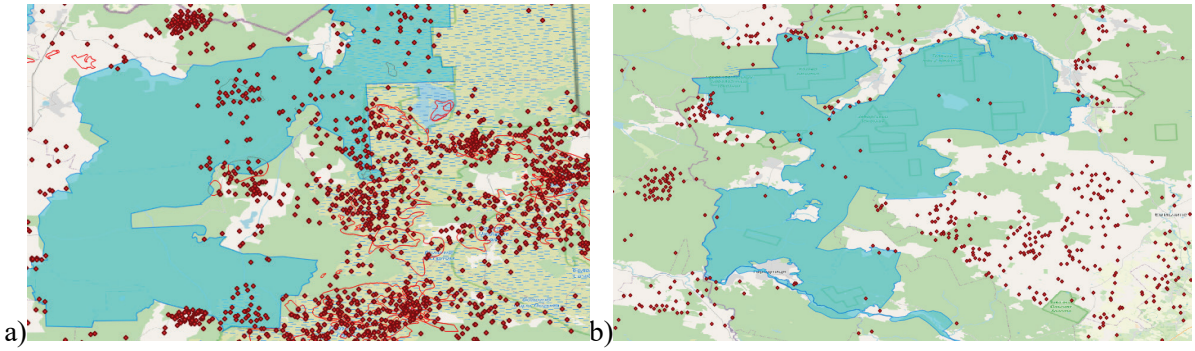
However, this indicator varies significantly in different objects. In 11 of them, the density is even higher than the average for the region (sites Chornohuzka, Poznan-Blazhove, Rivnenskyi Nature Reserve, Nyzhnii Sluch, Stokhid-Nobel, Zaplava Turia-Prypiat, Styr river valley in Volyn_region, Prypiat-Stokhid National Nature Park, Drevlianskyi Nature Reserve, Ovrutskyi, Dubrovytsko-Sarnynskyi). The majority of these are vast areas of river floodplains with reed-meadow vegetation in the north of the region.

Table 1 *Fire frequency within Emerald Network Sites.*

Site Name	*Site Area, ha*	*total of wildfires, 2012-202 4*	*density of wildfire, units per sq. km*	*Site Name*	*Site Area, ha*	*total of wildfires, 2012-202 4*	*density of wildfire, units per sq. km*
Chornohuzka	*2136*	*27*	*1,264*	*Korchyk_river_valley*	*2271*	*4*	*0.176*
Poznan- Blazhove	*7624*	*80*	*1,049*	*Shatskyi*	*54128*	*81*	*0.150*
Rivnenskyi Nature Reserve	*42924*	*362*	*0.843*	*Teteriv_river_valley*	*51710*	*59*	*0.114*
Nyzhnii Sluch	*13532*	*107*	*0.791*	*Liubokhynskyi*	*3793*	*4*	*0.105*
Stokhid -Nobel	*41874*	*268*	*0.640*	*Tsumanska Pushcha*	*42852*	*44*	*0.103*
Zaplava Turia-Prypiat	*16196*	*92*	*0.568*	*Nadsluchanskyi Regional Landscape Park*	*17248*	*17*	*0.099*

Styr_river_valley _ in_Volyn_region	*16847*	*93*	*0.552*	*Korostyshivskyi*	*41696*	*41*	*0.098*
Pripyat-Stokhid National Nature Park	*38940*	*195*	*0.501*	*Sluch_river_valley _ in_Rivne_region*	*3572*	*3*	*0.084*
Drevlianskyi Nature Reserve	*32178*	*153*	*0.475*	*Horodnytskyi*	*54260*	*38*	*0.070*
Ovrutskyi	*45237*	*213*	*0.471*	*Prybuzhzhia*	*14263*	*9*	*0.063*
Dubrovytsko-Sarnynskyi	*39469*	*183*	*0.464*	*Hrinnytskyi -Styr*	*5057*	*3*	*0.059*
Zakhidne Pobuzhzhia	*14222*	*49*	*0.345*	*Turiiskyi*	*17019*	*10*	*0.059*
Poliskyi	*36465*	*110*	*0.302*	*Zakhidno-Ovrutskyi*	*33452*	*19*	*0.057*
Slovechanskyi Kriazh	*95849*	*256*	*0.267*	*Bober_river_valley*	*7313*	*4*	*0.055*
Dubrovytskyi	*38802*	*101*	*0.260*	*Cheremskyi Nature Reserve*	*2949*	*0*	*0.0*
Dermansko-Ostrozkyi National Nature Park	*5436*	*13*	*0.239*	*Markovychi*	*53*	*0*	*0.0*
Irsha_river_valley in_Zhytomyr_region	*1011*	*23*	*0.227*	*Cherevaskyi Lis*	*1749*	*0*	*0.0*
Sluch_river_valley in_Zhytomyr_region	*7746*	*16*	*0.207*	*Zdolbunivski Stavky*	*208*	*0*	*0.0*

But a visual analysis of created maps often shows that a significant part of the territory of the Emerald Network sites is not covered by fires, or there are much fewer of them than in the surrounding areas (Fig 2).



a) b)

Figure 2 *Examples of fire density distribution around individual Emerald network objects (a - Dubrovytsko-Sarnynskyi, b - Horodnytskyi).*

25 of the 37 sites considered have a fire density index lower than average, 14 of them have less than 1 fire per 1000 ha. In 4 sites (Cheremskyi Nature Reserve, Markovychi, Cherevaskyi Lis, Zdolbunivski Stavky) not a single hotspot has been recorded in 13 years. At the same time, Cherevaskyi Lis is a well-known tourist destination, and Zdolbunivski Stavky is located near densely populated areas.

By identified areas of large fires (more than 30 hectares) for 2020-2024, the largest indicators (over 1 thousand hectares) are in Ovrutskyi, Prypiat-Stokhid, Stokhid-Nobel, Poliskyi, Rivnenskyi Nature Reserve, Drevlianskyi Nature Reserve, Slovechanskyi Kriazh. Most of these fires occurred in March-April 2020. In Ovrutskyi, Prypiat-Stokhid, and Stokhid-Nobel sites, more than 10% of the territory has burned. However, 17 sites have not recorded a single burned area in the previous 5 years, and 5 sites have only one burned area each.

Conclusions

Retrospective analysis of remote sensing data makes it possible to establish the main spatiotemporal features of fire spread, including in protected areas. Assessment of fire occurrence in the Emerald

Network sites in the three northern regions of Ukraine showed that such sites were mostly much less affected by fires than the surrounding areas (density of about 0.2 per sq.km). The exceptions were some facilities in the northern areas, which are mostly dominated by meadow-floodplain vegetation, and only in a few cases by forest.
The largest number of fires occurred in 2014-2015 and 2019-2020. More than half of the fires occurred in March-April and a significant part in August-October. March-April 2020 is distinguished by the largest burned area, March-April 2022 and September 2024 are significantly smaller. However, almost half of the Emerald Network sites did not record any wildfire area.
Thus, despite their different structures and protection status, the Emerald Network areas generally provide greater protection of habitats from fire threats. However, due to increasing climatic and anthropogenic threats, they also require detailed monitoring and more protection.

Acknowledgements

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