

Fire in the protected areas of Eastern Ukraine

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Abstract: In this study, we perform analysis of the spatial extent of the pyrogenic impact on steppe nature reserves in Donetsk and Luhansk regions during 2007–2016. The interest of researchers in remote investigation of steppe fires has increased significantly in recent years due to Ukraine's loss of control over a part of the territory of both regions because of the armed incursion and occupation of the territory from 2014 until the present. The number of fires within the anti-terrorist operation (ATO) zone detected by remote sensing in 2014 was 14.1 times higher than in 2013. Our study shows that during 2015–2016 more than 50% of steppe areas were affected by pyrogenic impacts. During 2007–2016, fires took place in the vast majority of steppe sites; only small patches of steppe territories remained unaffected.

Keywords: fire; nature reserve; protected area; pyrogenic impact; steppe; Ukraine.

Abbreviations: ATO = anti-terrorist operation; NRF = Nature Reserve Fund; PA = protected area.

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Introduction

Luhansk and Donetsk regions are located in the south-east of Ukraine. These regions are the most favourable for the development of steppe habitats since the whole area lies within the steppe climatic zone. As a result, the share of natural and semi-natural steppe landscapes in the regions is the largest in Ukraine. Within the Donetsk region, the area of steppe landscapes is about 2,140 km², while in Luhansk it is 5,113 km², which is 8.04% and 19.16% of the regions' areas respectively (Kolomytsev & Vasyliuk 2013).

The natural areas of the two regions mainly consist of steppe ecosystems: the central part of Donetsk and the south part of Luhansk regions holds the rocky steppes of the Donetsk ridge, while the northern part of Luhansk region supports steppe vegetation on surface exposures of chalk. The south of Donetsk region is occupied by the plains of black soil steppes bordering the Azov Sea.

From west to east, the region is intersected by the complex interzonal biotopes of the Siverskyi Donets river valley. This river forms a wide floodplain, occupied by meadow and forest vegetation, as well as sand arenas, which form partially preserved natural sandy steppes. These natural complexes should receive priority protection within the steppe zone biotopes of Ukraine.

However, much of the steppe area is not protected. For example, in Luhansk region, only 238 km² of the steppe zone are covered by the Nature Reserve Fund (NRF, Vasyliuk et al. 2012), which is about 29% of the region's pro-

ected territory, but it is only 4.65% of the steppe area located in the region. The amount of steppe conserved in Donetsk region is likely to be even smaller. The overall NRF within these territories covers only a small part of the natural and semi-natural steppe landscapes. Nevertheless, because of the poor environmental protection regime, negative impacts (such as pyrogenic impacts) affect the steppe areas inside the NRF as well as surrounding areas.

According to the results of our preliminary study of remote sensing data concerning the role of military actions on increasing the number of fires in natural vegetation (Kolomytsev et al. 2014), we found that just during the period from 1 July to 30 September 2014 in the ATO zone 2901 incidents of fires were detected. Thus, the number of fires in 2014 was 14.1 times higher than in 2013 (208 incidents of fires), and 5.2 and 5.9 times greater than during 2012 and 2011 (respectively, 566 and 501 cases of fires). Although in 2014 there was a higher density of fires both within and outside the ATO zone, the general distribution of fires remained similar and can be ascribed to traditional burning of crop stubble after the harvest period. The main reason for the higher number of fires was their unrestricted spread across the territory because of the absence of fire-prevention measures in the occupied territory. Between 1 July and 30 September 2014, fire damaged around 18% of the forest area within the ATO zone (12.19% of the total area of the fires) and 23.19% of the steppe area within the ATO zone (38.29% of the total area of fires; Vasyliuk et al. 2015). Previous studies also show the impor-

tance of hostilities in increasing pyrogenic impacts on steppe ecosystems (Kuksyn & Kreindlyn 2014).

