

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph.
Geology,
29(3), 483–494.

doi: [10.15421/112043](https://doi.org/10.15421/112043)

Vasyl O. Fesyuk, Iryna A. Moroz, Larysa T. Chyzhevska, Zoia K. Karpiuk, Serhii V. Polianskyi Journ. Geol. Geograph. Geoecology, 29(3), 483–494.

Burned peatlands within the Volyn region: state, dynamics, threats, ways of further use

Vasyl O. Fesyuk¹, Iryna A. Moroz², Larysa T. Chyzhevska¹, Zoia K. Karpiuk¹, Serhii V. Polianskyi¹

¹Lesya Ukrainka Eastern European National University, Lutsk, Ukraine, fesyuk@ukr.net

²Lutsk National Technical University, Lutsk, Ukraine, moroz.iryna1@gmail.com

Received: 16.12.2019

Received in revised form: 09.01.2020

Accepted: 10.03.2020

Abstract. The consequences of peat fires are complete or partial loss of soil fertility over a considerable area of land, decrease in biodiversity, razing of unique landscapes, deterioration of the conditions for life and health of the population, disturbed carbon cycle, increase in the greenhouse gas emissions, intensification of climate change, etc. Climatic tendencies

of recent years will further contribute to increase in peat fires and their negative aftermaths. Therefore, prevention of peat fires and recultivation of burned-out peatlands are extremely important nature-protective measures. The objectives of the article was evaluation of current condition of burned peatlands of Volyn Oblast, their territorial distribution, dynamics according to years, analysis of potential threats for ecological safety and development of recommendations for prevention of peat fires and overcoming the negative consequences. During the study we used: methods of collecting material, methods of statistical analysis of results, cartographic methods, methods of expert assessment. We determined that the problem of peat fires and burned peatlands is extremely relevant for Volyn Oblast, requiring development of a complex of measures to solve it. As of 2002, the area of burned peatlands in the Oblast accounted for 440 ha. For the period of 2002-14, a total of 803 ha of burned peatlands was recorded across Volyn Oblast. In 2015-19, their area increased by another 280 ha. The largest areas of burned peatlands were found in Kamin-Kashyrskyi (137.9 ha), Liubeshiv (26.72 ha), Manevychi (20.35 ha) districts. We determined the tendency towards increase in the number of fires and areas of burned peatlands starting from 2018. To prevent peat fires, two-sided (wetting and drying) regulation of water regime within reclamation systems, alkalization of peat soils, increase in their fertility, sanding-up of dried peat soils are proposed. Also, important measures include monitoring of burned peatlands and prevention of wildfires. In order to further use, rehabilitate and recultivate burned peatlands, it is suggested to inventorise burned peatlands, assess economic and ecological damages, develop a plan of further use of territories, determine priorities of development and propose corresponding economic and nature-protection measures.

Keywords: burned peatlands, peat fires, consequences of peat fires, dynamics of peat fires, measure to reduce negative effects of peat fires, recultivation of burned peatlands

Вигорілі торфовища в межах Волинської області: стан, динаміка, загрози, шляхи подальшого використання

В.О. Фесюк¹, І.А. Мороз², Л.Т. Чижевська¹, З.К. Карпюк¹, С.В. Полянський¹

¹ Східноєвропейський національний університет ім. Лесі Українки, Луцьк, Україна, fesyuk@ukr.net

² Луцький національний технічний університет, Луцьк, Україна, moroz.iryna1@gmail.com

Анотація. Наслідками торфових пожеж є повна чи часткова втрата родючості значних площ земель, зниження біорізноманіття, знищення унікальних ландшафтів, погіршення умов життя та здоров'я населення, порушення циклу карбону, збільшення емісії парникових газів, посилення змін клімату тощо. Кліматичні тенденції останніх років сприятимуть і надалі збільшенню кількості торфових пожеж та їх негативних наслідків. Тому попередження торфових пожеж та зменшення їх негативних наслідків у майбутньому, а також подальше використання, відновлення та рекультивація вигорілих торфовищ є надзвичайно важливими природоохоронними заходами. Метою статті є оцінка сучасного стану вигорілих торфовищ Волинської області, їх територіального розподілу, динаміки за роками, аналіз потенційних загроз для екологічної безпеки та розробка рекомендацій для попередження виникнення торфових пожеж та подолання їх негативних наслідків. Під час дослідження застосовано: методи збору матеріалів, методи статистичної обробки результатів, картографічні методи, метод експертних оцінок. Встановлено, що проблема торфових пожеж та вигорілих торфовищ для Волинської області є дуже актуальною і вимагає розробки комплексу заходів для її вирішення. Станом на початок 2002 р. в області площа вигорілих торфовищ становила 440 га. За період 2002-14 р.р. у Волинській області зафіксовано 803 га вигорілих торфовищ. У 2015-19 р.р. їх площа збільшилась ще на 280 га. З'ясовано, що найбільші площі вигорілих торфовищ у Камінь-Каширському (137,9 га), Любешівському

(26,72 га), Маневицькому (20,35 га) районах. Виявлено тенденцію до збільшення кількості пожеж та площ вигорілих торфовищ починаючи з 2018 р. Для попередження торфових пожеж запропоновано здійснювати двостороннє регулювання водного режиму в межах меліоративних систем, залуження торфових ґрунтів, підвищення їх родючості, піскування осушених торфових ґрунтів. Також дуже важливими заходами є моніторинг вигорілих торфовищ та профілактика виникнення пожеж в природних системах. З метою подальшого використання, відновлення та рекультивациі вигорілих торфовищ запропоновано своєчасно провести інвентаризацію вигорілих торфовищ, оцінити економічні та екологічні збитки, розробити план подальшого використання території, визначити пріоритети розвитку та запропонувати відповідні господарські та природоохоронні заходи.

Ключові слова: вигорілі торфовища, торфові пожежі, наслідки торфових пожеж, динаміка торфових пожеж, заходи зменшення негативних наслідків торфових пожеж, рекультивациа вигорілих торфовищ

Introduction. Natural peat ecosystems are important components of the landscape of particular territories. They perform various ecological functions. For example, peatlands accumulate products of photosynthesis and the process of peat formation is going on continuously. Peat is a valuable raw material for many fields of the economy, and also local renewable energy. Also, bogs and peatlands play an important role in accumulation of compounds of atmospheric carbon (Diggelen, 2018). In natural conditions, bogs absorb more of it than they emit into the atmosphere. Peatlands are exceptionally important for the formation of the hydrological regime of territories and are a natural filter of water. Furthermore, deposits of peat are often located in lands covered with forests, are a part of the territories and objects of nature-reserve fund, wetlands of international significance, places which maintain biodiversity. Peatlands have also great botanical-geographical importance. Peat fires lead to burning-out of deep layer of peat, degradation of soils, razing of vegetation and organisms which inhabit the soil, sinking of the surface and change in relief, emission of large amounts of pollutants into the atmosphere, including greenhouse gases. From the perspective of ecology, burning of peatlands as a result of fires could be considered as a local ecological crisis.

