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Evaluation of Field-Based Burn Indices for Assessing Forest Fire Severity in Luhansk Region, Ukraine

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Abstract. Evaluation of forest fire severity is a basis of post-fire forest management. Remote sensing-based methods enable reliable delineation of fire perimeters, however, assessments of the degree of forest damage need to be verified and adjusted through field sampling. The forest damage assessment conducted in this study is useful for practitioners to understand and justify the design of clear cuts for restoration purposes. Thus, the aim of the study is to verify the different approaches to field assessment of forest fire severity. In this paper, the authors present a site-specific assessment of large wildfires in Luhansk oblast, Ukraine occurred in 2020 using field-based burn severity indices. The Composite Burn Index (CBI) and the Geometrically Structured Composite Burn Index (GeoCBI) were used to estimate the extent of forest damage. The Burned Area Emergency Response (BAER) methodology was also tested to assess the extent of soil damage. The authors used PlanetScope images to delineate perimeters of burned areas. These perimeters were overlaid over a forest inventory database to extract forest attributes and site characteristics for all forested and unforested areas affected by fires. Within the fire perimeters, the burned area was stratified into six strata to independently account for forest damage in diverse types of land cover. In total 73 test plots were proportionally distributed among different classes of land cover to assess fire severity using CBI, GeoCBI, and BAER approaches. It was found that the fire's footprints covered 39,782 hectares. Among that area, 21.2% were forested lands. About 78% of burned forests were pine plantations. The highest fire intensity levels were estimated within pure pine plantations that were grown in very dry sites, while the lowest ones were associated with hardwoods forests in moisture site conditions. The average estimates of fire severity using the field-based indices varied within strata (CBI>GeoCBI) which could be an issue for assessing burn severity using remote sensing-based approaches. The authors also concluded that the BAER methodology contributed less to assessing the fire intensity because soil burn severity is not directly related to vegetation damage. This work creates a foundation for further assessment of fire severity using satellite imagery. As a result of this study, a spatial data set of sample plots was proposed that can facilitate calibrating approaches used to map fire severity in the region

Keywords: field-based burn severity indices, forest damage, burned area, site condition

Introduction

Forest fires are one of the main natural disturbances of Scotch pine forests in the southern and eastern regions of Ukraine. Wide use of fires to burn agriculture residues in Ukraine [1] results in permanent presence of ignition sources in landscapes of the region. During periods of extreme weather danger (e.g., low fuels moisture and high wind speed) with strong wind, agricultural fires can enter pine forests and within hours reach high intensity that pose a direct threat to villages located close to forests, similarly to other fire prone landscapes in the Mediterranean region or western United States [2; 3]. From a forest management perspective, the most obvious consequences of fires are accumulation of large amounts of dead biomass, degradation of forest stands, and reduction in their capacity for carbon sequestration [4; 5].

Problem of forest fires in Ukraine essentially escalated during the last two decades due to climate and land-use changes: single large fire event reached unprecedent

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for the country levels (15-60,000 ha) while occurrence of extreme fires has become more frequent [6; 7]. Since 2015 extreme fires repeatedly occurred every 3-4 years all over the country: the Chornobyl Exclusion Zone (1992, 2015, 2020) [6; 8], Kherson oblast (2007, 2012) [6; 9]; Zhytomyr, Lugansk, Kharkiv oblasts (2020) [10]. The main drivers of all large fires of the last decade were massive agricultural burnings combined with drought, fast wind, and essential fuel load in overcrowded Scotch pine plantations that drove extreme fire behaviour [1].