Steppe fires are having unknown impacts on the conservation status of steppe ecosystems within the NRF owing to the lack of effective mechanisms for controlling them, auto-ignition of vegetation, and poor monitoring of the state of NRF territories: in Ukraine, special administrations are present only in the largest 100 protected areas, out of 8,300 sites. In the past, pyrogenesis was one of the main factors in the formation of open grassy ecosystems (Tyshkov 2005). Today, in most cases it has become the cause of their degradation. On the one hand, regular burning leads to the gradual deterioration of steppe biotopes: loss of biodiversity, the appearance of more resistant invasive species and the loss of organic matter in the soil (Anylova 2012). On the other hand, due to the lack of grazing and the consequent litter accumulation, “hot” fires lead to a more extensive reduction in the number of species present on the site (Lysenko 2008). Grassland management through controlled burns, which would be conducive to the sustainable maintenance of steppes, and which has been effectively introduced in other countries (Myers 2006), is currently not practised in Ukraine.

In our study, which covers steppe fires in all NRF sites in Donetsk and Luhansk regions, we sought to detect the incidence of such fires and assess the extent to which they affected biodiversity the NRF. Up to now, actual information on the influence of fires on steppes in east Ukraine was known only from the publications by staff of the Luhansk Nature Reserve (Borovyk 2004, 2009, 2014) and the Ukrainian Steppe Nature Reserve (Tymoshenkov & Tymoshenkova 2007; Lymanskyi 2011, 2014) concerning fires in their territories. Our research aimed to identify the locations of pyrogenic impacts in the NRF of eastern regions of Ukraine, as well as identify areas that most needed measures to control ignition.

Materials and methods

An important task of our study was to locate ignitions and determine the spatial extent of affected areas. However, the point data available for us did not contain complete information on the area burned by a fire. However, we used the estimation of fire-affected areas according to the resource www.fires.kosmosnimky.ru, which extrapolates data and visualizes burned areas in the form of polygons. Taking into account the burned area determined by this resource, we calculated the original radius of the ignition field necessary for the formation of a particular polygon. Owing to the massive overlaps of the ignition polygons, we took the average radius of spread from the fire source (1712 m, $n = 403$), and used this number for spatial analysis of the burned area. After generating appropriate buffers around the fire points, we excluded settlements and rivers. Such a spatial model does not claim to be precise in detail, but we found it sufficient to determine the trends and general state of the overall pyrogenic impact on the NRF. A spatial analysis algorithm was implemented using

ArcGIS software based on spatial layers of administrative borders, settlements, and steppe areas. The algorithm we applied included the following steps:

1. Applying a buffer around the fixed fire points with the above defined radius of 1712 m. For each year (2007–2016), a separate polygonal layer was created. We derived this data from NASA datasets (NASA 2018).
2. Applying interference in the spread of fires, including settlements and the Siverskyi Donets river.
3. Separation of spatial objects and removal of isolated areas outside obstacles.
4. Aggregation of polygonal objects.
5. Identification of burned steppes.
6. Determination of the area and administrative units of the steppe areas derived from the steppe cadaster of Ukraine, developed by Kolomytsev & Vasyliuk (2013): import and data processing.

Results and discussion

In Donetsk region, we identified 124 NRF sites of which 73 fully or partially included steppe ecosystems. Moreover, 54 of the protected areas (PAs) lie within the zone of military conflict (45 of them are steppe PAs). Considering their distribution, we assume that most of the steppe areas within the NRF of Donetsk region are presently located in the occupied territories (ATO zone).

Over 10 years, firefighting was detected by means of remote sensing (Fig. 1) in 40 NRF sites, of which 22 are in the ATO zone, including 20 that are steppes.

Of the 18 NRF sites affected by fire outside the ATO zone, 10 are steppes (out of 29 existing steppe sites outside the ATO zone). Detailed information about the fires detected within NRF sites in Donetsk region from 2007 to 2016 is presented in Table 1.

