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Environmental & Socio-economic Studies

DOI: 10.2478/environ-2021-0009

Environ. Socio.-econ. Stud., **2021, 9, 2: 39-51**

Original article

The current landscape fire management in Ukraine and strategy for its improvement

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ABSTRACT

Recurrent wildfires in Ukraine exert severe impacts on the environment, human health and security as well as damage to private and public assets. From 2007 to 2020, the frequency of large wildfires has increased and reached a level that has not occurred previously. The period during April-October 2020 was the worst in modern Ukrainian history for the occurrence of catastrophic fires, e.g. in the Chernobyl Exclusion Zone (67 000 ha), Zhytomyr oblast (43 000 ha), Lugansk oblast (35 000 ha) and Kharkiv oblast (8 000 ha). In Ukraine there is the additional problem of open burning, mainly burning agriculture residues, which covers two million hectares (ha) annually. State forestry enterprises who are responsible for the management of 71% of the Ukrainian forests (7.6 million ha)and agricultural holdings are also responsible for the management of 41.3 million ha of croplands. The remaining forest users manage forest areas of 3.1 million ha within reserves and national nature parks. This article presents a brief overview of the problem of forest fires as well as of fires in other landscapes in Ukraine, and includes a critical reviews of the current wildfire management system and a description of the main features of the national wildfire management strategy. It also highlights the results of a survey of numerous stakeholders conducted on landscape fires in Ukraine. Based on the review of global and regional experiences, as well as existing fire risks in Ukraine, recommendations were developed for implementing an integrated landscape level national fire management approach.

KEY WORDS: wildfires, national wildfire statistics, fire management organization, National Fire Management Policy, Ukraine

ARTICLE HISTORY: received 23 March 2021; received in revised form 11 June 2021; accepted 14 June 2021

1. Introduction

Over the last decades, the change in fire regimes towards their higher occurrence and intensity has become increasingly evident at a global scale. Communities all over the world have faced catastrophic fires, like «Black Saturday Fires» in Australia in 2009 and «Black Summer Fires» in 2020 (NOLAN ET AL., 2020; MORRIS, 2020), wildfires in Israel in 2010, the Russian Federation in 2010 (GOLDAMMER, 2010), «CarrFire» in the USA in 2019 (ANONYMOUS, 2020), Siberia during 2015-2020 (PONOMAREV ET AL., 2019), Chile in 2017 (PLISCOFF ET AL., 2020; GFMC, 2017), Ukraine on terrain contaminated by radioactivity in 2015 (EVANGELIOU ET AL., 2016) and 2020 (TALERKO ET. AL., 2021). This relatively short list of catastrophic fires, from a much larger complete list of fire incidents, as well as other reports, which have been published over the last two decades (FAO, 2001, 2005, 2006; GOLDAMMER, 2013a; GFMC, 2017; SAN-MIGUEL-AYANZ ET AL., 2020) on fires in natural landscapes confirms the severity of the problem around the world, and includes Ukraine.

In Ukraine extreme wildfires have become more frequent: in 1992 in the Chernobyl Exclusion Zone, in 1993 in Crimea, in 1996 in Kyiv, Donetsk, Luhansk, Chernihiv oblasts (ZIBTSEV ET AL., 2019);

in 2007 in Kherson oblast (9 000 ha) and in Crimea (1 000 ha) (ZIBTSEV, 2007); in the Chernobyl Exclusion Zone in 2015 (2 events – 15 000 ha) (EVANGELIOU ET AL., 2016). The year 2020 became the worst year in modern Ukrainian history. Catastrophic fires occurred during April-October in the Chernobyl Exclusion Zone (67 000 ha), Zhytomyr oblast (43 000 ha), Lugansk oblast (35 000 ha) and Kharkiv oblast in 2020 (8 000 ha). The main driver of all the fires in 2020 was unprecedented droughts and strong winds that were never previously observed in Ukraine.

Fire management system along with changes in land use, increasing anthropogenic pressure on ecosystems, increasing human mobility and climate change (BALABUKH, 2017; BALABUKH & ZIBTSEV, 2016; SHEVCHENKO ET AL., 2014) are the main factors of fire safety. The organizational structures of forest fire management of individual countries with their own political-administrative decentralization and organizational cultures differ as well. These add to the complexities of understanding fire risk. For example, in Portugal, the Agency for the Integrated Management of Rural Fires (AGIF) has responsibility for the coordination of measures of prevention, fuel management, and awareness campaigns (PORTUGUESE REPUBLIC, 2018). Coordination of suppression is the responsibility of the National Civil Protection Authority. The suppression activities are carried out by fire brigades, most of which consist of associations of civil society – volunteers. Fire brigades can also develop surveillance activities coordinated by the Municipal Service of Civil Protection (TEDIM ET AL., 2015). Another example is France where forest firefighting is the responsibility of the Fire and Rescue Service that is a part of Civil Protection. There is a total of seven defence zones and 95 «local circumscriptions», each with a fire and rescue department composed of around 30 to 60 fire brigades being responsible for prevention and fighting namely of forest fires. The local fire and rescue departments are financially run by local authorities, but they follow national rules and methods (TEDIM ET AL., 2015). In Greece fire suppression is the responsibility of the Greek Fire Brigades. The Forest Service maintains a role in fire prevention (e.g., prevention planning, forest fuel management, forest road network maintenance) while the General Secretariat for Civil Protection has a coordinating function, including facilitating the supporting role of volunteer groups and of the resources of the local authorities for the suppression activities (XANTHOPOULOS, 2012). A new system and the respective establishment of a coordination agency for inter-agency cooperation, similar to the AGIF of Portugal, has been discussed since 2019 (GFMC, 2019; XANTHOPOULOS ET AL., 2019). In Poland, policy regulation, coordination and funding of fire management are provided by the Ministry of Environment (coordination of the National Parks, State Forests, Research Institute) and by the Ministry of Internal Affairs and Administration (coordination of the State Fire Service). In general, fire management brigades function in 22 National Parks and 439 Forests Districts. The State Fire Service provides support for fire suppression with its own resources in case of complex fire incidents. The wide involvement of volunteers is an important feature of fire management in Poland (Voluntary Fire Services) (UBYSZ, 2002). In Belarus, the personnel of forest fire stations, that function within 118 state forest enterprises, fight fires. Forest enterprises (forest users) provide the full range of fire management measures, including suppression. Forces from other agencies, such as the Ministry of Emergencies and the Ministry of Defence, are involved in extinguishing fires and dealing with emergencies (USENYA, 2017). In the case of Ukraine, forest fire prevention, detection and suppression are the responsibilities of the Forest Service. The State Fire and Rescue Service provides support for forest fire suppression when the forces of the Forest Service are not enough, typically in emergency situations.