During second half of XIX century, Ukraine was a relatively safe country with low frequency of extreme forest fires [6; 9; 10]. Thus, the forest fire management in Ukraine lacks a national policy toward shifting to landscape fire management [6; 7]. This could be illustrated with the absence of specific fire research centres that study landscape fires. First fire lab in Ukraine was established in 2013 at the National University of Life and Environmental Sciences of Ukraine supported by the Global Fire Monitoring Centre (GFMC) and Council of Europe [11; 12]. Recently, a few studies were undertaken for postfire damage research mostly based on ground assessment of stands burned [13; 14]. Under these circumstances, many issues related to landscape fires in Ukraine remain unexplored, for example, methods for assessing forest fire damage, remote sensing-based forest fire mapping, etc. Post-fire management in Ukraine regularly faces a challenge because of the lack of empirical evidence on the accuracy of fire severity assessment in various regions and forest types while good restoration practices require detailed information on losses of ecological and social functionality of burned forested landscapes that are related to the extent and severity of fires [14; 15].

Today, remote sensing methods and numerous products developed using satellite imagery enable assessment not only the perimeters of fires but also the degree of forest damage [2; 16]. While a rapid evaluation of the spatial pattern of burned areas can be performed using merely satellite imagery, detailed information on forest damage is highly dependent on field data collected after the fire [17]. In most cases, remote sensing-based indices of fire severity and any estimates of the degree of forest damage need to be verified and adjusted on the site.

Characterising wildfire severity over large geographical regions is challenging due to the necessity of measurements of various parameters (e.g., char height, foliage death etc.) taken in multiple locations of a landscape. Often the accessibility of such location can be limited due to topography factors, logistic constraints, or threats to human life such as in the war zone. Thus, remote sensing approaches provide strong support for decision-making regarding recently burned forest areas [16; 18]. A reliable evaluation of the fire effect imposed on the forest ecosystem though is needed to produce the most accurate maps of burned areas.

Several methods have been proposed to estimate burn severity from field sampling using an examination of post-fire soil and vegetation conditions [2; 19; 20]. Among them, the Burned Area Emergency Response (BAER) process was developed for the rapid assessment of wildfires on soils [21; 22]. Safford et all. [22] criticised the underlying methodology and stated that BAER maps cannot be used to estimate fire effects on vegetation. Therefore, figuring out how tree mortality is changing in response to fire severity is a key concern of many studies. For example, Whittier and Gray [23] developed a fire severity classification scheme based on tree mortality regarding species and tree sizes in the western USA.

Composite Burn Index (CBI) is well documented and widely used by forest community to support an operational methodology for burn severity assessment [17], specifically at national scale in the USA under the framework of the FIREMON (Fire Effects Monitoring and Inventory Protocol) project [24]. The CBI index considers five vertical strata of vegetation that are inspected during field visits. Based on the effect of fire on vegetation, numerical scores are assigned to each stratum (from 0 – unburned to 3 – completely burned) and averaged into understory, overstorey, and overall composite burn rating. Stambaugh et al. [25] demonstrated that the CBI could be successfully applied to produce more accurate fire severity maps within forested areas than within grasslands. Further evaluation of the CBI in conjunction with remote sensing data showed a very diverse variation between field-based and remote sensing-derived fire severity indices [26]. The issues in retrieving CBI and comparing its performance with different indices to evaluate forest fire severity is widely discussed in many publications [27-29]. An updated version of the CBI namely GeoCBI (Geometrically structured Composite Burn Index) was proposed [2] to improve the retrieval of burn severity from remote sensing data. In contrast to the CBI, this version of the burn index considers the fraction of the vegetation (FCOV) that has a positive effect if remote sensing data are utilised for mapping fires [16].

Given the remarkable progress in developing methods for fire severity assessment both using field- and remote sensing-based approaches, there was no detailed examination of such approaches in Ukraine. Since the occurrence of large wildfires has increased in different regions, knowing the impact of fire on forest cover is of foremost importance for fire management [12]. To the authors' best knowledge, there were only a few studies focused on fire severity assessment in Ukraine [8; 13; 14], however, none of them relied on field-validated data to support mapping efforts.

This paper presents a site-specific assessment of large wildfires in Luhansk oblast, Ukraine occurred in 2020 using field-based burn severity indices. The specific objective of this study was to test performance of the CBI and GeoCBI for fire severity assessment in various land cover and forest types. In Ukraine, methods for estimating the intensity of forest fire severity have not yet been studied. This work is the first attempt in Ukraine to examine various field-based fire severity indices that can support accurate forest fire mapping in the region.

