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Remote sensing-based research of potential areas of wildfire hazard using Google Earth Engine

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SUMMARY

The study is focused on identifying potential areas of wildfire hazard in Ukraine using the Google Earth Engine (GEE) cloud platform, which provides processing of large volumes of satellite and geospatial data. The relevance of the topic is due to the increased risk of wildfires caused by climate change, anthropogenic impact, and the consequences of full-scale war, which pose a threat to natural ecosystems and biodiversity. The study did not distinguish between types of fires, but covered the natural forest and steppe ecosystems characteristic of Ukraine. The methodology involved determining the fire-hazardous period (April–November) and forming an integrated fire hazard index based on six key factors: surface temperature, precipitation, soil moisture, vegetation moisture, wind speed, and slope. The eight open satellite datasets from the GEE catalogue cover the period from 2003 to 2024. The datasets were processed by reclassifying the index values and generating thematic maps. The results showed that the highest level of wildfire hazard is observed in the south and east of Ukraine, while the mountainous regions of the Carpathians and northern regions have a lower level of risk. The data obtained are consistent with MODIS archival satellite observations of fire areas. The study can aid in planning preventive fire safety measures in areas with higher risk.

Keywords: Google Earth Engine; GIS; remote sensing; geospatial analysis; fire hazard; climate change; reclassification; monitoring; forests; MODIS

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Introduction

Wildfires are uncontrolled fires in natural ecosystems caused by lightning strikes, spontaneous combustion of hay and peat, unextinguished sulfur, smoldering cigarette butts, sparks from vehicles, and other ignition sources. The main types of wildfires that can cover large areas, ranging from hundreds to thousands of hectares, include forest fires, peat fires, and grassland (steppe) fires. In this study, the authors did not analyze wildfires separately according to their specific types. Instead, the research focused on natural ecosystems such as forests and steppes, which are widespread within the territory of Ukraine.

The significance of this study is highlighted by the growing risk of wildfires in Ukraine, driven by climate change and human activities. The ongoing full-scale war exacerbates the situation, leading to the degradation of natural ecosystems and posing a threat to biodiversity. In this context, it is imperative to use modern methods of geoinformation modelling (Karpinskyi et. al., 2021) and cloud technologies (Piao et al., 2022; Tavakkoli Piralilou et al., 2022), such as Google Earth Engine, to process large amounts of geospatial data and quickly identify potentially dangerous areas and monitor fire hazard dynamics to prevent environmental disasters.

The study aims to identify potential areas of wildfire hazard using cloud technologies, remote sensing methods, and satellite data, considering the trend of increasing air temperatures, decreasing precipitation, and increased wind speeds in Ukraine. The study defines the fire hazard period as the part of the year when forest and steppe fires occur (from the moment the snow cover melts in spring until the onset of stable wet autumn weather or the formation of snow cover), from April to November.

Method and Theory

Google Earth Engine is a cloud-based platform for planetary-scale geospatial analysis that brings Google's massive computational capabilities to bear on a variety of high-impact societal issues, including deforestation, drought, disaster, disease, food security, water management, climate monitoring and environmental protection (Gorelick et al., 2017).

The evaluation of wildfire vulnerability utilizing the geoinformation platform and machine learning techniques was explored by researchers in various studies (Costa-Saura, 2022; Cinar & Aydin, 2023; dos Santos et al., 2023; Chen et al, 2024; Jodhani, 2024; Matsala et al., 2024; Kin et al., 2025; Mohammed Khan et al., 2025), which considered factors related to climate, terrain, hydrology, and human activity.

Another important indicator for analyzing wildfires is the Fire Weather Index (FWI). FWI is a meteorological index used to assess fire danger in a region. It consists of components that take into account the influence of fuel moisture and wind on fire behavior and spread. The higher the FWI, the more favorable the meteorological conditions are for initiating a forest fire.

The paper proposes the following method for identifying potential areas of wildfire hazard: determining the territory and period of the study; identifying favorable conditions for the occurrence of natural forest and steppe fires; forming a mathematical model of the integral indicator of wildfire hazard; reclassification – establishing correspondence between indicator values and physical quantities of earth surface temperature, precipitation, soil moisture, plant moisture, slope, and wind speed; collection and processing of input geospatial data on the GEE platform; determination of the integral indicator of wildfire hazard for the territory of Ukraine; comparison of research results with MODIS satellite monitoring data and construction of thematic maps.

Results

We used geospatial data sets that are publicly available on the GEE platform to conduct the study. The main metadata for these data sets are presented in Table 1. The license for each data set is specified

separately on the metadata page for each set in the catalog, but all data sets used are published under an open license.

Table 1. *Description of source data*

Dataset for the research	***Name of the source dataset***	***Period***	***Units of measurement***	***Link to the function***
Administrative units	FAO GAUL 500m: Global Administrative Unit Layers. ADM1_NAME	2014-12-19	0.5 pt	ee.FeatureCollection ("FAO/GAUL_SIMPLIFIED_500m/2015/level1")
Precipitation	TerraClimate: Monthly Climate and Climatic Water Balance for global terrestrial surfaces. Precipitation accumulation	2010-08-01 – 2018-08-15	mm	ee.ImageCollection("IDAHO_EPSCOR/TERRACLIMATE")
Soil moisture	TerraClimate: Monthly Climate and Climatic Water Balance for global terrestrial surfaces. Soil moisture, derived using a one-dimensional soil water balance model	2010-01-01 – 2022-12-31	mm	ee.ImageCollection("IDAHO_EPSCOR/TERRACLIMATE")
Vegetation moisture	USGS Landsat 8 Collection 2 Tier 1 TOA Reflectance. Near-infrared and Shortwave infrared 1	2013-01-01 – 2023-12-31	-	ee.ImageCollection("LANDSAT/LC08/C02/T1_TOA")
Ground surface temperature	MOD11A1.061 Terra Land Surface Temperature and emissivity values	2003-01-01 – 2024-01-01	K	ee.ImageCollection("MODIS/061/MOD11A1")
Wind speed	MERRA-2 M2T1NXFLX: Surface Flux Diagnostics. Surface wind speed	2023-01-01 – 2023-12-31	m/s	ee.ImageCollection("NASA/GSFC/MERRA/flx/2")
Digital elevation model	NASADEM: NASA NASADEM Digital Elevation 30m. Integer heights in the merged void-free DEM files are relative to the EGM96 geoid	2000-02-11	m	ee.Image("NASA/NASADEM_HGT/001")
Fires in Ukraine	MCD64A1.061 MODIS Burned Area Monthly	2003-01-01 – 2023-11-01	-	ee.ImageCollection("MODIS/061/MCD64A1")