There are 183 NRF sites in Luhansk region, of which 108 fully or partially include steppe ecosystems. This number includes 81 NRF sites presently located within the ATO zone, of which 51 are steppes. Given this distribution of sites, it can be seen that half of all steppe sites are in the ATO zone, and also that the steppe sites make up 61% of all NRF sites in the ATO zone.

Between 2007 and 2016, we detected fires in 66 NRF sites in Luhansk region (Fig. 1, Fig. 2), of which 27 were in the ATO zone. Out of the latter sites, 24 are steppes meaning that almost all of the affected areas in the ATO zone of Luhansk region are steppe ecosystems. The 39 non-ATO NRF sites struck by the fire included 31 are steppes (out of 57 existing steppes outside the ATO zone). Thus, the NRF steppe sites most affected by fire are those within the ATO zone (Table 2).

The spatial analysis and assessment of fires occurring within the steppes of Eastern Ukraine shows the widespread character of pyrogenic effects: during 2015–2016 we detected burning of more than 50% of steppe areas

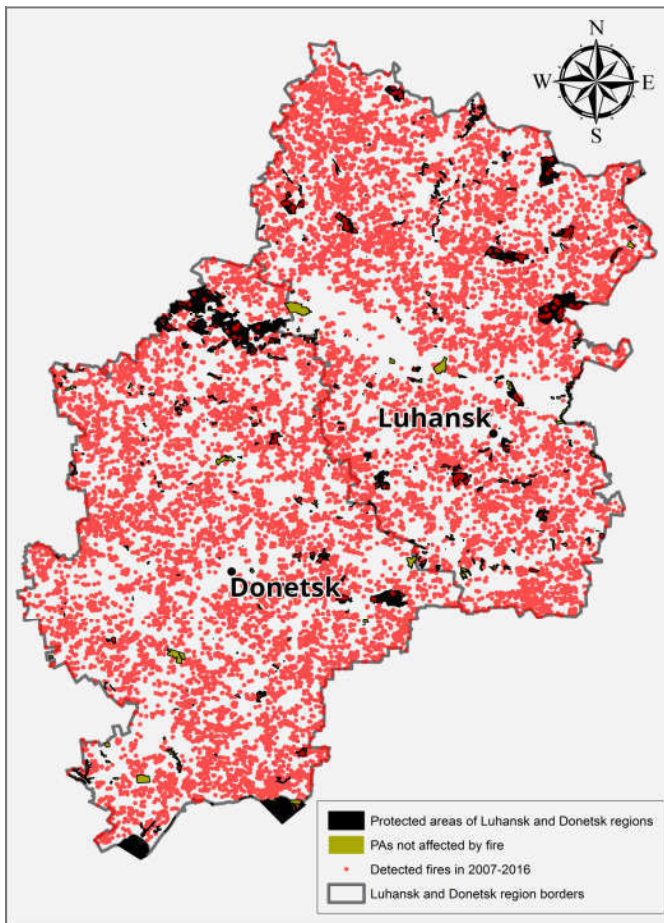


Fig. 1. Distribution of detected fires and protected areas in the Luhansk and Donetsk regions. Black areas indicate protected areas affected by fires.