Causes of peat fires are decrease in the levels of ground water in polder systems and separation of the capillary layer from peat deposits (Zajdelman, 2011). As a result of anthropogenic interference, peatlands, being especially valuable lands, have lost their natural resistance and became extremely vulnerable to natural and anthropogenic factors. Fires in soil massifs occur when groundwaters are located at the depth of 0.8-0.9 m and lower. Spread of fires is also driven by traditional annual burning of dry tree stands in pastures, stubble in tilled lands, domestic wastes in households of the local population. This degradational process continues to spread also due to inappropriate exploitation of the polder system and cessation of reconstruction of drying systems. The reasons for peat fires may also be tourists and local population due to carelessness in lighting fires. Recently, another factor which adds to the danger of fire danger has

been actively increasing – climate change. Over the last several years (2015-19), many temperature records have been broken, there has been a decrease in the amount of precipitations, change in patterns of precipitations from steady downpour rainfall to heavy rains. This underlies the worsening of the territorial water balance, drying up of wells, etc. Decrease in the level of groundwater causes change in the base levels of erosion, significantly intensifying erosion of the lands (water and wind erosion). Lowland peatlands, due to decrease in moisture, generate large amounts of heat, causing ignition. Recently, problems of peat fires for some districts of Volyn Oblast have become catastrophic in extent.

At the same time, the Oblast has no effective regional program of measures against peat fires and overcoming their negative ecological consequences. No monitoring of the condition of burned peatlands is conducted. Obviously, the problem of peat fires and their ecological consequences should not be ignored. It is necessary to study the current condition of burned peatlands, analyze the dynamics of peat fires, their reasons and consequences, assess the threats to ecological safety of local communities, develop directions and measures for reducing negative effects of peat fires. This is what makes the article relevant.

Review of previous research. There are many scientific studies of peatland fires and burned peatlands. This problem is being actively described in the works of European scientists. The most thoroughly studied situation is the distribution and preservation of wetlands in Europe (Diggelen, 2018). Also, detailed studies were undertaken on peatland fires and their consequences in Ireland (Stracher et al., 2019), South-East Asia (Taylor, 2010), Africa (Barbosa et al., 1999), Central Kalimantan (Indonesia) (Hosciloet et al., 2011), Klias Peninsula (Malaysia) (Phua et al., 2007).

Noteworthy are generalizing reviews of influence of fires on global ecosystemic patterns and processes, distribution and structure of vegetation, cycle of carbon and climate (Bowman et al., 2009). Scientists pay much attention to the peculiarities and patterns of carbon emission during peat and forest-fires. Among the researches in this direction, we

should note the study on carbon emission as a result of fires in tropical and subtropical ecosystems (van der Werf et al., 2003), carbon balance in the North-American swamps (Bridgman et al., 2003), global assessments of pyrogenic emissions during various types of fires in natural ecosystems (Andreae et al., 2001), assessments of impact of fires in forest and peat massifs on atmospheric pollution, condition of the environment and climate (Langmann et al., 2009). Interesting are also the researches where authors try to evaluate the potential vulnerability of peatlands to ignitions. Such studies were conducted for province of Alberta (Canada) and measured the differences in waterproof and hydrophysical capabilities of burned and unburned organic soils (Elmes et al., 2019). For Canada, an attempt was also made to quantitatively assess the changes in the main aspects of migration of nutrients in the system soil-plant-water during first years after fires (van Beest et al., 2019) and assess the sensitivity of peatlands to climate warming (Tarnocai, 2006). This researcher determined that around 60% of the total area of Canadian peatlands and 51% of mass of organic carbon in all Canadian peatlands, as expected, will be heavily or severely affected by climate change.

In Russia, scientists also pay great attention to the issues of pyrogenic degradation of peat soils and recultivation of burned peatlands (Zajdelman et al., 2002, 2006, 2011), and change in the chemical properties of dried peatlands under the influence of fire factor (Badmazhapova et al., 2014). Scientific researches in this field are being also conducted in Belarus (Tanovickaja et al., 2009).

In Ukraine, studies on the consequences of peat fires and pyrogenic peatlands are being conducted by scientists in the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky (Truskaveckij et al., 2010) within Polesia Minor – Ivan Franco National University of Lviv (Gaskevich et al., 2008). Among important results of the studies of burned peatlands, we should note also the assessment of dynamics of migrational capability of some heavy metals in soils of Kharkiv Region under the effect of the pyrogenic factor (Butsetal., 2019). This problem in Volyn Oblast was studied by specialists of Volyn Oblast State Projective-Technological Center of Protection of Fertility of Soils and Quality of Production (Zinchuk et al., 2007). Also, the Polesia Research Station of the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky developed recommendations for cultivation and agricultural use of peatlands damaged by fires (Shevchuk et al., 2006). A system of measures has been suggested for pro-

tection of peat soils against pyrogenic degradation (Polianskyi, 2006).

The purpose of the article. The objective of the article was assessing the current condition of burned peatlands of Volyn Oblast, their territorial division, dynamics according to years, analysis of potential threats to ecological safety and development of recommendations for prevention of ignition of peat fires and overcoming their negative effects.

Material and methods of research. For the article we used the materials of the Polesia Research Station of the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky, Volyn Oblast State Projective-Technological Center of Protection of Fertility of Soils and Quality of Production, Management of the State Emergency Service in Volyn Oblast, and also the materials of our own researches. During the studies we used a broad range of methods of scientific research: methods of collecting materials (work with fund materials, reconnaissance, expedition method), methods of statistical analyses of the results, cartographic methods (development of analytical maps, work with electronic cartographic services), method of expert assessments (to develop recommendations for prevention of peat fires).

Results and their analysis. According to the analysis of the extent of research made regarding pyrogenic degradation of landscapes in Volyn Oblast, 3 periods may be distinguished:

- until 2004. – soil surveys of the issue were undertaken, and a state program of monitoring of degraded (including pyrogenic) soils was made;
- 2005-2014 – absence of surveys, occasional scientific publications (Zinchuk et al., 2007);
- 2015-19 – absence of surveys, extents of pyrogenic degradation were assessed according to the materials of the Center of State Emergency Service in Volyn Oblast (statistics of recorded fires in peat massifs).

Over the period of 2002-14, in Volyn Oblast, over 803 ha of burned peatlands were recorded (Table 1, Fig. 1, 2). Until 2003, in the territory of the Oblast, there were already over 440 ha of such lands. The largest areas were in Kamin-Kashyrskiy district (200 ha), Kovelskiy (181 ha), Ratnivskiy (51.8 ha), Starovyzhivskiy (5 ha), Kivertsivskiy (3 ha). In 2003 the largest area of pyrogenic formations was observed in Ratnivskiy district (20 ha), and in 2004 – Shatskiy (102 ha), Liubeshivskiy (30.5 ha), Kamin-Kashyrskiy districts (12 ha).