Materials and Methods

Study area

This study was conducted in the Luhansk region, which is the easternmost in Ukraine. Luhansk region is characterised by three types of landscapes – agricultural, steppe and forest. Forests cover 8.6% of the region‘s territory and are very unevenly distributed, 87% of the territory is occupied by agricultural lands and natural steppes. The forests are mostly located in the basins of the Siversky Donets and Aidar rivers (Kreminsky and Stanychno-Lugansky districts). The total area of forests in the region is 339.6 thousand hectares more than 250 thousand hectares of which are occupied by planted forests [30].

The climate of Luhansk oblast is fire prone and characterised by hot, windy, and dry summers often with drought-dry phenomena, cold and snowless winters. The average annual air temperature varies between +7.5°C and +8.5°C. The average temperature in July is +21°C. Precipitation in the oblast is unevenly distributed, most of it falls in the southwestern part of the region, and the least in the central, eastern, and north-eastern parts. The average rainfall per year is 400-500 mm [31] but recent studies indicate the essential changes in climatic characteristics in the nearest future [32].

The study area is in the western part of Luhansk oblast and fits into a rectangle 100×50 km (Fig. 1). The region where the fires occurred is sandy arenas along the Siverskyi Donets river, where pure pine plantations have been created in 1950-1960. Typical feature of this region is the mosaic of the landscape's types – pine forests alternate with forestless steppes with deciduous islands in the depressions.

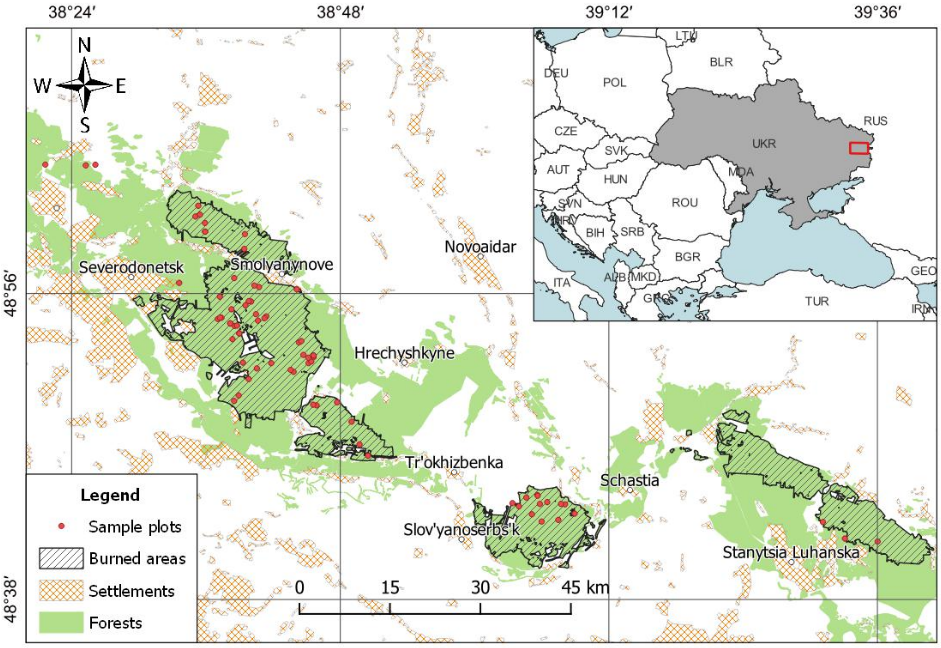

Figure 1. Study area overlaid with perimeters of burned areas and distribution of sample plots

Two large forest fires occurred in the Luhansk oblast in 2020. The first forest fire with a total area of 24,6 thousand hectares occurred in July 2020 in Severodonetsk and Novoaydar districts, which destroyed 84 houses, damaged 24 houses in Smolianynove village, killed 5 people died, and 471 were injured. The second series of fires happened in the same districts in September–October 2020 on a total area of 15,2 thousand hectares. As a result, 32 settlements were damaged, 573 houses were burned completely and 60 houses were damaged by fires, 12 people died, and 390 were injured [10]. The fires of 2020 became the largest and the most catastrophic in the history of this region.