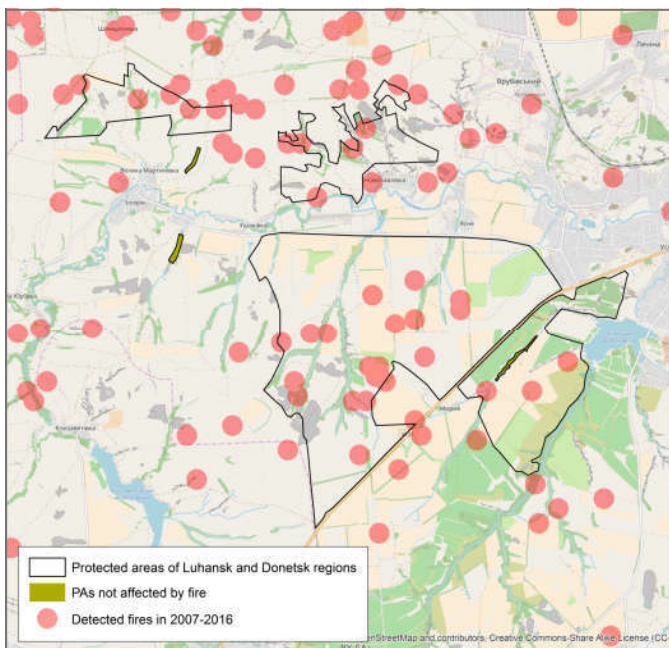


Fig. 2. Example of fires within protected areas, Luhansk region.

within the studied area. Moreover, the study did not take into account the fact that a number of sites, according to extrapolation of fire-affected sites, burned twice or more each year. During the entire period covered in the study, fires took place in the vast majority of steppes; only the smallest patches of the steppe sites remained unburned (Figs. 1 and 2). The full impact of fire on steppe areas still needs to be elucidated in detail, in order to define spatial rules of the occurrence of fires.

Author contributions

V.O. planned the research and wrote the paper, K.G. designed the methodological approach and conducted the spatial analysis of areas affected by pyrogenic impact, while all authors critically revised the manuscript.

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Table 1. Number of fire events detected within the NRF sites of Donetsk region, 2007–2016.

NAME	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Reserve "Mayatska Dacha"	1	0	2	0	0	0	0	0	0	0
Reserve "Balka Sukha" *	0	1	0	0	0	0	1	1	0	0
Reserve "Ridkodubia"	1	0	0	0	0	0	0	0	0	0
Reserve "Stupki-Golubovsky"	0	0	0	0	0	0	1	0	0	0
Reserve "Balka Orlynska"	0	0	0	0	0	0	0	1	1	0
Reserve "Verkhnesamarsky"	0	0	0	0	0	0	0	0	0	1
Reserve "Hectova balka "	0	0	0	1	0	0	0	2	0	0
Reserve "Zoryansky step" *	0	1	0	0	0	0	0	0	1	0
Reserve "Kovil near the village of Grigorivka"	1	0	0	0	1	0	0	0	0	0
Reserve "Kohane"	0	0	1	0	0	0	0	0	0	0
Reserve "Cretaceous vegetation near the village of Kirov"	1	0	1	2	0	1	0	0	0	0
Reserve "Palimbia"	0	0	0	0	0	0	0	0	0	1
Reserve "Pristenskoe" *	0	0	0	0	0	0	0	0	1	0
Reserve "Uvochishche Obushok" *	1	0	0	0	0	0	0	1	0	0
Reserve "Razdolnensky" *	0	0	0	0	0	0	0	1	0	0
Reserve "Kruglik" *	0	0	1	0	0	0	0	0	0	0
Protected tract "Mariupol Forest Cottage" *	0	0	0	0	0	0	0	1	0	0
Protected tract "Shyroky lis"	0	1	0	0	0	0	0	0	0	0
Protected tract of local significance "Myrne pole"	0	1	0	0	0	0	0	0	1	0
Reserve "Oak plantations"	2	1	0	0	0	0	0	0	0	0
Forest reserve "Artemivsk garden-dendrological plantings"	1	1	4	2	2	1	3	5	0	4
Forest reserve "Balka Skeleva" *	0	0	0	0	2	1	0	0	0	0
Forest reserve "Shchucha Zavod"	0	0	0	0	0	0	0	1	1	0
Forest reserve "Berdiansky" *	0	4	0	0	0	0	0	5	0	0
Forest reserve "Urochysche Leontievo-Bayrakske" *	0	0	3	0	0	0	0	0	1	0
Forest reserve "Urochysche Ploske" *	0	0	0	0	1	0	0	0	0	0
Forest reserve "Urochysche Sofiivske" *	0	2	0	0	0	0	0	0	0	0
National Nature Park "Meotida" *	9	8	5	2	6	2	2	10	13	6
National Nature Park "Sviati gory" *	16	5	12	0	4	1	2	9	5	5
Forest reserve "Priazovsky chapelnyk" *	1	0	1	0	1	0	0	1	3	0
Ukrainian Steppe Nature Reserve "Kalmiuski" *	0	0	0	2	0	0	0	5	0	1
Ukrainian Steppe Nature Reserve "Kreydiana flora" *	0	0	1	0	0	0	0	2	0	0
Ukrainian Steppe Nature Reserve "Khomutovsky Steppe" *	1	4	0	0	0	0	0	0	0	0
Regional Landscape Park "Kleban-Byk" *	0	0	0	0	0	0	2	2	0	0
Regional Landscape Park "Slavic Resort" *	1	0	0	0	0	0	0	0	0	0
Regional Landscape Park "Donetsk Ridge" *	2	0	0	2	0	3	0	22	0	0
Regional Landscape Park "Zuyevsky" *	1	1	1	2	2	0	0	4	0	0
Regional Landscape Park "Kramatorsky" *	2	1	3	0	3	1	0	3	1	0
Regional Landscape Park "Polovetsky Steppe"	2	1	0	0	2	0	0	0	5	0
Total number of detected fires	43	32	35	13	24	10	11	76	33	18