This article contains a brief discussion of fire management, a review of the institutional organization of the fire management system that is currently in place in Ukraine, and makes suggestions for its future enhancement. Section 1 contains an overview of the trend in fire occurrence in Ukraine. Section 2 describes the data and methods used. Section 3 contains a description of statistical data concerning wildfires in Ukraine with brief reference to the forests of Ukraine. Section 4 contains a short review of the forest fire management system components in Ukraine. Section 5 describes the results of the analysis of the forest fire management system in Ukraine by components as well as the results of the survey of the visions of practitioners for its improvement. Section 6 deals with strategic recommendations based on this analysis. It also includes the recommendations of central executive bodies in Ukraine.

2. Materials and methods

For the analysis of the fire history in Ukraine, official data of government agencies, scientific publications and the results of research, including remote sensing methods, were used (ZIBTSEV ET AL., 2020; HALL ET AL., 2021). Information on regulations relating to the forest fire and wildfire management

in Ukraine (i.e. shared rules, norms, strategies, policies, and practices) were explored.

The literature review was supplemented with a survey involving numerous stakeholders involved with landscape fires in Ukraine (rural and city populations, farmers, forestry enterprises, emergency service brigades, military, police, medicine, air quality control etc.). This involved stakeholders in the political processes of discussion and information exchange and contributed to clarifying the main causes of fires, ignition sources, fire regimes in relation to socio-economic development, land use change dynamics and the main consequences of fires for human and environmental security. A total of 154 respondents from 21 regions of Ukraine were also interviewed. The wide discussion of stakeholders including all main branches of authorities allowed researchers to find gaps in the current fire management system, to investigate international experiences, and to develop recommendations for capacity building in the new principles of fire management. The institutional problems identified in the process of the literature review have been considered for triangulation based on the results of the survey.

3. Overview of wildfires in Ukraine

The area of forests in Ukraine (as of 1 January 2019) is 10.7 million ha (18.5% of the country's area), nearly 30% of which are fire-prone pine forests (ANONYMOUS, 2012). Nearly 73% of all forests are managed by the State Agency of Forest Resources of Ukraine (397 state forestry enterprises) (SFRAU, 2019). More than half of all forests in Ukraine are of artificial origin with single species stands that are not resilient to fires. Other than forest lands – 41.3 million ha (71.3% of land area of Ukraine) are in agricultural use (cropland, pastures, meadows, etc.).

According to official data, within the period between 1990 and 2019 in Ukraine, an average of 3 000 forest fires burned around 4 000 ha annually (ZIBTSEV ET AL., 2019; SSSU, 2000-2020). The new era of climate change increased the average statistical indicators. The fire extreme year of 2020 (period 1990-2020) doubled the area of firers to 7 000 ha per year. The average area of one fire during this period was 2.8 ha in state-owned forests (81% of the average annual area of one fire was less than 1.4 ha) and was 2.2 ha in other forests (municipal). The average rates of forest fires in state forests and forests of other forest users do not differ significantly. This is primarily due not to the fire management system in these forests, but to the spatial characteristics of forests – the forests of other users are usually small and highly fragmented. Such spatial features of not state forests, often create the conditions under which forest fires that have occurred in the forests of other users are transferred to state forests. The long-term dynamics of forest fires is illustrated in Figure 1.

The statistical data reveal that between 1990 and 2020 on average three to four catastrophic fires occurred in each decade. Human settlements near forests and intense human activity are widespread in Ukraine, which further increase the risk of human-caused ignition. Extreme droughts associated with extreme heat waves constitute a major contributory factor to catastrophic fires. Responses to the periodic catastrophic fires indicate that the capabilities of the current forest fire management system is limited to effectively respond to fires in critical weather conditions.

A new additional challenge to the fire situation in Ukraine is the presence of military operations in Eastern Ukraine. Between July and October 2014 in the zone of military conflict in Donetsk and Luhansk regions 12 500 fires were recorded, 405 of which were forest fires (OSCE, 2017). The area of pine forests affected by fires reached 20 000 ha or 22% of all forests in the region (ENVIRONMENTAL ASSESSMENT, 2017). Three fire episodes in July and September-October of 2020 in Luhansk Oblast burned 400 houses and resulted in 16 fatalities and forest damage over an area of 35 000 ha, that constituted 45% of all pine forests of Luhansk oblast.