Remote sensing data

The authors of this paper used data on thermal anomalies which were interactively analysed using web-interface [33] to detect fire events in the region. Thus, the dates of two large fires were identified, which occurred between July and October 2020.

PlanetScope multispectral satellite images PlanetTeam [34] were used to determine approximate perimeters of burned areas. The images were chosen according to the start (July 6, 2020) and the end (October 9, 2020) dates of the fire period that was identified using MODIS [35] and VIIRS [36] data on thermal anomalies. PlanetScope satellite images, acquired during July 3-5, 2020, characterised the state of the territory before the fire, while those acquired on October 9, 2020, depicted the state of the territory after the fire. Considering that the analysis was done visually, there were no specific requirements for the image mosaics regarding seasonality of images acquisition (e.g., summer or autumn images), but the dates were chosen based on availability of cloudless images. High spatial resolution (3 m) together with spectral bands combination (Red-NIR-Green) allowed us to outline perimeters of burned areas that consisted of nine separate polygons (Fig. 1).

Forest inventory data

The forest inventory database provided by the Ukrainian State Forest Project Association (PA "Ukrderzhlisproekt") was incorporated in the study to characterise land cover and attributes of forest stands affected by fires in 2020. This information was coupled with polygon coverage and used to design field sampling. For each forest polygon, the authors of this paper identified its area, a land cover type (i.e., stocked forest, and temporally unforested area, non-forest land), and attributes of forest stands (dominant species and site condition). They are characterised by the following indicators: the total area of forested land is 172 thousand hectares; 18% of forests are forests of natural origin; the predominant tree species is Pinus sylvestris L. (78% of the area), the rest of the area is occupied by such tree species as *Quercus robur* L., *Betula pendula* Roth. *Alnus glutinosa* (L.) Gaerth., *Populus nigra* L. Forest land distribution by site conditions according to the Ukrainian forest types classification [36] shows that most areas are characterised by poor and dry types – 82% (A_1, A_2, B_1, B_2; where A, B, C, D – soil fertility (from poor to fertile), and 0, 1, 2, 3, 4, 5 – soil moisture (from very dry to very wet)), the remaining conditions occupy insignificant areas less than 4%.

Field data

Field sampling

A stratified random sampling was applied to allocate sample plots for burn severity assessment within perimeters of burned areas. The authors used information extracted from the database of PA “Ukrderzhlisproekt” on land categories, types of forest conditions, and dominant tree species before the fire to stratify the burned areas into six homogeneous strata (Table 1). The authors’ stratification approach aimed to sample diverse types of land cover (forested and temporally unforested areas, non-forest lands), and potentially characterise the different effects of fire on vegetation. To address the combined effect of species composition and site conditions on fire behaviour, the pine-dominated forests that grow in site conditions A_{2-3} and B_{2-3} were distinguished [37], which are optimal for Scots pine. All dry sites were also disaggregated regardless of their soil fertility and species composition (A_{0-1}; B_1; C_1; D_1). The remaining forested areas represented relatively wet site conditions with various soil fertility. In the authors’ stratification, two separate strata were also created for temporally unforested areas in dry site conditions as well as other unforested and non-forest lands. The minimum number of test plots in the stratum accounted three samples, while their maximum number reached up to 25 samples. The number of sample plots in each stratum was established proportionally to the area of the stratum but finally was slightly changed in the field due to proximity to the zone of the military conflict and the inaccessibility of certain plots. As many as 73 sample plots were established within the study area that were accompanied by five control plots located on unburned areas (Fig. 1). The sampling frame for field survey was created in Quantum GIS (3.2.1), the location of each plot was identified on the site using GPS.