In 2005-14 the area of pyrogenic formations continued to increase. According to expert assessments the increment accounted for 197 ha. Detailed

Table 1. The area of burned peatlands in the Volyn region in 2015-19.*

| District /Years | 2015 | | 2016 | | 2017 | | 2018 | | 2019 * | | 2015-19 | |
|---------------------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|
| | Area, ha | Number of fires | Area, ha | Number of fires | Area, ha | Number of fires | Area, ha | Number of fires | Area, ha | Number of fires | Area, ha | Number of fires |
| Starovyzhivskiyi | 6.55 | 7 | 2.3 | 3 | 1 | 1 | 3.35 | 4 | 6.5 | 2 | 19.7 | 17 |
| Manevytskyi | 1.36 | 5 | 9.14 | 12 | | | 8.25 | 6 | 1.6 | 5 | 20.35 | 28 |
| Kamin-Kashyrskiyi | 127.6 | 17 | 1.39 | 3 | 0.5 | 1 | 3.6 | 6 | 4.8 | 4 | 137.9 | 31 |
| Liubeshivskiyi | 11.4 | 10 | 6.08 | 7 | | | 3.34 | 10 | 5.9 | 8 | 26.72 | 35 |
| Liuboml'skiy | 3.88 | 6 | 0.61 | 3 | | | 1.7 | 3 | 0.55 | 3 | 6.74 | 15 |
| Shatskiy | 6.06 | 9 | 0.94 | 2 | | | 3.9 | 5 | 1 | 1 | 11.9 | 17 |
| Ratnivskiy | 1.64 | 7 | 0.5 | 1 | 0.4 | 2 | 1.22 | 5 | 6.95 | 3 | 10.71 | 18 |
| Turiiskiy | 1.1 | 4 | | | | | 1.25 | 3 | | | 2.35 | 7 |
| Lokachynskiy | 1 | 1 | 0.5 | 1 | | | 0.05 | 1 | | | 1.55 | 3 |
| Horokhivskiy | 0.06 | 1 | 0.5 | 1 | | | 0.35 | 1 | | | 0.91 | 3 |
| Rozhyshechenskiy | 5 | 2 | 9.5 | 4 | | | 1.72 | 4 | | | 16.22 | 10 |
| Kivertsivskiy | 0.5 | 1 | 1.4 | 3 | | | 1.3 | 3 | | | 3.2 | 7 |
| Volodymyr-Volynskiy | 2.6 | 4 | 1.62 | 4 | 2.5 | 2 | | | 2.95 | 4 | 9.67 | 14 |
| Kovelskiy | 5.5 | 2 | 4.55 | 6 | | | 2.5 | 2 | 0.92 | 2 | 12.47 | 12 |
| Lutskiy | 0.01 | 1 | | | | | | | | | 0.01 | 1 |
| Ivanychivskiy | | | 0.03 | 1 | | | | | | | 0.03 | 1 |
| All over the Volyn region | 174.3 | 77 | 39.06 | 51 | 4.4 | 6 | 32.53 | 53 | 31.17 | 32 | 280.4 | 219 |

* – As of 1/12/19

studies of pyrogenic soils at that time were not being conducted due to absence of financing. The greatest increment of the areas of burned peatlands occurred in Kamin-Kashyrskiyi (110 ha), Ratnivskiyi (25 ha), Starovyzhivskiyi (17 ha), Shatskiy (16 ha), Kovelskiy (12 ha), Liubeshivskiyi (8 ha), Kivertsivskiyi (5 ha), Liuboml'skiy districts (4 ha). As for late 2014, the largest areas were characteristic (Fig. 1.) for Kamin-Kashyrskiyi (322 ha), Kovelskiy (193 ha), Shatskiy (118 ha), Ratnivskiyi (96.8 ha), Liubeshivskiyi (38.5 ha) districts.

In 2015 (Fig. 3, 4), the largest areas of peat massifs affected by fires were recorded in Kamin-Kashyrskiyi district (127.61 ha). Out of these areas, over 100 ha were burned out during one of the peat fires (19.08.2015) near villages Vyderta and Vorokomle. The second largest area of burned peatlands was in Liubeshivskiyi district (11.4 ha), third and fourth – Starovyzhivskiyi (6.55 ha) and Shatskiy (6.04 ha), fifth – Kovelskiy (5.5 ha). In other districts of the Oblast the areas accounted for less than 5 ha.

These numbers correlate with the quantity of fires recorded by the Center of State Emergency Service of Ukraine in Volyn Oblast, the correlation coefficient equaled 0.78. Therefore, in 2015, 17 fires were recorded in Kamin-Kashyrskiyi district, 10 in Liubeshivskiyi district, 9 in Shatskiy, and 7 in each Ratnivskiyi and Starovyzhivskiyi districts. In all other regions 1-5 fires

were recorded. Only in Ivanychivskiyi district were no fires recorded.

In 2016, largest areas of peat massifs affected by fire were recorded in Rozhyshechenskiy (9.5 ha) and Manevytskyi districts (9.14 ha), and also Liubeshivskiyi districts (6.08 ha). In all other districts the areas of burned peatlands during the year increased less than by 5 ha. The highest number of fires was also recorded in Manevytskyi (12), Liubeshivskiyi (7), Kovelskiy (6), Rozhyshechenskiy and Volodymyr-Volynskiy districts (4 in each). In other districts less than 3 fires occurred. In Lutskiy and Turiiskiy districts no fires were recorded. Correlation coefficient between the area of burned peatlands and the number of fires was 0.79.

Compared with the previous year the number of fires also decreased, equaling 51 compared with 77 and the area of burned peatlands was 39 ha compared with 174 ha (74 ha not taking into account the largest fire in the peat massif between villages Vyderta and Vorokomle of Kamin-Kashyrskiyi district).

In 2017, the lowest number of fires for the recent years was recorded – only 6 and the area of burned peatlands was 4.4 ha. The main reasons are likely to be the climatic peculiarities of the year (regarding distribution of air temperature and amount of precipitations), but the issue requires further study. Two fires were recorded in Ratnivskiyi (0.4 ha) and Volodymyr-Volynskiy (2.5 ha) districts, one in each