Most large-scale negative impacts on the environment in terms of black soil damage and regional level of CO_2 emission is related to massive open burning in Ukraine. According to ZIBTSEV & GOLDAMMER (2019), the total annual area of open burning in Ukraine amounted to 1.28 million ha in 2010 and 5.27 million ha in 2014 (ZIBTSEV & GOLDAMMER, 2019). Remote sensing methods estimated the territory of Ukraine burned by fires during the period 2001-2019 (ZIBTSEV ET AL., 2020; HALL ET AL., 2021) as 2 million ha, with 11 700 fires annually. The majority of open burning is related to illegal burning of agricultural residues by small landowners (ZIBTSEV ET AL., 2020). Agricultural burning often causes forest fires, including fires on protected areas (ZIBTSEV ET AL., 2020; REGULATION (EU) 1306/2013, 2013).

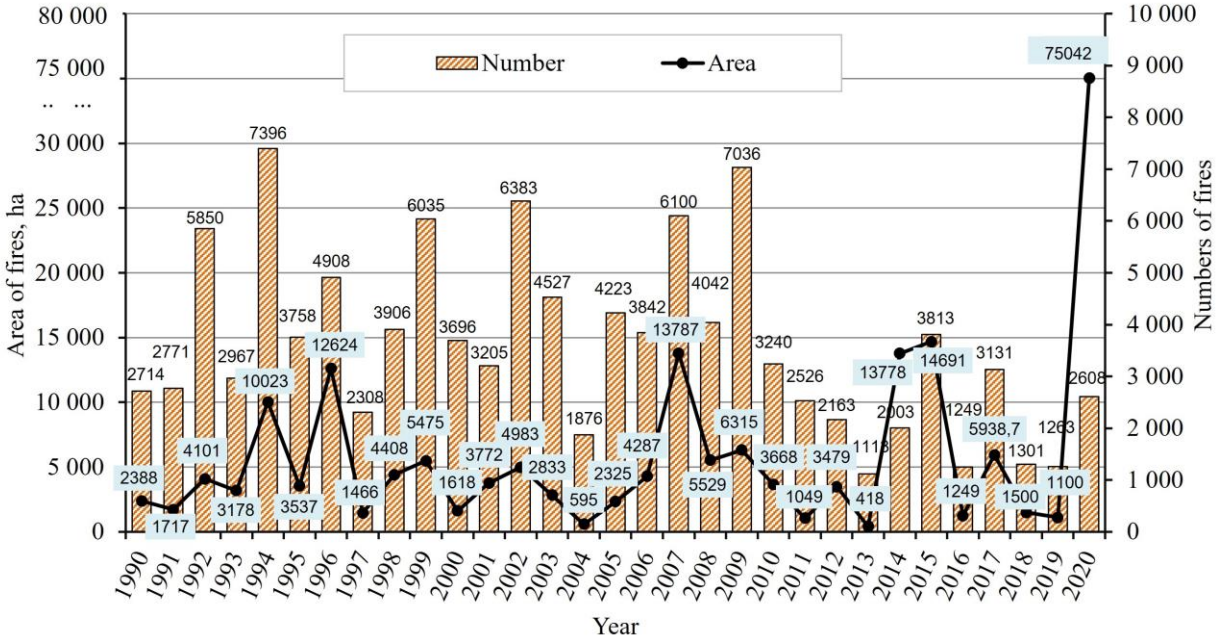

Fig. 1. Number (poles) and area (line) of forest fires in Ukraine, 1990-2020 (Source: SSSU, 2000-2020)

4. Review of the current wildfire management system

4.1. Organizational structure of the fire protection system

Wildfire management in Ukraine is aimed at "no fire" which means the goal is for the maximum prevention and suppression of all possible fires as was the case in Mediterranean countries like Greece, Spain and Italy in the past (TEDIM ET AL., 2015). Traditionally, Ukrainian foresters consider forest fires as "negative" events that damage forests and cause economic losses. Post-fire successions are often not similar to the foresters' expectations, which is aimed at growing highly productive forests. Such an approach has no chance of being implemented where there are large numbers of ignition sources in natural and cultural landscapes, and the wide use of fire for land management and climate change. Nevertheless, highly efficient organization systems of fire management, along with the use of new technologies and integrated approaches can reduce the size of burnt areas.

Carrying out fire management is obligatory for all forest users in Ukraine: state forest enterprises («Ahrolishospy» – managed forests of former «Kolhospy»), municipal forests, military forests, the Chernobyl Exclusion Zone and protected areas (ZIBTSEV ET Al., 2020). In fire-hazardous pine forests, there are usually organized forest fire stations. In other forests fire-fighting equipment is available. Nature reserves (for conservation) are not provided with fire management plans and equipment.

Forests managed by the State Forest Resources Agency of Ukraine (SFRAU) provide vertical command and support required for fire prevention, detection, initial attack and suppression. In the remaining forests, the level of fire management is mostly unsatisfactory and low, with a few exceptions. Protected areas also do not have targeted funding for fire management and do not have enough firefighting personnel and equipment nor do personnel have sufficient training.

The State Emergency Service of Ukraine (SESU) with its resources takes responsibility for incident management organization in case fires reach the level of emergency and threaten the population and settlements. SESU may assist forest management enterprises to put out small and medium-size fires. Fire management on agricultural land is the responsibility of the landowners and/or land users. United Territorial Communities provide on-site support for these endeavours.

SFRAU and its state forestry enterprises – responsible for the management of 71% of the Ukrainian forests (7.6 million ha) and agricultural holdings and farmers are responsible for the management of 41.3 million ha of croplands and are the main stakeholders of the national landscape fire management system. Small land users (64.1% of all), with low levels of environmental awareness, are most often the culprits of agricultural burning (burning straw after harvest/stubble burning). The remaining forest users who manage forests with an area of 3.1 million ha are reserves and national nature parks.