Table 1. The scheme of stratification of the study area

Code of the strata	Land cover class before fire	Site conditions*	Dominant species	Percentage of the area, %	Number of plots
1	Forested areas	A_{2-3}	Scots pine	27	25
2	Forested areas	B_{2-3}	Scots pine	22	13
3	Forested areas	A_{0-1}; B_1; C_1; D_1	Deciduous species, Scots pine	10	17
4	Forested areas	A_{2-3}; B_{2-3}; B_4; C_{2-5}; D_{2-5}	Deciduous species	14	4
		C_{2-3}; D_{2-3}	Scots pine		
5	Temporally unforested areas	A_{0-1}; B_1; C_1; D_1	–	9	6
6	Other temporally unforested areas and non-forest lands	A_{2-3}; B_{2-3}; B_4; B_{2-5}; D_{2-5}	–	18	3

Note: * A, B, C, D – soil fertility (from poor to fertile) and 0, 1, 2, 3, 4, 5 – soil moisture (from very dry to very wet)
Source: [37]

The implemented scheme is justified by the similarity of site conditions (soil fertility and moisture) which determine the similarity of forestry measures.

Field-based burn indices

To assess field-based burn severity, each sample plot was visually evaluated using the CBI index [17; 24], and its geometrically modified version, namely the GeoCBI index [2]. These indices provide a comprehensive scoring of the degree of fire damage imposed to various strata of vegetation, i.e., duff, litter, shrubs, stands.

According to the field protocol, the average post-fire conditions are visually assessed on sample sites within a radius of 15 m by five separate layers: (A) substrates; (B) herbs, low shrubs, and trees less than 1 meter, (C) tall shrubs and trees 1 to 5 meters; (D) intermediate trees (subcanopy, pole-sized trees); (E) big trees (upper canopy, dominant, codominant trees). The CBI considers litter and fuel consumption, soil colour change, leaf or cover change, canopy mortality and soot height. These attributes are evaluated in numerical scores from zero (unburned) to three (completely burned). The scores for each group are averaged over the total area. Different attributes for each layer are evaluated and averaged in the protocol [24]. The GeoCBI index additionally considers the percentage of projected coverage of each stratum (FCOV) and is therefore more efficient in terms of estimating the intensity of fires [2; 16]. The fraction of coverage (FCOV) of the vegetation, with respect to the total plot was visually evaluated for separate layers B, C, D and E. FCOV was scored from 0 to 100 percent and used as a weighting factor. The GeoCBI was calculated as follows:

$$\text{GeoCBI} = \frac{\sum_{m_1}^{m_n}(CBI_m \cdot FCOV_m)}{\sum_{m_1}^{m_n} FCOV_m} \quad (1)$$

where *m* refers to each vegetation layers (B, C, D, and E), and *n* denotes the number of the strata.

Furthermore, soil samples were taken from each test plot to determine the degree of fire impact on its structural characteristics according to the BAER approach [21; 22]. On each plot, soil properties were evaluated (ground cover, ash colour and depth, soil structure, condition of roots, and water repellence) using special form as it is described by Parsons et al [21].

Finally, a series of images were taken on each sample plot using technique of creating 360-degrees panoramic photography of virtual reality VR360 [38; 39].

Results and Discussion

Fire extent

Using PlanetScope multispectral satellite images, the perimeters of the burned areas were determined and the approximate area affected by fires was estimated to be 39.782 hectares (Fig. 1). The outlines of the fires and the forest inventory data allowed us to evaluate the scale of forest losses in the region.

The characteristics of the damaged landscapes were evaluated based on the established areas affected by fires, using the forest inventory database (Table 2 and Table 3). Among the damaged forests, 78% of the area is pine, 6% birch, and other tree species occupying less than 5% of forested area.

