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Climate impact drivers provoke fires in protected areas of Polissia

***V. Karamushka** *(National University of Kyiv-Mohyla Academy)*, **S. Boychenko** *(National University of Kyiv-Mohyla Academy; S. I. Subbotin Institute of Geophysics of the NAS of Ukraine)*, **O. Nazarova** *(National University of Kyiv-Mohyla Academy)*

SUMMARY

The purpose of the research was to analyze the dynamic of the climate impact drivers (CIDs) in the Regional Landscape Park Mizhrichynskyi (RLPM), Chernihiv Region, and to determine changes occurred in the protected areas affected by CIDs using the satellite monitoring data. It is shown that in the region for the period 1991-2021, such CIDs as the average annual surface temperature have a tendency to increase (the rate is 0.68ºC per 10 years, average annual value is 8.4±0.9ºC), while atmospheric precipitation tends to decrease by 5-7% per 10 years (-24 mm per 10 years, an average annual value is 581±94 mm). During periods with minimal precipitation and high temperatures, conditions favorable for the development of fires arise. Such conditions were observed in 2020. As a result of the fire in the RLPM (April 2020), more than 650 hectares of forest ecosystems were affected. Using the satellite monitoring data, the area of the territory covered by the fire was determined, and using the Normalized Difference Vegetation Index as an indicator, the development of successional processes in this territory was recorded. Field studies confirm the occurrence of pioneer species in the fires. The list of these species includes but not restricted to *Viola tricolor, Pinus sylvestris, Salix rosmarinifolia, Corynephorus canescens, Oenothera biennis* L., *Hieracium pilosella* L.

Introduction

Long-term studies of the natural ecosystems of the Ukrainian Polissia show that they are characterized by a wealth of biodiversity and biotopes. However, they remain under the influence of anthropogenic and natural factors and are very vulnerable. The most significant among the natural factors are those related to climate change. The Intergovernmental Panel on Climate Change Sixth Assessment Report (*IPCC, 2021*) on the physical scientific basis of climate change identifies 32 climate impact drivers (CIDs). These factors create the conditions under which human society and natural ecosystems are developing and changing. However, not all of the identified CIDs are active in the Polissia region. In particular, CIDs for coastal and oceanic systems are not applicable. Relevant for this region are CIDs related to such characteristics as temperature, humidity, solar radiation, air currents. Short- and long-term changes of these characteristics, which are determined by analysing data from meteorological observations from local weather stations, NASA databases and other sources, cause some impact on natural and anthropogenic systems. Such impact can be significant. In particular, climatic conditions play a triggering role in the spread of forest fires, which affects almost all continents of the planet (*Melnyk and Voron, 2021*). And although the cause of the vast majority of fires is the human factor, long periods of high temperature and lack of precipitation create conditions favourable for the occurrence and spread of fires in natural systems.

In 2020, it was observed a waterless spring and dry summer. At the same time, multiple fires covered most of the countries of Europe. In Ukraine, the area of forests affected by such fires has reached tens of thousands of hectares (*Karamushka et al., 2020*). One such fire occurred in April 2020 on the territory of the Regional Landscape Park Mizhrichynskyi (RLPM), Chernihiv Region, and resulted in complete or partial damage of hundreds of hectares of forest systems. The purpose of the paper is to describes briefly results of the study aimed at the analysis of the climatic conditions in the region and, using the satellite monitoring data, to determine what changes occurred in the protected areas affected by fires. The study was focused on the territory and ecosystems of the Regional Landscape Park Mizhrychynsky.

Methods and data sources

Trends in changes of climatic indicators (surface air temperatures and atmospheric precipitation) were determined by analysing observation data at the nearest meteostation Oster for the period 1991-2021 (*CGO, 2021*). The state and changes in the vegetation activity of the territories were assessed using the Normalized Difference Vegetation Index (NDVI) (*Rouse et al., 1973*). NDVI values were obtained automatically using the optional RS&GIS image processing module. Territorial distribution of NDVI obtained from the space images of the Sentinel-2 satellite applying the EO-browser tool (https://apps.sentinel-hub.com/eo-browser). The main source of data on fires in natural ecosystems were the open materials of the State Emergency Service of Ukraine, in particular, presented in the National reports on the state of man-made and natural safety in Ukraine in 2002-2015, analytical reviews of the state of man-made and natural safety in Ukraine in 2016-2018 (see, for example, *SESU, 2019*) and other reporting materials.