4.2. Regulatory policy

Forest Fire Management in Ukraine focuses traditionally on prevention and suppression systems. Issues are regulated by a number of laws and bylaws (about 20 national ones), including: the Forest Code of Ukraine (1994); Code of Civil Protection of Ukraine (2012); Law of Ukraine on the Nature Reserve Fund of Ukraine (1992); Rules of Fire Safety in the Agro-industrial Complex of Ukraine (2006); Regulations on State Forest Protection (2009); Classification of emergency situations (2018); Rules of fire safety in the forests of Ukraine (2004); Regulations on forest fire stations (2009) and others (USENYA ET AL., 2018). Of the latter, in 2017, the «Procedures for the Organization and Use of Aviation and Means for Forest Fire Extinguishing» was adopted, which determines the involvement of aircraft in extinguishing forest fires. In 2020, after a large number of fires, this law was passed, providing for a significant increase in fines for violating forest fire safety requirements and the unauthorized burning of dry vegetation. Furthermore, for violating the forest fire safety rules the penalty was increased ten fold to 15,300 UAH (about 440 €). In general, the main function of laws and policies is to regulate the system of Fire Management of natural areas. Most attention is paid to the prevention of forest fires.

4.3. Fire statistics

To date, the most complete source of data on forest fires are collected and published by the State Statistics Service of Ukraine (SSSU) and the State Emergency Service of Ukraine (SESU). The State Agency of Forest Resources also maintains detailed statistics on forest fires, but only within the forests subordinated to the agency. Data on the number and area of forest fires in Ukraine is given in the annual statistical publications of the SSSU (SSSU, 2000-2020). However, the data of the State Forest Agency and the SESU of Ukraine often have significant differences with the data of the SSSU, which indicates the imperfection of the fire information collection system. For example, in 2014, according to the SSSU, there were 2 000 forest fires on a total area of 13 800 ha. Furthermore, according to the State Forest Agency, in the forests under its jurisdiction, there were 1 500 fires on a total area of 16 700 ha. In 2015, according to the SSSU, there were 3 800 fires on the territory of Ukraine on a total area of 14 700 ha, 11 200 ha of which were in the Kyiv region, when there were only two large fires in the Exclusion Zone, which covers an area of 14 800 ha (EVANGELIOU ET AL., 2016).

Today, all fires are registered by satellites, and numerous products with geospatial information systems about fires provide free access to fire information, e.g. products such as FIRMS, WorldView, OroraTech, GOFC-GOLD, EFFIS, GWIS and others (GOLDAMMER, 2021), which simplifies access to actual data on fires in natural landscapes and creates new opportunities for monitoring systems.

4.4. Prevention systems

The system of fire prevention in the forests of Ukraine involves the use of traditional methods that were developed in the last century, when computers, electronic communication and remote sensing technologies had not been used. The traditional system included the creation of a network of fire barriers (fire breaks, fuel breaks), ground patrolling and monitoring of fires by observers from fire outlook towers. The configuration of firebreak grids was designed by considering fire hazard of forests (fuel load and flammability) based on the experience of forest managers. The current fire prevention system is based on regulatory requirements and does not take into account modelling of factors determining wildfire risk.

4.5. Fire danger rating system

Fire risk in natural landscapes is determined by the ability of combustible material to be ignited and spread and the intensity of fire as influenced by weather conditions. The wildfire early warning system in Ukraine until recently was based on the Nesterov Index (NI) with some improvements - taking into account precipitation over the past day (NESTEROV, 1949).

$$NI = k \cdot NI_{n-1} + t \cdot (t - \tau), \qquad (1)$$

where: NI – Complex Weather Index of fire hazard; NI_{n-1} – complex weather index of fire hazard from the previous day; t – temperature (°C), τ – dew point (°C), determined at 13 o'clock in the afternoon, k is the coefficient that takes into account the precipitation of the previous day. Further modernization of the coefficient k is carried out by taking into account not only the precipitation for the past day, but also the wind speed (KUZYK, 2011).

Current rules set the levels of fire hazards of weather conditions: Class I – NI ≤400 (no fire danger); Class II – NI 401-1 000 (low danger); Class III – NI 1 001-3 000 (average fire danger); Class IV – NI 3 001-5 000 (high fire danger); Class V – NI> 5 000 (emergency fire danger). The limit

of the 1st class of fire weather danger (lowest danger – wet conditions) is the value of NI at which up to 5% of fires are observed, 2nd class – 15% of fires, 3rd and 4th class – 25% of fires, and 5th class – 30% of fires. Forestry enterprises receive daily information on the fire hazard class of the weather from local meteorological stations.

4.6. Technical capacity for fire suppression

Among all land and forest users, state forestry enterprises, which function under the management of SFRAU, have the highest capacity for detection and suppression of wildfires. The enterprises widely use video surveillance systems for the reliable detection of forest fires. However, at present, almost 80% of fire engines are 30 to 40 years old and this often puts firefighting personnel at risk during incident management operations. A typical fire engine is presented in Figure 2.

Currently in Ukrainian forest fire pick-up trucks (called fire modules) are widely used with a small (up to 1 ton) water capacity for rapid response and initial attack (Fig. 3). Hand tools like flappers, shovels and backpack fire extinguishers are also widely used in Ukraine.