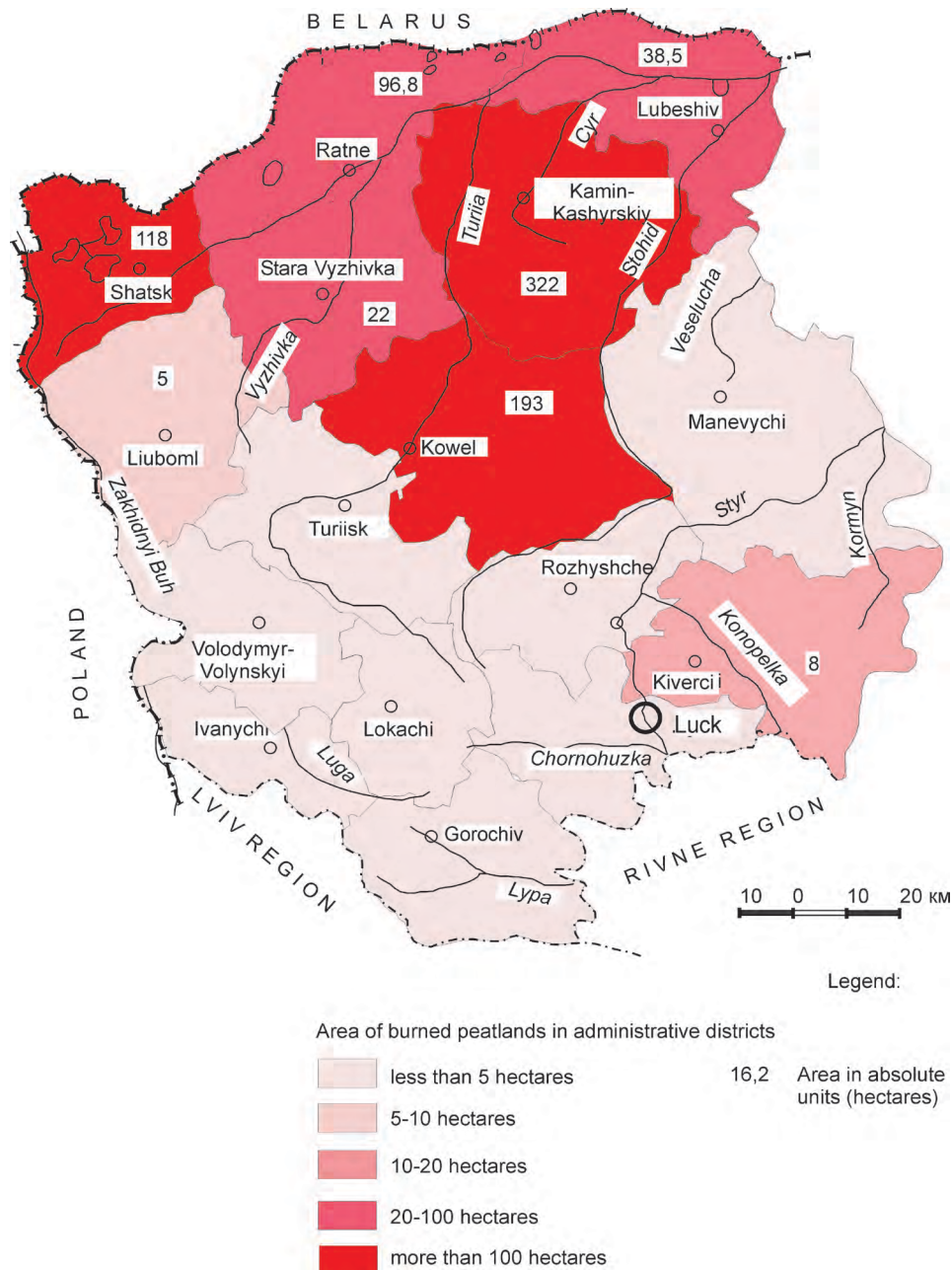


Fig. 1. Area of burned peatlands according to administrative districts of Volyn Oblast in 2002-14.

Starovyzhivskiyi (1 ha) and Kamin-Kashyrskiy (0.5 ha). Correlation coefficient between the area of burned peatlands and the number of fires was also low – 0.42, which is atypical compared with other years.

In 2018 the situation with fires in peat massifs was exacerbated again compared with 2017, almost hitting the indicators of 2016. A total of 32.53 ha of peatlands burned out. Therefore, in particular, the largest areas of burned peatlands were in Manevytskyi (8.25 ha), Starovyzhivskiyi (3.35 ha), Liubeshivskiyi (3.34 ha), Kamin-Kashyrskiyi (3.6 ha), Shatskyyi (3.9 ha) districts. In other districts the parameter equaled less than 2 ha.

The total number of fires in peat massifs in 2018 in the territory of Volyn Oblast was 53 (almost the

same as in 2016). Highest number of fires was recorded in Liubeshivskiyi (10), Manevytskyi and Kamin-Kashyrskiyi (6 in each), Shatskyyi and Ratnivskiyi districts (5 in each). In Lutskiy, Volodymyr-Volynskiyi and Ivanychivskiyi districts no fires were recorded. Correlation coefficient between the area of burned-out area of peatlands and amount of fires equaled 0.58.

In 2019, 32 fires were recorded, covering the area of 31.17 ha. In fact these indicators compared with 2016 and 2018 are much higher than in 2017. The most damaged were Liubeshivskiyi (8 fires, 5.9 ha), Kamin-Kashyrskiyi (4 fires, 4.8 ha), Starovyzhivskiyi (2 fires, 6.5 ha), Ratnivskiyi (3 fires, 6.95 ha), Volodymyr-Volynskiyi (3 fires, 2.95 ha), Manevytskyi (5 fires, 1.6 ha) districts.

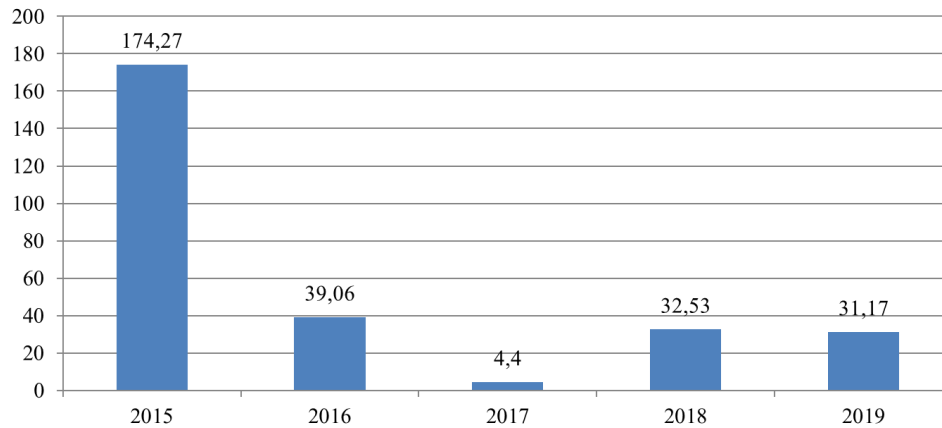


Fig. 2 Dynamics of area of burned peatlands in Volyn Oblast for 2015-19.

Summing up the consequences of fires in peat massifs, it should be noted that the processes of pyrogenesis cause destruction in the structure of soil column and properties in peat soils. Over 2015-19, the Center of State Emergency Service of Ukraine in Volyn Oblast recorded 219 cases of ignition in peat massifs. A total of 280.43 ha burned out. The largest areas of burned

peatlands in 2014 and 2019 (Fig. 1, 4). The largest area of burned peatlands in 2019, similarly to 2014, was in Kamin-Kashyrskyi district. This was predicted. As of 2002, their area equaled 200 ha, increment for 2003-14 accounted for 122 ha, while for 2015-19 – 174.9 ha. The most problematic area is located be-

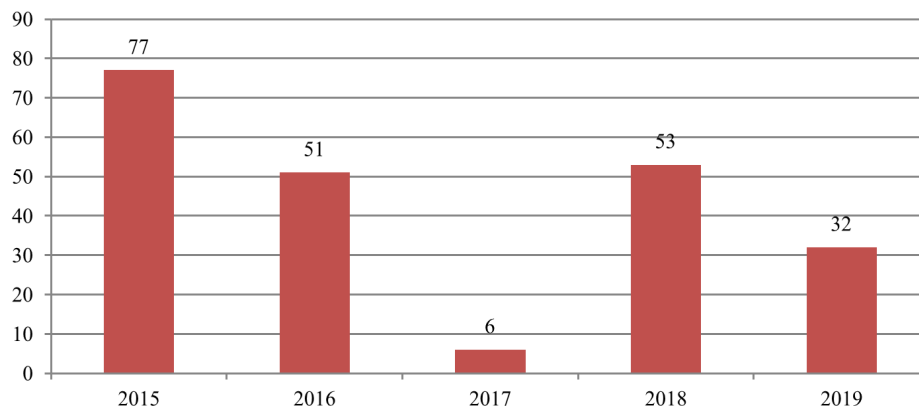


Fig. 3. Dynamics of number of peat fires recorded by the State Emergency Service in Volyn Oblast

peatlands (Fig. 5) was seen in Kamin-Kashyrskyi, measuring 137.9 ha (49.17% of the indicator for the entire oblast), Liubeshivskyi – 26.72 ha (9.53%), Manevytskyi – 20.35 ha (7.26%), Rozhyshchenskyi – 16.22 ha (5.78%), Starovyzhivskyi – 19.7 ha (7%), Kovelskyi – 12.47 ha (4.45%), Shatskyi – 11.9 ha (4.24%), Volodymyr-Volynskyi – 9.67 ha (3.45%), Liubomlskyi – 6.74 ha (2.4%), Ratnivskyi districts – 10.71 ha (3.82%), in other districts – less than 1% (Fig. 5).