Results

As can be seen from the data presented in Figure 1, in the studied region at least for the period 1991-2021 the average annual surface temperature has a pronounced tendency to increase at a rate of 0.68ºC per 10 years (with an average annual value for the period of 8.4±0.9 ºC). Average annual value of the sum of atmospheric precipitation is 581±94 mm per year. During 1991-2021 it tends to decrease by 5-7% per 10 years (-24 mm per 10 years). Note that relatively rapid increase in surface temperature and a decrease in the amount of atmospheric precipitation, especially in summer, has become characteristic of the entire territory of Ukraine *(Boychenko et al., 2016, 2018; Karamushka et al., 2022).*

The seasonal variation of trends of temperature and precipitation for meteostation Oster for the periods 1991–2021 are shown in Figure 2. As can be seen, the temperature is increasing throughout the year, while the amount of precipitation is decreasing mainly in the warm period of the year. In addition, weather conditions vary from year to year. In particular, let's point out the situation in the region in 2001: the average annual temperature was the lowest (7.7ºC), while for the same period the most precipitation fell (734 mm). In 2018-2020, the opposite situation was observed: at the highest values of the average annual temperature (9.9 and 10.3 °C), the lowest precipitation rates (338 mm and 480 mm) were recorded.

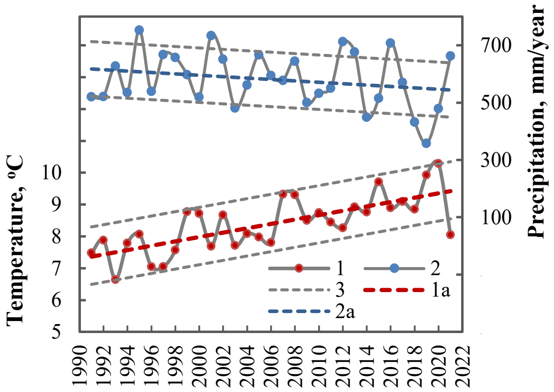

Figure 1 *Dynamic of the average annual air temperature (1) and the average annual amount of precipitation (2) for the meteostation Oster (1a and 2a are linear trend, 3 is ±σ from trend) for the period 1991–2021*

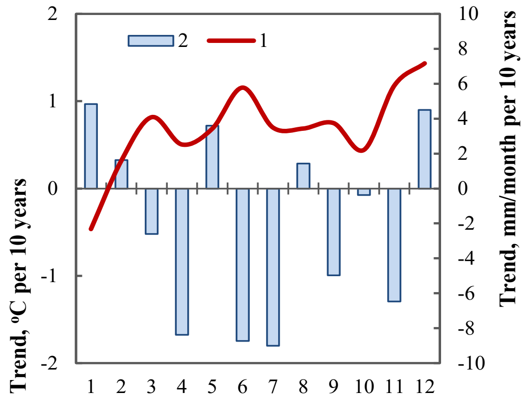

Figure 2 *Seasonal variation of trends of temperature (1) and precipitation (2) for the meteostation Oster for the period 1991–2021*

Such weather conditions were favourable to the occurrence and spread of fires in Ukraine. Perhaps that is why the area of forest fires in Ukraine in 2020 was the largest since at least 2010 (Figure 3), while their number did not much exceed the average annual and summer average monthly values. So, on April 8, 2020, a fire broke out in the Regional Landscape Park Mizhrychynsky. According to the data of the State Enterprise "Chernihiv State Forestry", the area affected by the fire was 731.6 hectares.