Fig. 2. The most common fire engine in a typical forest fire station in Ukraine (AT-40 on the chassis ZIL-131. Paryshiv Fire Station, Chernobyl Exclusion Zone)

Fig. 3. Forest fire patrol car with a pick-up fire suppression unit as used in Cherkassy Oblast (Source: lis-ck.gov.ua)

Currently, there is no special funding from the central state budget for land and forest users to support ground fire management. Under such conditions, forestry enterprises in the southern and eastern regions of Ukraine, which do not have incomes from sales from commercial timber harvesting due to poor forest growth in the dry climate and site conditions, are unable to prevent large wild fires due to the absence of funds, low human and technical capacities. In 2019 and 2020, a small amount of funds was allocated from the state budget for firefighting measures. However, these funds were sufficient only for partial, non-systemic, support and can be considered temporary measures. In 2016, the fire aviation system in Ukraine, that provided information to forest enterprises on the level of fire danger from the weather, carried out air patrols of forests and fire reconnaissance, was phased out. As a result, the training of aviation observers and forest firefighters was stopped. Currently, the aircraft of the State Emergency Service of Ukraine is involved, but only during the extinguishing of large fires in declared emergency situations.

4.7. Fuel management

Fuel management has three components: establishment of fuel-breaks, fuel reduction, and silvicultural measures, which include conversion of fire-prone pure pine stands to fire-resilient mixed forests. Currently, in Ukraine, there is no explicit policy aimed at fuel management, other than establishing firebreaks (the most common are 1.4 m wide) and fuel barriers (50-150 m wide). There is no practical application of two other above-mentioned fuel management activities. Most silviculture measures in fire prone Scots pine forests are aimed at forming productive and healthy stands. Fire resilient structure is not included in the objectives of forest management in Ukraine.

4.8. Response and suppression

The incident (emergencies) management system in Ukraine for wild fires consists of three levels of coordination and provision of the necessary human and financial resources during firefighting: local, regional and national.

Responding to a fire primarily involves the use of the resources of the forest owner who usually leads the initial attack with assistance of the local SESU brigade if needed. After re-classification of a fire, if it became uncontrollable and evolving into an emergency, SESU takes responsibility for incident management; all actions will be decided by consent

from the forest owner. If the fire continues to grow and local SESU and forestry fire brigades are not able to control it, fire resources of neighboring forest users (oblasts), fire brigades of SESU from neighboring oblasts will be deployed to the scene. Figure 4 illustrates the departmental organization of protecting landscapes in Ukraine from fire.

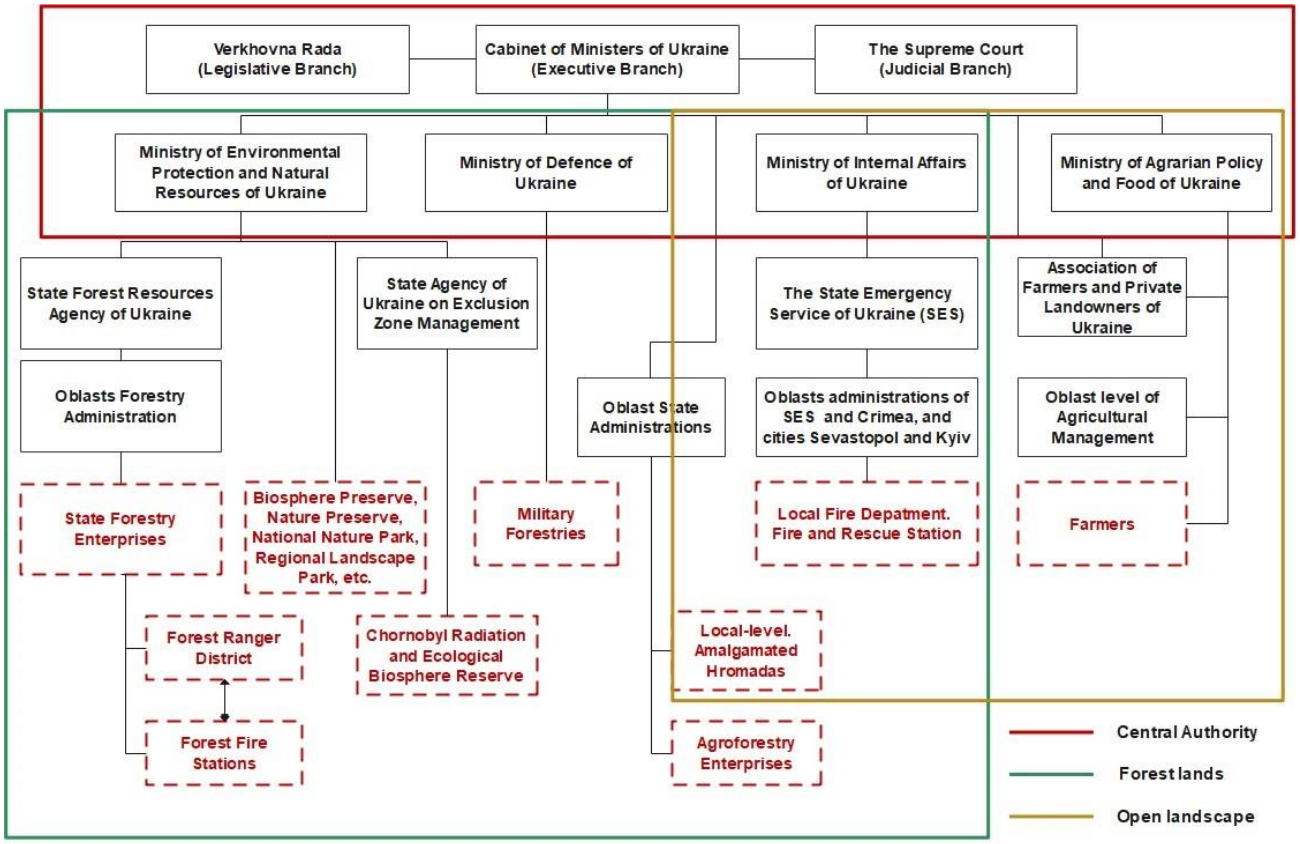

Fig. 4. Departmental Organization of protecting natural and cultural landscapes in Ukraine from fire