A somewhat different statistical distribution of recorded fires for his period was found in the peatlands in Kamin-Kashyrskyi district, accounting for 16%, Liubeshivskyi – 14%, Manevytskyi – 13%, Starovyzhivskyi, Shatskyi, Ratnivskyi – 8% for each, Liubomlskyi – 7%, Volodymyr-Volynskyi – 6%, Rozhyshchenskyi and Kovelskyi – 5% for each. Three districts (Kamin-Kashyrskyi, Liubeshivskyi, Manevytskyi) comprise 43% of all the fires.

tween villages Vyderta and Vorokomle, where fires flare up regularly, and burned-out areas sometimes exceed 100 ha (Fig. 6). The category of districts with the largest areas of burned peats in 2014 also included Kovelskyi (193 ha) and Shatskyi (118 ha). As of 2019 the situation in these districts slightly improved. They were identified to the third group according to scales of pyrogenic degradation (within 10-20 ha). Therefore, during 2015-19, 12.47 ha of peat burned out in Kovelskyi district, and 11.9 in Shatskyi district.

The area of burned peatlands also decreased in that period in Ratnivskyi district (from 96.8 ha to 10.71 ha), Liubeshivskyi (38.5 ha to 26.72 ha), Starovyzhivskyi (22 ha to 19.7 ha), Kivertsivskyi (8 ha to 3.2 ha). Instead, the burned area increased in Liubomlskyi district (5 ha to 6.74 ha).

Moreover, in 2015-19, peatland fires were recorded in the districts where they had not occurred before, for example, in Manevytskyi district (20.35

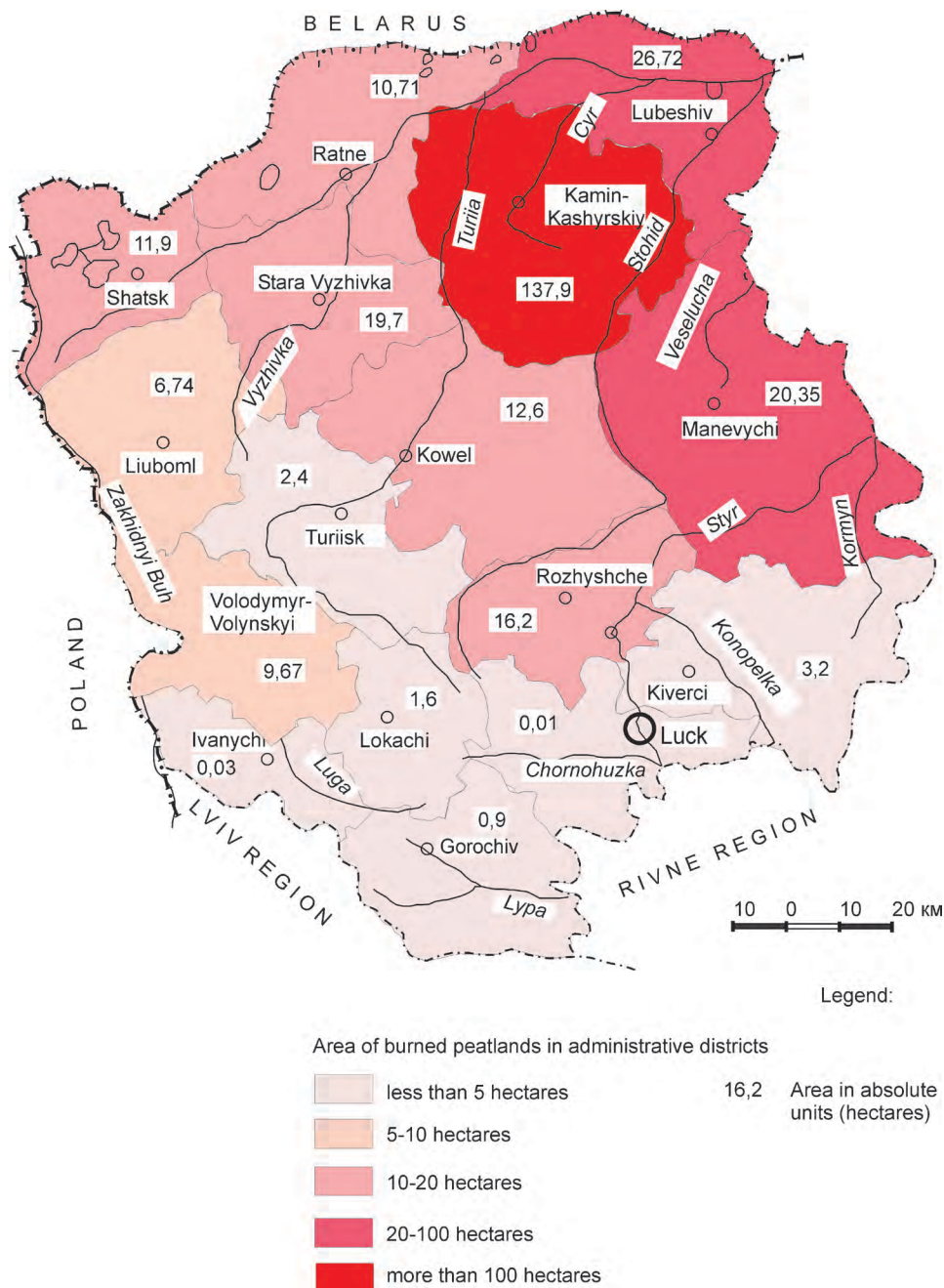


Fig. 4. Area of burned peatlands according to administrative districts of Volyn Oblast in 2015-19.

ha), Turiiskiy (2.35 ha), Lokachynskiy (1.55 ha), Rozhshychenskiy (16.22 ha), Volodymyr-Volynskiy (9.67 ha). Therefore, currently, cases of burning-out of peatlands were recorded not only in the districts where they were usually recorded (so-called north-Polesia districts – Kamin-Kashyrskiy, Ratnivskiy, Liubeshivskiy, Shatskiy), but also increased in the so-called south-Polesia districts (Turiiskiy, Lokachynskiy, Rozhshychenskiy, Liuboml'skiy, Volodymyr-Volynskiy, Manevytskiy, Kivertsivskiy) and were even recorded in administrative districts of the subzone of broad-leaved forests – Lutskiy (0.01 ha), Horokhivskiy (0.91 ha), Ivanychivskiy (0.03 ha).

Specialists of the Center of State Emergency Service of Ukraine and scientists assess the tendencies of the dynamics of peat fires pessimistically. The main reason of fires is burning of dry tree stands in pastures and of hayfields against the background of decrease in the level of groundwater and the dry climate of recent years. In mass media and social media, an active campaign for combating burning of dry grass and leaves has been started, but it has not proved sufficiently effective so far.