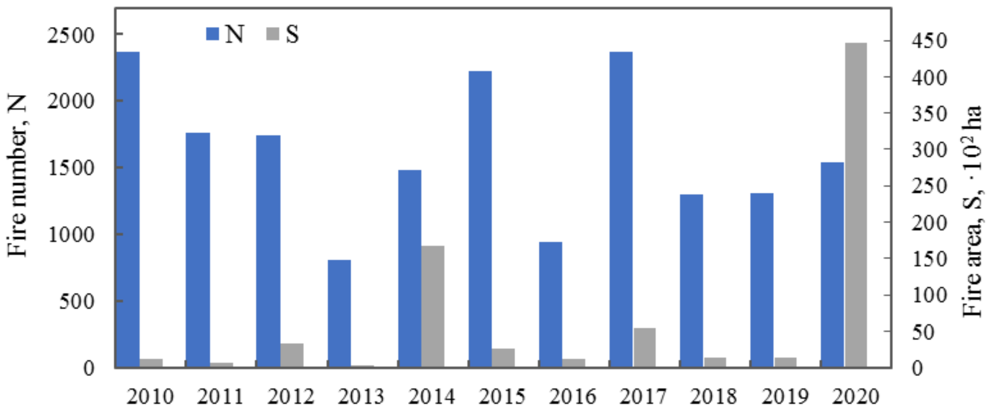

Figure 3 *The number (N) and area (S) of forest fires in Ukraine in 2010 - 2020 according to the data of the State Emergency Service of Ukraine (SESU, 2019)*

According to our estimates based on satellite monitoring data, the territory of the MRLP affected by the pyrogenic factor has a smaller area (Figure 4). The fire covered massive areas of both natural forests and areas of relatively young plantations. Among the tree species, *Pinus sylvestris* dominated. The burned area included mosaic islands of groups of trees that were partially burned or completely preserved. Solid grass cover of the areas affected by the fire was mainly absent as early as November 2020, but the processes of secondary succession in the form of individual plants were already visible. *Viola tricolor, Pinus sylvestris*, *Salix rosmarinifolia*, *Corynephorus canescens, Oenothera biennis* L., *Hieracium pilosella* L. and some others are among the pioneer species. Evaluation of the photosynthetic activity of the plant cover of this area, using NDVI, shows its minimum values precisely in the affected area. Therefore, the area of the territory with the minimum NDVI values corresponds to the area of the MRLP affected by the pyrogenic factor and, according to the data, is about 657 hectares. Pictures in infrared light are indicative in this regard (Figure 4). Discrepancies in estimates of the affected area by remote sensing and *in situ* survey can have different reasons, but satellite monitoring makes it possible to monitor the processes of physiological activity of the plant cover remotely without field visits.

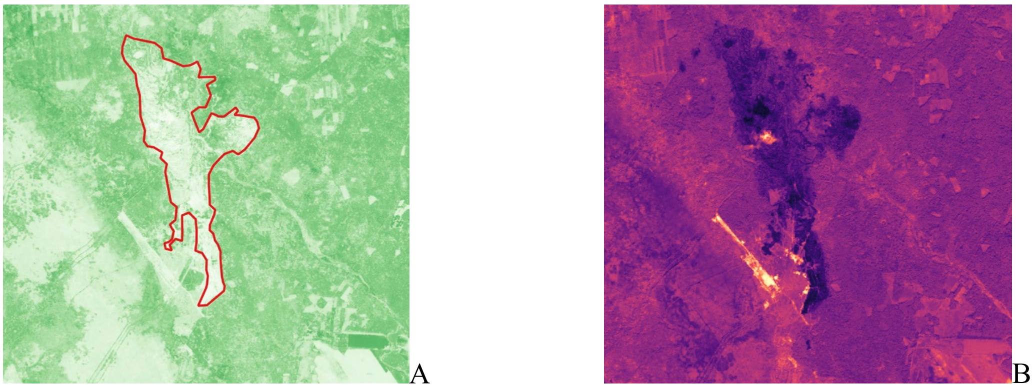

Figure 4 *Visualization of the photosynthetic activity of plant cover (by NDVI) of the MRLP area affected by the pyrogenic factor in the visible (a) and infrared (c) parts of the spectrum. The pictures show the state of the territory on May 2, 2020.*