This table and table 2 does not include NRF sites that were not affected by fires during 2007-2016. Selected cells indicate the period before the NRF sites were established.

* – NRF sites within the current or former ATO zone.

Table 2. Number of fire events detected within the NRF sites of Luhansk region, 2007–2016.

NAME	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Zoological Reserve "Illirijsky"*	4	11	3	3	0	2	0	3	4	2
Forest Reserve "Vrubivsky"	0	1	0	0	0	0	0	0	0	0
Forest Reserve "Novogannivsky"	0	0	0	1	0	0	0	0	0	0
Forest Reserve "Kamjansky"	0	0	0	2	1	0	0	0	1	0
Forest Reserve "Balakirivsky"	0	0	1	0	0	0	0	0	0	0
Forest Reserve "Vedmezhsanska"	2	5	0	7	0	0	0	8	8	0
Reserve "Kosharsky"*	1	0	0	0	0	0	0	0	2	0
Forest Reserve "Barsucha Balka"*	0	0	0	0	0	0	0	2	0	0
Reserve "Ganivsy lis"	0	0	1	1	0	0	0	0	0	0
Reserve "Velikocky"	0	0	1	0	0	0	0	2	0	0
Reserve "Bilorichensky"	0	3	0	3	1	2	0	4	2	0
Forest Reserve "Stepovi rozlogi"*	0	1	0	0	2	0	0	0	1	0
Forest Reserve "Lugansky"*	0	0	1	0	0	0	0	3	0	0
Forest Reserve "Pershozvanivsky"*	0	2	0	0	0	0	0	0	0	0
Reserve "Novorozsoshansky"	1	1	0	0	0	0	0	0	0	0
Reserve "Novochervonensky"	1	0	0	0	0	0	0	1	0	0