4.9. Scientific research

During the first two decades after the end of the Soviet era, fire research was not systematically carried out in Ukraine. In 2013, the First Forest Fire Laboratory was established at the Research Institute of Silviculture and Gardening of the National University of Life and Environmental Sciences of Ukraine. This laboratory was further strengthened by the establishment of the Regional Eastern Europe Fire Monitoring Center (REEFMC) with the support of the Global Fire Monitoring Center (GFMC) and financed by the Council of Europe (GFMC, 2013; GOLDAMMER, 2021). Climate change, land use and societal dynamics (rural exodus, urbanization, increasing the mobility of people, etc.), and scientific and technological progress require the implementation of the latest technologies and modern approaches to fire management. In Ukraine, some fire research is carried out within the research programs of the Ministry of Education and Science of Ukraine. The research agenda includes Ph.D. studies and various international cooperative grants.

5. Results of baseline analysis

Traditional methods of forest fire management, which included maintaining a network of firebreaks, human-based fire detection and manual suppression worked quite effectively until recently. However, with increasing weather extremes, notably droughts, as a consequence of climate change, these traditional methods are insufficient to cope with the problems of increasing wildfire risk. New organizational and managerial approaches and technologies in fire management, which are currently implemented in the Chernobyl Exclusion Zone, include use of remote sensing methods for fire history analysis and the development of a land cover layer, fire prevention planning based on probabilistic techniques, forest fire behaviour models, burn probability, ignition probability and support of implementation. These approaches, which are supported by projects financed by international donors, should be applied over the whole territory of Ukraine.

The components of the current fire management system on natural and cultural landscapes in Ukraine were analyzed. The disadvantages of the current institutional responsibilities are listed and recommendations for improvement are given in Table 1.

Table 1. Disadvantages of the current system and brief recommendations for measures to be taken to prepare the current system to address new challenges

Components	Disadvantages of the current system	Recommendations for future improvement of Governance for Fire Management
Organizational structure of fire management	– lack of a single organizational structure for all enterprises – personal responsibility of heads of enterprises for the number and area of fires – similar fire management organization for all forests without take into consideration the functional purpose of them – lack of fire zoning – lack of a single organizational system for protection of agricultural land from fires – the system of fire protection of the SESU of Ukraine is designed primarily for settlements, the location of fire calculations often does not facilitate a rapid response to natural fires	– evaluate the effectiveness of protection of natural landscapes from fires by the average area of a single fire – develop a generally accepted and scientifically sound structure of protection of natural and cultural landscapes from fires, taking into account the functional purpose of these areas – regulate comprehensively the use of fire on agricultural lands – develop an alternative to the use of fire on agricultural lands – provide special training for those involved in firefighting, fire management guidelines and an interagency coordination and command system for large wildfire events
Regulatory policy	– unregulated issue of forest firefighters' qualification levels – the ban on burning plant remains has led to anonymous, uncontrolled burns – there are no approved guidelines for forest fire management – «Ukrdiprolis», which had been carrying out fire-fighting forest management for many decades and had accumulated considerable experience, was abolished – identical (very simmilar), often a formal approach to the development of firefighting projects, without allowing for the modern challenges, shortcomings of the previous projects and advanced world achievements – notably, there is no accepted forest firefighter clothing, like the protective clothing used by forest firefighters in European countries or in the United States. There are only recommendations on the material from which it should be made	– legally approve the qualifications of a forest firefighter – legally regulate the issues of special training of forest firefighters and forest fire extinguishing managers – offer an alternative to the use of fire to clean fields after harvest (material support, training in safe technologies of controlled burns, etc.) – develop fire-fighting management projects using risk models for the occurrence and spread of fires – approve a sample of forest firefighters clothing
Monitoring system	– defective fire monitoring system – information on fires in open landscapes is not recorded in the statistical collections of the SSSU – discrepancies between the data of the SFRAU, the SESU of Ukraine and the SSSU – distorted fire statistics do not allow realistic assessments of the scale of the problem nor allow appropriate management decisions within the country – personal heads responsibility of land (forest) users for fire indicators, in particular the area of fires, that influence on underestimation of real data (Zibtsev et al., 2019) – information of the State Agency of Forest Resources of Ukraine about fires is only departmental	– improve the system of collecting information on fires in natural landscapes (to ensure the representativeness of data, to add information on fires in open landscapes) – apply remote sensing methods to verify fire data – develop a national electronic database of fires, which would be common to all users and contain spatial and temporal information about fires
Prevention systems	– use of traditional methods, which included an elaborate network of fire lines, block lines, early clearing and simple technologies of fire detection and suppression, was quite satisfactory in the past but already outdated	– implement the latest technologies planning probabilistic techniques, remote sensing, geographic information systems, models of forest fire behaviour, burn probability, ignition probability and fire risk analysis techniques