Therefore, we can ascertain the fact that burning peat massifs is becoming a significant ecological problem, jeopardizing not only the agroecological condition of soils, but also the safety of life of the

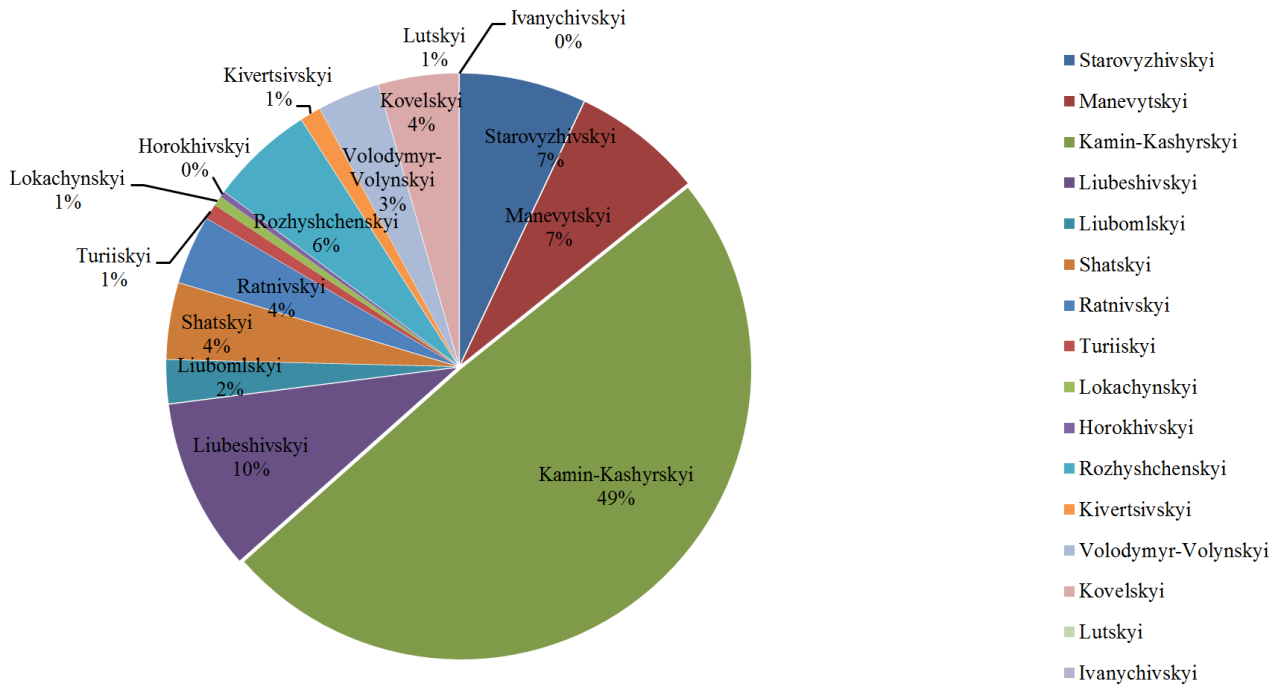


Fig. 5. Shares of the areas of burned peatlands according to administrative districts of Volyn Oblast (in %) for 2015-19.

population. Pyrogenic formations occupy large areas, adversely affect the conditions of agricultural activity, sometimes threatening the territories and objects of the nature reserve fund. The main threats posed by peat fires are:

- Decrease in fertility of soils and exclusion of land from agricultural use;
- Decrease in biodiversity and degradation of landscapes;
- Spread of smoke over large territories, pollution of atmospheric air with poisonous substances
- Decrease in the health of the population;
- Pollution of surface waters;
- Disturbance of the carbon cycle and increase in the emission of greenhouse gases.

Loss of soils as a result of peat fires in Volyn Oblast has already been evaluated above. It has to be noted that those soils are being destroyed which were used in agriculture. Soils are not only a necessary condition for agriculture for the local population, but a material resource of development and capabilities of local communities. This question becomes especially important due to decentralization.

The fall in biodiversity due to peat fires takes place specifically in these districts of Volyn Oblast which have highest nature reserve coefficients in the territories. Therefore, for example, Kamin-Kashyrskiy – 7%, Liubeshivskiy – 27.7%, Ratnivskiy – 7.9%, Shatskiy – 66.7%, Liuboml'skiy – 4%, Manevytskyi – 6.4%, Starovyzhivskiy – 6%. Peat fires can spread also within the objects and territories of the nature-reserve fund. Moreover, the Polesia latitudinal ecological cor-

ridor of national importance with centers and nodes of an ecological network of international, national and regional importance is located in these territories. There are also wetlands of international significance from the list “Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat”: Shatskiy Lakes, Floodplain of the Prypiat River, Floodplain of the River Stohid, Cheremsky Wetlands Complex in the territories of the Emerald Network, the number of which accounts for 13, most of them located in the northern Polesia districts of the Oblast.

We have not studied specifically the pollution of the atmospheric air with poisonous substances in the context of peatland fires. But as is known from the scientific publications (Gennadiev et al., 2013), during smoldering of peat in the conditions of insufficient oxygen, there accumulates benzo[a]pyrene – dangerous substance present in the associations of polycyclic aromatic hydrocarbons, which has carcinogenic effect. According to the materials (Zajdelman, 2011), during the intense peat fires, in the central region of the Russian Federation in 2010, the mortality of the population increased by 1.5-2 times. That is, peat fires in the recent years have also become a significant factor of increase in ecological danger.

In the global balance of greenhouse gases, wetlands and peatlands are natural accumulators of carbon which reduce the content of carbon dioxide and emission of greenhouse gases. In the swamped lands and peatlands dried for agricultural use or extraction of peat, the emission of greenhouse gases is much higher than in territories preserved in



Fig. 6. Burned peatland (Svydnyky village of Kovelskyi district) according to the materials (Zinchuk, 2019)

the natural condition or dried out and ferruginized (Crill et al., 2000). Thus, for example, wetlands and peatlands in natural condition absorb 856 kg/ha of CO₂ per year, dried out and salinised wetlands and peatlands – 515 kg/ha of CO₂ per year, and dried out wetlands and peatlands used in intense agricultural production by contrast produce 1,300-31,000 kg/ha of CO₂ per year. During the peat extraction, emission accounts for 10,600 kg/ha of CO₂ per year. Burned peatlands do not perform this important ecological function.

Therefore, the development of a complex of measures to prevent peat fires and overcoming their negative impacts is extremely important. These measures should ensure the execution of 2 important tasks:

- prevention of peat fires and reduction of negative effects in the future;
- further use, rehabilitation and recultivation of burned peatlands, re-naturalization of peatlands to natural wetland ecosystems.

Prevention of peat fires requires the following measures:

- two-sided (wetting and drying) regulation of water regime within reclamation systems;
- priority of using peatland soils for grasslands;
- increase in the fertility of dried-out soils by introduction of organic and mineral fertilizers, bio-preparations;
- sanding-up of dried peat soils (Zajdelman, 2011);
- monitoring of burned peatlands;
- prevention of ignitions in natural ecosystems.

Two-sided (wetting and drying) regulation of water regime within reclamation systems not always is easily performed due to the fact that many of these systems were not projected for two-sided regulation. Some were developed considering only fall of excess of groundwaters. Currently, even systems of two-sided regulation are not always in good exploitation condition, therefore could not be effectively operated. Out of 346.7 thou ha of lands of reclamation fund of Volyn Oblast, the two-sided regulation of water regime is used only in 157.7 thou ha, while in 47.8 thou ha the polder systems are constructed. According to the data of inventory checking of reclamation systems of Volyn Oblast, there are 37 thou ha of lands in which the water regime is not regulated at all due to unsatisfactory technical condition of hydro-technical constructions and pump stations (Lishchuk, 2014). Problem of regulation of water regime within separate non-working reclamation systems developed only considering that the one-sided water discharge could have been solved by waterlogging a part of the reclamation system which is not being used. This would allow increasing the level of groundwaters and biological productivity of phytocenoses, therefore reducing the level of danger of ignition.