Table 2. Continuation

NAME	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Forest Reserve "Nagolny krjash"*	1	0	0	6	0	0	0	1	2	0
Forest Reserve "Kruzhilivsky"*	0	1	0	0	0	0	0	0	0	0
Zoological Reserve "Mistkivsky"	6	4	1	0	0	0	0	6	5	0
Forest Reserve "Minyevska dibrova"	0	1	0	0	0	0	0	0	0	0
Forest Reserve "Novozvanivsky"*	1	0	0	0	0	0	0	2	0	0
Forest Reserve "Juskina river valley"*	0	1	0	0	0	0	0	2	1	0
Forest Reserve "Orihova river valley"*	0	1	0	1	0	0	0	1	0	0
Zoological Reserve "Urochishhe Murzine"	0	0	0	0	0	0	0	0	1	1
Forest Reserve "Gorihivska Dibrova"*	0	0	2	0	0	0	0	0	0	0
Reserve "Urochishhe Rozsohuvate"	0	0	1	0	0	0	1	0	0	0
Forest Reserve "Urochishhe Skelevate"	0	0	0	0	0	0	0	1	0	0
Forest Reserve "Shariv Kut"*	0	0	0	0	0	0	0	1	2	0
Reserve "Lisnopoljanska"	0	0	1	0	0	0	0	0	1	0
Reserve "Zarichna"	0	0	1	0	0	0	0	0	0	0
Zoological Reserve "Goncharivsky"	4	3	3	4	4	0	0	0	7	0
Reserve "Klenovij lis"	0	1	2	0	0	0	0	0	0	1
Forest Reserve "Samsonivska zavod"	0	1	0	0	0	0	0	0	0	0
Zoological Reserve "Lisova perlina"	3	0	4	1	0	0	0	3	0	0
Entomologic Reserve "Krimsky"*	0	0	1	0	0	0	0	0	0	0
Geologic Reserve "Krimska Dacha"*	0	0	1	0	0	0	0	1	0	0
Reserve "Selezniivska balka"*	0	0	0	0	0	0	0	1	0	0
Zoological Reserve "Perevalsky"*	2	0	0	0	0	11	4	18	1	5
Protected Tract "Kiseleva balka"*	0	0	0	0	0	1	0	0	0	0
Reserve "Grishino"*	0	0	0	0	0	1	0	0	1	0
Forest Reserve "Krasnjanske vodoshovishhe"*	1	0	0	1	0	0	0	4	4	0
Protected Tract "Pischane"*	0	0	0	0	0	0	0	3	0	0
Reserve "Kanyshnyansky"*	0	0	0	0	0	0	0	1	0	0
Reserve "Znamyany yar"*	0	0	1	0	0	0	0	0	0	0
Reserve "Lisne"*	0	0	0	1	0	0	0	2	1	0
Reserve "Kuryachy"	0	0	0	0	0	0	0	0	1	0
Zoological Reserve "Balka berezova"	3	6	0	0	0	0	0	0	5	0
Regional Landscape Park "Bilovodsky"	7	10	4	1	1	0	6	8	19	0
Zoological Reserve "Geraskivsky"	1	3	2	1	1	0	0	2	3	0
Protected Tract "Kapitanivsky lis"	0	0	0	1	0	0	0	0	2	0
Zoological Reserve "Yevsug-Stepove"	6	1	4	1	1	3	2	9	3	0
Zoological Reserve "Geraskivsky"	0	0	2	0	0	0	0	1	0	0
Luhansk Nature Reserve "Striltsivsky step"	3	0	0	0	0	0	0	0	0	0
Luhansk Nature Reserve "Triohizbensky step"	1	0	0	0	0	0	0	0	0	0
Luhansk Nature Reserve "Stanychno-Luhanske"	5	0	1	0	0	0	0	0	14	1
Luhansk Nature Reserve "Provalsky step"	0	1	4	0	0	4	0	8	0	0
Protected Tract "Bokovo-Platovo"*	0	0	1	0	0	0	0	2	0	0
Zoological Reserve "Kononivske"	10	17	2	3	4	0	3	4	1	0
Zoological Reserve "Terny"	2	1	2	0	0	0	0	1	2	0
Zoological Reserve "Miluvatsky lyman"	0	2	0	1	0	0	0	1	0	0
Forest Reserve "Bilolutsky"	7	2	0	0	2	0	0	0	0	0
Forest Reserve "Novoposkovsky"	0	2	1	0	0	1	0	0	0	0
Reserve "Balka ploska"	2	4	0	0	0	0	4	0	0	0
Reserve "Osnyivska"	3	1	1	0	0	3	0	6	4	0
Protected Tract "Moskovske"	1	0	0	0	0	1	0	0	1	0
Total number of detected fires	78	87	49	39	17	29	20	112	99	10

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