Meteorological data system	– use of the comprehensive Nesterov indicator of fire hazard according to weather conditions with some improvements - taking into account precipitation over the past day (Nesterov, 1949) – a comprehensive indicator cannot always effectively warn about the risks of fire occurrence (Balabukh, 2017; Kuzyk, 2011)	– carry out special scientific research on the scale of fire danger according to weather conditions – develop and implement a universal system for providing information on the class of fire danger for forest and land users, which will ensure the appropriate level of fire safety measures and preparedness in accordance with the current danger
Logistics	– non-profit enterprises are deprived of the opportunity to ensure an adequate level of protection for natural landscapes from fires – obsolete equipment (in the State Agency of Forest Resources of Ukraine almost 80% of firefighting equipment is 30-40 years old – abolition of the basic aviation protection of forests, which provided prompt information to forestry enterprises on the level of fire danger from the weather, aviation patrol of forests, and fire reconnaissance	– develop and implement a financing program for the systematic protection of natural landscapes from fires to provide the opportunity for non-profit enterprises – develop a plan for modernizing equipment and immediately start renewing it – ensure the performance of all functions performed by the air base of forest protection (using unmanned aerial vehicles, video surveillance cameras, etc.)
Fuel management	– lacking a fuel management system (only a system of fuel-breaks)	– develop fuel management systems in high risk pine forests, which include reduced fuel load and conversion into fire-resistant forests on fire hazard forest ages – use prescribed burning (Goldammer & Montiel, 2010; Goldammer, 2013b)
Response system	– imperfect system of interaction – outdated methods of monitoring and response	– improve interactions of all agencies – use modern technology for early detection and quick response
Scientific research	– lack of scientific institutions that would conduct systematic forest pyrological research – fire protection measures without enough scientific substantiation – the scale of fire hazard according to weather needs to be improved, as in some cases it underestimates the real fire hazard (Hilitukha et al., 2011), which causes low staff readiness – no complete data on stocks of combustible materials, their humidity and structure – no models of risks of occurrence and forecast of fire behaviour	– carry out the organization of fire protection of natural areas by taking into account scientific research – establish a specialized organization with functions for systematic scientific research, determine priorities, develop scientific and practical recommendations, develop fire-fighting regulations, and participate in the development of a regulatory framework

Table 2. Views and visions of practitioners for improving the Landscape Fire Management System (Source: Evaluation of a questionnaire based on returns by154 respondents from 21 oblasts of Ukraine (2020)

Categories	Ranked answers, %
Update of equipment & machinery/ (forest firetruck, firefighter equipment etc.) and modern technical equipment needed	21
Provision of State funding for Landscape Fire Management	14
Strengthening the responsibility of citizens and land users	12
Use of modern systems and technologies for fire detection	12
More active and effective educational work among the population (citizens)	11
Local authorities must regulate and control the implementation of fire prevention measures in their territories	5
Carrying out of preventive fire-prevention actions	5
Air patrol of forests	4
Land users bordering the forest must carry out fire prevention measures	2
Modern equipment and personal protective equipment needed	2
Report of the consequences of forest fires in the media	2
Improve interaction of the different agencies	2
Creation of volunteer fire brigades	2
Establishment of an interagency fire service to respond to large fires	2
Improving the policy for Landscape Fire Management	2
Prohibit forest visits during the high fire hazard period	1
Fuel load regulation	1

Note: 71% of respondents were foresters, 21% were workers from reserves and national nature parks and 8% were workers from SESU, NGOs, scientific organizations and farmers.

The development of a landscape scale Fire Management System (FMC), based on highly coordinated inter-institutional mechanisms and the application of innovative technologies, is critical. For a deeper analysis of the FMS, respondents from Forestry Enterprises, National Parks, Nature Reserves, SESU, NGOs, scientific organizations and farmers were surveyed. Table 2 lists the survey results that respondents deemed to be important for improving wildfire management.

Respondents were also asked about interagency cooperation, in which 15% answered the lack of joint training and exercising, 13% indicated insufficient staff training, and 11% indicated no policies for effective interaction. Only 6% indicated there was a coordinated interaction. Respondents also reported that 84% of fire trucks were obsolete, average age of trucks was 46 years.

6. General strategy for improvement

The common practice of fire management in forests has two main goals: preventing fires, and suppressing fire as quickly as possible once detected. Based on a review of global and regional experiences, as well as existing fire risks in Ukraine, the following recommendations were developed together with the Global Fire Monitoring Center (GFMC) towards the implementation of a national Integrated Landscape Fire Management approach:

- develop a framework for cross-sectoral national policy which addresses the consequences of changes in land-use, socio-economic developments, and climate change, which accelerate the risk of wildfires affecting the territory and society of Ukraine;
- propose proactive and future-oriented measures to increase the resilience of Ukrainian landscapes and society against the adverse effects of wildfires
- assess the ecological role of fires in different landscapes of Ukraine, including protected conservation areas;
- determine the strategic goals of fire protection;
- develop state policy that will correspond to all normative and material maintenance;
- develop and implement a program of financial support for fire management;
- conduct the systematic education of the population on ecological and economic awareness of fire use;
- implement a policy for the continuous improvement of fire prevention and extinguishing technologies by taking into account international best practices, trends and innovations, such as effective and early detection of fires with video systems, quick response by aerial means (including Unmanned Aerial Systems – UAS), fire suppression chemicals, as well as systems for monitoring and predicting parameters influencing wildfire risk at short term (fire danger rating) and long term (fire hazard as influenced by vegetation characteristics and climate change);
- support scientific research related to fire hazards in the natural landscapes of Ukraine;
- provide forest firefighters and forest fire fighting managers with training courses, with different levels of complexity;
- encourage land and forest users to protect territories from fires as well as the people involved in firefighting.

The findings also highlight that fire management would benefit from greater use of scientific products and technologies, such as models and forecast tools for fire management decision making processes.

7. Discussion

The forest fire management policy in Ukraine focuses on traditional prevention and suppression activities even though forest and land management are the core of the forest fire problem. The current system of protection of natural areas from fires requires the development of a strategy for improvement, and determination of strategic goals including use of prescribed burning. The main efforts should be focused on prevention measures, which include fuel management. The practice of benefitting from lessons learnt should be applied to fire analysis, especially for large ones. Particularly, as there was insufficient analysis and a lack of appropriate decisions after the fires in 2015 in the Chernobyl Exclusion Zone which led to a recurrence of the situation in 2020 (ENVIRONMENTAL ASSESSMENT, 2017; TALERKO ET AL., 2021).