The priority of using peat soils for grasslands is due to the fact that currently most of the dried peatlands are used in agriculture. They are intensively being exhausted, their surface is open to ignition and farming contributes to decomposition of organic mass of peat and emission of CO₂. Instead, using dried peatlands as grasslands and meadow-pasture lands, planting peren-

nial plants on them would contribute to decrease in the tempi of decomposition of peat by 2-3 times, decrease in deflation, danger of ignition, and also would provide conditions necessary for the development of effective animal husbandry (Zajdelman, 2011).

Increase in fertility of dried soils by introduction of organic and mineral fertilizers, biopreparations, and in the acidic peat soils – also liming, would increase the resistance of soils to fires, contribute to structuring and reduce deflation.

Sanding-up of dried peat soils. Experience of developed European countries indicates that there the number of peat fires and their negative impacts on nature are much lower than in Ukraine. This is due to the high culture of farming, use of polder systems with two-sided regulation of water regime, restoration using perennial herbs, and also use of mixed, covering or mixed-layer-by-layer sanding-up. Such approach allows one to a great extent of completely exclude the possibility of surficial ignition of dried peatlands (Zajdelman, 2011).

Monitoring of burned peatlands and areas of high risk of possible peat fires is also an effective measure for prevention of peatland fires. As indicated by the analysis of materials of the State Emergency Service concerning the localization of peat fires during 2015-19, they are repeated practically every year in the same massifs. For example, within Vorokomliv and Vydert village councils, the largest peatland fire in Volyn Oblast occurred on 9.08.2015. Also ignitions of peat within or near this peatland were recorded on 25.03.2015, 10.05.2015, and 2.05.2019. Similar examples could be provided for other places of ignitions. Therefore, it is important to conduct inventory checking of burned peatlands, distinguish areas with high possibility of peatland fires and perform their constant agroecological and reclamation monitoring. Organizing of monitoring needs a developed and properly funded program of monitoring peatlands. Sources of financing should comprise regional and local funds of nature protection.

Prevention of fires includes constant informational work of subdepartments of the State Emergency Service with population, village councils and united territorial communities aimed at preventing ignitions in natural systems and following the rules of fire safety. Especially important is abandoning the practices of burning leaves in autumn and dry grass in meadows in spring. Also important is timely liquidation of non-sanctioned landfills, burning rubbish, which is often the cause of fires.

To perform the second important task – the following use, renewal and rehabilitation of already

burned peatlands, realization of a complex of measures must be provided depending on the extent of pyrogenic degradation of peatlands and priority of the direction in the nature protection sphere. For example, most often two approaches are considered to solve this task (Zajdelman, 2011): extensive and intensive approaches. The first consists of use of the territories occupied by pyrogenic formations with close embedding of groundwaters for creating farms of breeding waterfowl, ponds for fishery, lands for recreational hunting or fishing, and also for plantations of energetic willows or other undemanding quickly growing energetic crops. The intensive approach is creating new mineral fertile soils in the places of pyrogenic formations. On pyrogenic formations, in the column of which the peat has completely burned out, deep recultivation should be performed. At the same time, recultivation of pyrogenic formations, formation of fertile horizons and return of such massifs into agrarian production is associated with such problems as absence of experience of such work; low fertility of formations; waterlogging of the territory (Shevchuk et al., 2005).

Choice of particular measures should include inventory checking of burned-out peatlands, assessment of economic and ecological damage, development of a plan of further use of the territories, determining priorities of development and measures for realization of determining priorities. Within Volyn Oblast, centers of burning out of peatland usually occupy not especially large areas (up to several ha). Therefore, fires were more or less quickly liquidated. Cases of complete burning out of peat down to parent rock are not frequent. It is expedient to exclude the burned-out peat lands from agricultural processing, separate areas allocated to the elements of the regional and local econetwork, buffer zone of nature-protected objects, perform restoration with grasses, water-supply development (if the condition of drying system allows it) Another effective way could be the use of pyrogenic formations for creating plantations for growing cranberries with prior artificial waterlogging of the territories, and also blueberries.

Conclusions. Therefore, problem of peat fires and burned out peatlands in Volyn Oblast is extremely relevant and requires a complex of measures to solve it. As of early 2002, the area of burned peatlands in the Oblast accounted for 440 ha. For the period of 2002-14, over 803 ha of burned peatlands were recorded across Volyn Oblast. In 2015-19 their area increased by 280 ha more. The largest areas of burned peatlands were in Kamin-Kashyrskyi district – 137.9 ha, Liubeshivskyi – 26.72 ha, Manevytskyi – 20.35

ha, Rozhyshchenskyi – 16.22 ha, Starovyzhivskyi – 19.7 ha, Kovelskyi – 12.47 ha, Shatskyi – 11.9 ha, Ratnivskyi – 10.71 ha.

The climatic tendencies of the recent years indicate an increase in the number of peat fires and their negative effects, including: decrease in soil fertility, decrease in biodiversity, degradation of landscapes, deterioration of the health condition of the population, changes in the carbon cycle and increase in the emission of greenhouse gases. Therefore, it is necessary to prevent fires and decrease their negative consequences in the future, and also to ensure further use, restoration and recultivation of burned peatlands.

Prevention of peat fires requires a two-sided water regime within reclamation systems, restoration with grasses of peat soils, increasing their fertility, sanding-up of dried peat soils. Also, important measures include monitoring of burned peatlands and prevention of ignitions in natural systems.

To further use, restore and recultivate burned peatlands, it is important to perform in good time inventory checking of burned peatlands, assess economic and ecological damages, develop a plan of further use of the territory, determine priorities of development and propose corresponding economic and nature-protection measures.