Table 2. Distribution of the burned area by site conditions

Forest site index	Area, thousand, ha	Proportion
C_4	0.452	0.011
C_3	0.579	0.015
C_2	0.871	0.022
B_3	1.818	0.046
B_1	1.899	0.048
A_1	4.165	0.105
A_2	13.26	0.333
B_2	13.625	0.342
Others	3.112	0.078
Total	39.78	1.00

Table 3. Distribution of the burned area by the land covers

Land cover type	Area, thousands ha	Proportion
Forested lands (i.e., planted and natural forests)	8.436	0.212
Unforested (i.e., harvested areas, glades, unstocked forests, forest plantation less than 8-year-old, dead forests, etc.)	28.513	0.717
Non-forest lands (i.e., fire breaks, sands, sparse vegetation, built up area, etc.)	2.833	0.071
Total	39.78	1.00

It was estimated that 30% of the forested area affected by fire were covered by young forests (less than 40 years), 34% were middle-aged (41-60 years) and 28% pre-mature (61-80 years) forests, remaining 8% represented mature (over 80 years) forests. This age characteristic of forests damage reinforces the statement of low resistance of these forests to fires (survival), as resistance to cambium kills is dependent on normalised bark thickness [40]. In terms of species composition 88% of damaged forests by stock were pine forests (4.75 mill. m^3), 5% were birch forests (0.28 mill. m^3), 2% were oak forests (0.15 mill. m^3) and 5% other tree species (0.29 mill. m^3).

Fire Severity

Field-based on CBI and GeoCBI indices have been assessed burn severity. The examples of the areas of different degrees of damage and the corresponding CBI and GeoCBI values are shown in Figure 2.

a) b) c)

Figure 2. Examples of three levels of fire severity assessed based on CBI and GeoCBI indices: (a) high; (b) moderate; (c) low

According to the results of field surveys, the indices of pine plantation damage in each test plot were determined. Summary data of the results of field surveys within individual strata are presented in Table 4. Detailed information on each site is presented in [41] Annex 2.

Table 4. Statistics of damages within the stratum

Code of the strata	Number of plots	CBI			GeoCBI		
		Mean	Range (min/max)	Skew	Mean	Range (min/max)	Skew
1	25	2.60	1.2/3.0	-1.62	2.30	1.2/2.9	-1.34
2	13	2.34	1.1/3.0	-0.99	2.13	1.1/2.6	-0.98
3	17	2.69	1.1/3.0	-2.19	2.43	0.9/3.0	-2.17
4	4	2.13	1.2/3.0	-0.19	1.95	1.1/2.6	-0.92
5	6	2.42	1.1/3.0	-1.11	1.95	1.5/2.6	0.25
6	3	2.07	1.0/2.8	-1.39	2.07	1.0/2.8	-1.39

The highest intensity of forest damage is observed in stratum 3, which is characterised by low soil moisture – pure pine plantations in very dry sites on top of sandy arenas. The lowest intensity of damage is in stratum 4, which is due to the species composition of forests – the presence of deciduous species and higher soil moisture - fresh, moist, and wet conditions [37]. Strata 5 and 6 characterise damage to non-forested areas, which has less negative effect compared to forest losses. It was noted that the CBI index tends to have higher values in forest landscapes than its geometrically modified version, i.e., GeoCBI index. However, the inclusion of the FCOV in GeoCBI calculation could have positive effect on precise estimation of forest damage using remote sensing-based approaches.

The data obtained in this study promotes application of remote sensing approaches for further mapping fire damage. Specifically, field-validated data collected across the gradient of fire severity and within various landscapes (i.e., forested, unforested) are essential to calibrate satellite-derived burn severity metrics and link their values to field-based indices [16; 42]. The authors of this paper believe that apart from the fires under study, the prepared spatial data set can be used to effectively map burned landscapes throughout the territory of the region. Availability of such maps are necessary to support the forest restoration strategy.

The degree of soil damage according to the BAER methodology [21] has shown an indirect relationship between the intensity of the fire and its impact on the soil [41] Annex 1. In general, only two degrees of soil damage were recorded during the field survey, i.e., low and medium. In most cases, the soil damage was characterised by the combustion of forest understory while structural changes in the soil were not detected. Notably, this survey was delayed for six months after the last fire, and therefore some soil characteristics could not be recorded on the site (e.g., water repellence). Nevertheless, the authors of this study agreed with the conclusion of Parsons [21] on the limitation of the BAER methodology to map the effect of fires on vegetation.