The NDVI value is very sensitive to changes in the vegetation activity of the plant cover. Such indicators are minimal at the beginning of spring for both the native and damaged territory (Figure 4), but increase with warming, in particular, in May. This indicates that the territory, covered by the fire, include areas where the vegetation was less damaged or completely preserved during the fire. The increase in NDVI becomes especially noticeable in the images that record the condition of the site after one year and two years later (Figure 5). This is an evidence of the restoration of the affected area. At the same time, the NDVI values of the affected areas are noticeably different from the values of the preserved areas, which can be seen in the pictures during the specified observation period (2020-2022). The area of the forest turned into a forest fire has practically lost its original ecological capacity, which is gradually being restored.

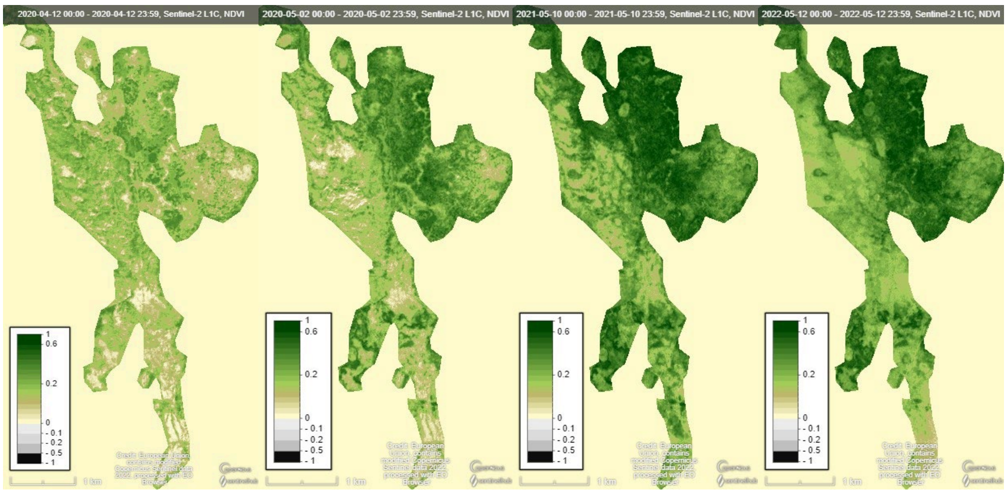

Figure 5 *Distribution of NDVI in the area of the MRLP affected by the fire on April 8, 2020. Data received (from left to right) on 12 April 2020, 02 May 2020, 10 May 2020 and 12 May 2022.*

Conclusions

The average annual surface air temperature in the region of Chernihiv Polissia (location of the MRLP) has been increasing markedly for at least the last 30 years. In the same period, the average annual precipitation is slowly decreasing. The uneven manifestation of these changes is the cause of weather conditions that can have a significant impact on natural and anthropogenic systems. In particular, fires in natural ecosystems are largely caused by the human factor. However, conditions that increase fire hazards and pose a real threat to human and natural environments can result from exposure to CIDs. Such conditions were observed at the beginning of 2020 as a result of a dry winter, a spring with little water and relatively high temperatures in the cold season. In this situation, the influence of such CIDs as air temperature (it was elevated) and atmospheric precipitation (it was significantly decreased) was very effective. That is why fires, provoked mainly by human activity, covered large areas of natural ecosystems, human settlements, and agricultural lands.

Forest ecosystems affected by fires lose their ecological capacity and ability to provide ecological services for a long time. This results in the restriction of the access of local communities to important natural resources. The satellite monitoring data as a tool for monitoring the state of territories affected by fires indicate the development of successional processes after a fire in such territories. In particular, remote sensing data confirm the results of field studies of the fire-affected area of the MRLP (April, 2020) with an area of more than 650 hectares and testify to the ability of the forest ecosystem to recover.

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