References

- Andreae, M., Merlet, P., 2001. Emission of trace gases and aerosols from biomass burning. *Global Biogeochemical Cycles*. 15(4). 955-966. doi: 10.1029/2000GB001382.
- Badmazhapova, I., Hyninova, A., Honchykov, B., 2014. *Izmenenye khymicheskikh svoystv osushennykh torfianykh pochv pod vliyaniem ohnevoho faktora*. [Change in the chemical properties of drained peat soils under the influence of the fire factor]. *Vestnyk KrasHAU*. 5. 50-55. (in Russian).
- Barbosa, P., Stroppiana, D., Grégoire, J., Pereira, J., 1999. An assessment of vegetation fire in Africa (1981-1991): Burned areas, burned biomass, and atmospheric emissions. *Global Biogeochemical Cycles*. 13(4). 933-950. doi:10.1029/1999GB900042.
- Bernard-Jannin, L., Binet, S., Gogo, S., Leroy, F., Perdereau, L., Laggoun-Defarge, F., 2017. Modeling dissolved organic carbon dynamics in a rehabilitated sphagnum-dominated peatland. *Carbon Balance of Western Siberian Mires in the Context of Climate Change: Proc. of the International Conference*. Tomsk. 100-108.
- Bowman, D., Balch, J., Artaxo, P., 2009. Fire in the earth system. *Science*. 324.(5926). 481-484. doi:10.1126/science.1163886.
- Bridgham, S., Megonigal, J., Jason K., Keller, J., Bliss, N., Trettin, C., 2006. The carbon balance of North American wetlands. *Wetlands*. 26. 889-916. doi: 10.1672/0277-5212(2006)26[889:TCBONA]2.0.CO;2
- Buts, Y., Asotskyi, V., Kraynyuk, O., Ponomarenko, R., Kovalev, P., 2019. Dynamics of migration property of some heavy metals in soils in Kharkiv region under the influence of the pyrogenic factor. *Journal of Geology, Geography and Geocology*. 28(3). 409-416. doi: 10.15421/111938.
- Crill, P., Hargreaves, K., Korhola, A., 2000. *The Role of Peat in Finnish Greenhouse Gas Balances*. Ministry of Trade and Industry, Finland.
- Diggelen, R., 2018. *Mires and Peatlands of Europe: Status, Distribution and Conservation*. Schweizerbart Science Publishers, Stuttgart.
- Elmes, M., Thompson, D., Price, J., 2015. Changes to the hydrophysical properties of upland and riparian soils in a burned fen watershed in the Athabasca Oil Sands Region, northern Alberta, Canada. *Catena*. 181. 157-170. doi: 10.1016/j.catena.2015.104077.
- Gennadiev, A., Cibart, A., 2013. *Faktory i osobennosti nakopleniya pirogennykh policiklicheskih aromatcheskih uglevodorodov v pochvah zapovednykh i antropogenno-izmenennykh territorij*. [Factors and features of the accumulation of pyrogenic polycyclic aromatic hydrocarbons in the soils of protected and man-made territories]. *Pochvovedenie*. 1. 32-40. doi:10.7868/S0032180X13010024. (in Russian).
- Haskevych, V., Netsyk, M., 2008. *Pirohenna dehradatsiia hruntiv Maloho Polissia: hruntovo-ekolohichni ta sotsialno-ekonomichni aspekty*. [Pyrogenic degradation of soils of the Male Polesia: soil-ecological and socio-economic aspects]. *Visnyk Lvivskoho Universytetu. Seriya heohrafichna*. 35. 49-57. (in Ukrainian).
- Hoscilo, A., Page, S., Tansey, K., Rieley, J., 2011. Effect of repeated fires on land-cover change on peatland in southern Central Kalimantan, Indonesia, from 1973 to 2005. *International Journal of Wildland Fire*. 20 (4). 578-588. doi: 10.1071/WF10029.
- Langmann, B., Duncan, B., Textor, C., Trentmann, J., van der Werf, G., 2009. Vegetation fire emissions and their impact on air pollution and climate. *Atmospheric Environment*. 43(1). 107-116. doi: 10.1016/j.atmosenv.2008.09.047
- Lishchuk, N., 2014. *Problemy funktsionuvannia mizhhospodarskykh ta vnutrihospodarskykh melioratyvnykh system*. [Problems of the functionalities of the intergovernmental and internal meliorative systems]. *Zbalansovane pryrodokorystuvannia*. 1. 65-73. (in Ukrainian).
- Phua, M., Tsuyuki, S., Lee, J., Sasakawa, H., 2007. Detection of burned peat swamp forest in a heterogeneous tropical landscape: A case study of the Klias Peninsula, Sabah, Malaysia. *Landscape and*

- Urban Planning. 82(3). 103-116. doi: 10.1016/j.landurbplan.2007.01.021.
- Polianskyi, S., 2006. Systema zakhodiv po zakhystu torfovykh gruntiv vid pirohennoi dehradatsii. [System of measures for protection of peat soils from pyrogenic degradation]. Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu im. V. H. Hnatiuka. Serii: Heohrafiia. 1. 170-176 (in Ukrainian).
- Shevchuk, M., Koloshko, L., Havryliuk V., 2005. Rekomendatsii zosvoiennia isilskohospodarskoho vykorystannia torfovysch, yaki poshkodzheni pozhezheiu. [Recommendations for the development and agricultural use of peatlands damaged by fire]. PDS IHA im. O.N. Sokolovskoho. Luck. (in Ukrainian).
- Stracher, G., Yearsley, J., 2019. Peat Fires in Ireland Coal and Peat Fires. Coal and Peat Fires: A Global Perspective. Elsevier Science. doi:10.1016/C2009-0-16444-9.
- Swindles, G., Morris, P., Wheeler, J., Smith, M., 2016. Resilience of peatland ecosystem services over millennial timescales: evidence from a degraded British bog. *Journal of Ecology*. 104(3). 621-636. doi: 10.1111/1365-2745.12565.
- Tanovytskaia, N., 2009. Sovremennoe sostoianye ispolzovanye bolot i torfianykh mestorodzhenyi Belarusy. [Current state and use of swamps and peat deposits of Belarus]. *Pryrodopolzovanye*. 16. 82-88. (in Russian).
- Tarnocai, C., 2006. The effect of climate change on carbon in Canadian peatlands. *Glob. Planet. Chang.* 53. 222–232. doi: 10.1016/j.gloplacha.2006.03.012.
- Taylor, D., 2010. Biomass burning, humans and climate change in Southeast Asia. *Biodiversity and Conservation*. 19(4). 1025-1042. doi: 10.1007/s10531-009-9756-6.
- Truskavetskyi, R., 2010. Torfovi grunty i torfovyscha Ukrainy. [Peat soils and peatlands of Ukraine]. Miskdruk. Kharkiv (in Ukrainian).
- van Beest, C., Petrone, R., Nwaishi, F., Waddington, J., Macrae, M., 2019. Increased Peatland Nutrient Availability Following the Fort McMurray Horse River Wildfire. *Diversity-Basel*. 11(9). doi: 10.3390/d11090142.
- Van der Werf, G., Randerson, J., Collatz, G., Giglio, L., 2003. Carbon emissions from fires in tropical and subtropical ecosystems. *Global Change Biology*. 9(4). 547-562. doi: 10.1046/j.1365-2486.2003.00604.x
- Zaidelman, F., Morozova, D., Shvarov, A., Batrak, M., 2006. Rastytelnost y pochvoobrazovanye na pyrohennykh substratakh torfianykh pochv. [Vegetation and soil formation on pyrogenic substrates of peat soils]. *Pochvovedenie*. 1. 19-28. (in Russian).
- Zajdelman, F., 2011. Rekomendacii po zashhite torfjanykh pochv ot degradacii i unichtozhenija pri pozharah. [Recommendations for the protection of peat soils from degradation and destruction during fires]. Knizhnyj dom «Librokom». Moskva. (in Russian).
- Zajdelman, F., Shvarov, A., 2002. Pirogennaja i gidrotermicheskaja degradacija torfjanykh pochv, ih agrojekologija, peschanye kul'tury zemledelija, rekul'tivacija. [Pyrogenic and hydrothermal degradation of peat soils, their ecology, sandy crops, reclamation]. Izd-vo Mosk. un-ta. Moskva (in Russian).
- Zinchuk, P., Shevchuk, M., Vlasiuk, O., Koloshko, L., Zinchuk, M., Halytskyi, A., Shtan, S., Merlenko, I., 2007. Pirohenno-dehradovani torfovi grunty Volynskoi o blasti ta zakhody shcho do yikh vykorystannia v narodnomu hospodarstvi. [Pyrogenic-degraded peat soils of Volyn region and measures for their use in the national economy]. Nature of Western Polesie and surrounding areas. 1. 23-29. (in Ukrainian).
- Zinchuk, M., Shevchuk, M., Gavryljuk, V., Didkovska, T., 2019. Stan, problemy ta perspektyvy vykorystannja gruntiv zemelnogo fondu Polissja Volyni. [State, problems and prospects of using soils of the Polissya Volyn land fund]. Retrieved from http://agrovoly.gov.ua/sites/default/files/attachments/zinchuk_prezentac_nim_ukr_dialog.pdf (in Ukrainian).