National fire management policy must take into account trends in changing wildfire risk as reflected by national fire statistics. Gaps in the national system of collecting statistical information has resulted in the absence, or distortion, of fire statistics, which does not allow a realistic assessment of the scale of the problem and nor does it facilitate the making of appropriate management decisions within the country (ZIBTSEV ET AL., 2019). The current system only takes into account forest fires (without fires in other types of landscapes), which has led to a lack of environmental awareness within the

population and decision makers about grass fires and agricultural burns.

Among all oblasts, relatively high rates of flammability are observed in the territories of Dnipropetrovsk, Donetsk, Kirovohrad, Kharkiv, Odesa, Poltava, Luhansk, Zaporizhia, Kherson and Mykolayiv, where the forest areas are small and the agriculture land areas are large. Proof of the problem of agricultural burning is the seasonal dynamics of fires. The largest total area of fires occurs in July and August, which occurs during the harvest of cereals (ZIBTSEV ET AL., 2020). In 2020, the most frequent forest fires occurred in the oblasts of Kyiv, Kharkiv and Luhansk. By area, the largest number of fires, almost 30 000 ha, occurred in the Luhansk region, which in relation to the low forest cover of the region (11.0%) is an especially negative phenomenon (ZIBTSEV ET AL., 2019).

In comparison to fires (burns) on agricultural land, the problem of forest fires is of a much smaller scale. However, given the consequences of forest fires for ecosystems and the economy of the country, this problem cannot be ignored. From 2007 to 2020, the large forest fires in Ukraine, which killed people, destroyed houses and industrial and social infrastructures, and caused enormous environmental and economic damage, indicate that Ukraine can no longer be regarded as a country with low fire risks.

The Nesterov Index, which is used in Ukraine, needs improvement. For example, during a large forest fire in August 2007 in the Kherson region, the current NI indicated the 3rd class of fire weather danger (medium) and even 2nd class (low) (KUZYK & KUCHERIAVYI, 2009). Also, it is advisable to develop and implement a universal system for providing information on the class of fire danger for forest and land users. This would ensure the nations preparedness for the current level of danger.

To determine the gaps in landscape fire management in Ukraine, a working group, under the leadership of the Ministry of Environmental Protection and Natural Resources of Ukraine and the Global Fire Monitoring Center (GFMC), with active support from Regional Eastern Europe Fire Monitoring Center (REEFMC), conducted a national survey of its stakeholders. The findings identified were as follows:

- Climate change, socio-economic changes and land-use changes impact fire regimes of the 21th Century. These trends, remind us of the situation in the Euro-Mediterranean region where the occurrence of large wildfires prompted governments (more than four decades ago) to adjust governance and capabilities in fire management. The increase in extremely severe wildfires is challenging the current fire management system, which is not prepared to address the increase in the level of risk.
- Only 72% of forest lands have a fire management system in place, which, in general, is not yet prepared for future scenarios.
- There is no single national authority that harmonizes the approaches and, in cases of emergency situations, coordinates all authorities concerned (forestry, emergencies, military, agriculture, public health, internal security/ police, traffic, volunteers).
- The system of fire incident management under the authority of the Forest Service, on one hand, and the SESU on the other hand, are different with regard to the level and qualification standards of training and equipment. This is an obstacle for the effectiveness of joint fire suppression operations.
- There is no profession of forest firefighter in Ukraine. Currently, forest fires are suppressed by workers of forestry enterprises who are not properly trained or equipped. This poses a risk during the suppression of severe types and very fast fires. This gap is also visible in incident command during forest fire emergencies.
- Gaps between agencies' responsibilities and skills and the lack of interagency cooperation create high risks for the safety of rural populations living near forests, thereby, requiring joint, well-coordinated actions.

8. Conclusions

Based on the data and discussions presented in the article, it is clear that the problem of fire in the natural landscape of Ukraine has become increasingly difficult. For decades, central and local authorities have paid insufficient attention to the issues of state support for the forest and landscape fire protection system, which has led to the practical destruction, or significant reduction, of/in the efficiency of the existing system. New climatic conditions, and changes in society and land use require the development of a new national fire management system and the adoption of urgent legislative, organizational, scientific and educational measures at the state level.

The current "fire-exclusion policy" in Ukraine is based on a very strong fire-suppression approach, which does often not address the roots of the problem. One of the main elements of effective fire management is fuel management, including the use of prescribed fire for wildfire hazard reduction, is currently missing in Ukraine. The system of forest

fire management must be essentially upgraded and improved given the current and prospective fire hazard scenario.

Currently, forest enterprises suffer from a deficit of funding for fire management, and are thus limited in complete implementing progressive modern technologies into the system. Only economically developed forestry enterprises of the State Forestry Agency are able to install video surveillance systems for fire detection and formation of mobile teams, or light fire units, or motorcycle patrols for early fire response. The amount and area of land affected by fire in open landscapes are much bigger than those in forests and often are the cause of large forest fires. A system of fire protection of agricultural land is almost non-existent and land users are not interested in protecting land from fires. Generally, in such areas, fires are extinguished by units of the SESU.

The very diverse and complex causes of fire highlight the need to consider not only fuel and weather hazards but also the social and cultural dimensions in any policy that addresses the problem of forest fires. It is important to attend to the complex and dynamic interrelationships between the social, economic, environmental, and political drivers.

Acknowledgements

We would like to thank for the support by Joe-Mar Perez from Office of Civil Defense, National Disaster Risk Reduction and Management Council of the Philippines, who helped to improve an earlier draft of this manuscript.

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