Conclusions

This study highlights the impact of the extreme fire events in the Luhansk oblast of Ukraine in 2020. The publication describes a method for field data collection to evaluate levels of forest damage affected by the fire. The results provided in this paper are preliminary, suggesting that the data in this study will provide information on the relationship between key forest characteristics and fire intensity observed remotely to map burned areas. However, field research allows assessing the levels of damage to pine forests that are dominant in the research area. This study showed that the FCOV component of the GeoCBI is important while damage to forest vegetation is characterised. In terms of further use of remote sensing-based approached, the CBI index potentially could overestimate the fire severity levels for forested landscapes. Based on the CBI and GeoCBI, the authors also found empirical evidence that fire severity depends on forest composition and tends to be higher in coniferous landscapes. This is the first use of field-based fire severity in Ukraine which can be used to assess fire damage in similar conditions. The results of these field assessment of forest fire severity can be used to estimate the fire severity of all damaged areas in the region using remote sensing methods.

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Польова перевірка індексів ступеня пошкодження пожежами лісів в Луганській області, Україна

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Анотація. Оцінка ступеня пошкодження внаслідок лісової пожежі є основою після пожежного ведення лісового господарства. Методи дистанційного зондування Землі (ДЗЗ), дозволяють надійно окреслити периметри пожежі, проте детальніша оцінка пошкоджень лісових насаджень потребує польових обстежень для верифікації та коригування даних, отриманих методами ДЗЗ. Оцінка ступеня пошкодження лісу є корисною практикам для обґрунтування проєкту рубок пошкоджених лісів та методів лісовідновлення. Отже, метою дослідження є верифікація різних підходів щодо польової оцінки ступеня пошкодження лісів пожежами. Дослідження виконано на прикладі лісів Луганської області, в яких у 2020 році відбулися великі пожежі. Для оцінки ступеня пошкодження лісових насаджень використовувалися комплексний індекс вигорання (CBI) та геопросторовий комплексний індекс вигорання (GeoCBI). Також для оцінки ступеня пошкодження ґрунту використано методику реагування на надзвичайні ситуації на пройдених пожежами територіях (BAER). Для окреслення периметрів пройдених пожежами територій використано супутникові знімки PlanetScope. Наклавши отримані периметри пожеж на базу даних таксаційної характеристики лісів отримано характеристики всіх ділянок вкритих лісом та невкритих, які були пройдені пожежами. В межах встановлених контурів пожеж, всі ділянки було розділено на 6 страт, для оцінки пошкодження в різних типах земельного покриву. Загалом за методиками CBI, GeoCBI та BAER обстежено 73 пробні площі для оцінки інтенсивності пошкодження, які пропорційно розподілені між різними стратами. Встановлено, що пожежами було пройдено загальну площу 39782 га, з яких 21,2 % вкриті лісом території. Серед пройдених пожежами лісів 78 % становлять соснові деревостани. Найвищі рівні інтенсивності пошкодження встановлено в чистих соснових насадженнях у дуже сухих умовах, а найнижчі в листяних лісах у вологих умовах. Середні індекси інтенсивності пошкодження варіювалися в межах окремих шарів кожної ділянки, тому геопросторовий комплексний індекс вигорання, який враховує частку кожного шару на ділянці у більшості випадків був меншим за комплексний індекс вигорання (CBI>GeoCBI), що важливо враховувати під час оцінки інтенсивності пошкодження за допомогою методів ДЗЗ. Методика BAER має менше значення в оцінці інтенсивності пошкодження, оскільки невстановлено значущої залежності між ступенем пошкодження ґрунту та інтенсивністю пошкодження рослинності. В результаті цього дослідження представлено набір просторових даних вибіркових ділянок, які можуть використовуватися для калібрування підходів, які використовуються для картографування інтенсивності пошкодження в регіоні дослідження

Ключові слова: польові індекси інтенсивності пошкодження, пошкодження лісу, пройдена пожежею територія, стан ділянки