The authors of the research developed a program using Google Earth Engine and a research method to identify potential areas of wildfire hazard in Ukraine over the past 20 years.

The research results webpage is available at the following link: https://ee-kindanylo.projects.earthengine.app/view/fwi-ukraine-eng.

The authors created a thematic map of potential areas of wildfire hazard (Fig. 1), which is based on the data obtained, and is showing a trend of rapid spread of wildfire hazard from south to north, with high and very high levels of hazard in the southern and eastern regions of the country, and above average in some western regions. The Carpathian Mountain range differs sharply in terms of hazard level (below average and low) from the surrounding areas due to the climatic conditions

observed there. A similar situation exists in northern Ukraine, in the Chernihiv and Sumy regions. In order to prevent the spread of wildfire hazards in Ukraine, it is necessary to develop and implement a set of measures to reduce anthropogenic impact on the environment in the regions and to prevent and eliminate deliberate arson of vegetation, as well as to increase citizens' responsibility for violating fire safety rules.

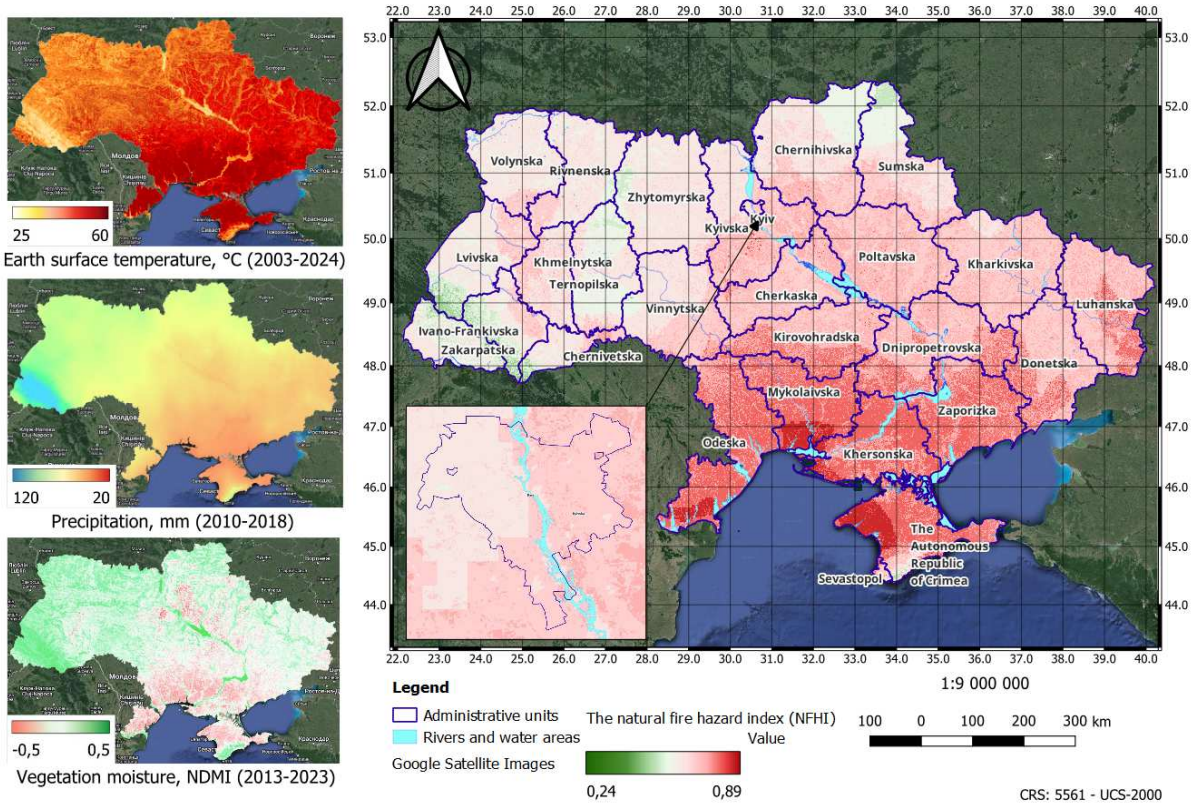


Figure 1. *Map of potential wildfire hazard areas (created by the authors).*

Conclusions

The eight datasets containing over 100 different types of satellite data from 2003 to 2024 were processed using the Google Earth Engine platform to identify potential areas of wildfire hazard.

Through reclassification and consolidation of datasets with relevant indicators, the authors determined an integrated wildfire hazard index, which takes into account ground surface temperature, precipitation, soil moisture, vegetation moisture, slope, and wind speed.

The results are consistent with 20 years of fire data from MODIS satellite imagery, which can help organize fire prevention measures in regions with above-average, high, and very high levels of wildfire risk.

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