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FOREST FIRES AND SYSTEM OF MEASURES TO CREATE FIRE BARRIERS IN THE FORESTS OF UKRAINE

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Data on the number and area of wild fires and stands, destroyed by fires and forest products, which burned down or was damaged by fire in 2006-2010, and the area of wild fires and volume of damaged by fire to standing for1990-2010 and distribution of forested areas according to the dominant species and age groups, subordinated to the State Agency of forest resources of Ukraine as of 01.01.2014. To increase the level of fire resistance of Ukrainian forests it has been proposed to carry out long-term silvicultural measures: the territory of forest stands of I - III classes of natural fire risk to split into basic and additional blocks by the system of fire barriers to prevent the spread of forest fires in large areas, introduction of deciduous tree species into pine plantations, removal of fire hazardous undergrowth and underscrub and cleaning of forest combustible materials on their territory and creation of fire-resistant borders.

Wild fires, number and area of wild fires, volume of forest produce damaged by fire, distribution of forested areas by dominant species and age groups, fire barriers and fire-resistant borders.

Wild fires cause significant losses of forestry of Ukraine, as they destroy wood, technical, medical, food, fodder and other forest products, reduce complex productivity of stands, sanitary and hygienic, safety, recreational, water protection and other environmental functions of forests.

Fire in the forest has a negative impact on long-term stands, middle-aged and young plantations, up to the point of termination of their growth and total destruction of woody vegetation, forest fauna and soil microorganisms. In addition, wild fires reduce acidity and forest soils trophicity. In the future due to global warming is expected increasing of fire danger in the forests of Ukraine.

The aim of the research. Analysis of information regarding forest fires and forests killed by fire because of 2006-2010 the over proposals to increase fire resistance of forests of Ukraine.

Materials and methods. For the past 30 years average number of fires in Ukraine increased by 2.6 times. In 1980s 1673 fires occurred on the area of 1176 ha, in the 1990s – 3917 on the area of 3962 ha, in 2000-2010 – 4743 on the area of 4367 ha [7]. Most of wild fires occurred in the years of high fire danger, of which 1997 and 2007 were especially fire danger years. In 2007 specific mass of wild fires in forests of Kherson region and the Autonomous Republic of Crimea was about 95% of their total amount.

Information on the number and area of wild fires, destruction of forest stands and amount of forest products, destroyed and damaged by fire in 2006-2010 are shown in Table.1.

1. Wild fires and caused damages in the forests of Ukraine

Indexes	Years					Over the 5-year period
	2006	2007	2008	2009	2010	
Number of wild fires, unit	3842	6100	4042	7036	3240	24260
The area of forest lands with fires, thousands of ha	4,3	13,8	5,5	6,3	3,7	33,6
Forested areas that were died in a fire, ha	1864	10995	3819	2727	3127	22532
Burned and damaged forest products, thousands of $м^3$	60,2	1308,2	402,8	226,6	433,5	2431,3

Analysis shows that during 2006-2010 in the forests of Ukraine over 24.2 thousand of wild fires happened, which covered an area of 33.6 hectares of forest lands, where more than 22.5 thousand hectares of forest plantations were lost, more

than 2.4 million of cubic meters of forest products were destroyed and damaged by fire.

Data on the area of wild fires in forest fund of Ukraine, which is subordinated to the State Agency of forest resources, from 1990 to 2010, destroyed and damaged by fire wood to standing [1], are shown in Table 2.

2. Area of wild areas and cubic mass of burnt and damaged by fire to standing wood for 1990-2010 years.

Years	Forest lands, passed by fires, ha				Burned and damaged wood to standing, thousands of m3
	uplands	grassroots	underground	total	
1990	1336	1022	1	2389	79,9
1991	1042	665	10	1717	38,3
1992	3318	672	111	4101	77,8
1993	2415	712	51	3178	174,5
1994	6061	3432	537	10030	392,0
1995	1695	1416	26	3137	147,6
1996	7163	5466	42	12671	315,1
1997	1355	110	2	1467	11,9
1998	3208	1208	2	4418	123,4
1999	2896	2632	14	5542	166,7
2000	1386	232	2	1620	20,6
Total	31905	17567	798	50270	1547,8
The average for 1990-2000	2900	1597	73	4570	140,7
2001	1992	1770	3	3765	139,6
2002	4245	657	64	4966	59,6
2003	2409	359	49	2817	20,1
2004	536	37	2	575	1,9
2005	2057	293	9	2359	34,3
2006	3729	557	1	4287	5,3
2007	6238	7549	0	13787	1308,2
2008	4218	1311	0	5529	395,3
2009	5300	1010	5	6315	223,0
2010	2616	1044	8	3668	344,5
Total	33340	14587	141	48068	2531,8
The average for 2001-2010	3334	1459	14	4807	253,2

The area of upland wild fires for 2001-2010 increased by 1435 hectares compared to their area for the previous 10-year period, and cubic mass of burnt and damaged by fire wood – by1.64 times. 1994, 1996, 2001, 2002, 2007 and 2009 were the years of the years of fire maximums for the 20-year period.

According to statistical reports, 93% of wild fires occurred as a result of improper rules handling with fire in a forest, 4 – of transport vehicles and 3% – agricultural fields and other factors.

In Europe during 1950-2000 years due to wild fires 5.6 million m3 of timber are annually damaged. Due to global warming the risk of wild fires is projected to increase, especially where pine forests with high flammability dominate [5, 7].

According to the State register of forests, as of 01.01.2011 by the area covered with forests and forest vegetation plots 6840 and 4294 ha or about ¾ of the total area of forest fund of Ukraine were subordinated to the State Agency of forest resources of Ukraine.

Summarized information on distribution area of covered with forest vegetation forest plots by dominant species and age groups of forests, which are subordinated to the State Forest Agency as of 01.01.2011 (Table 3).

Specific mass of coniferous young stands and middle-aged stands subordinated to the State Forestry Agency of Ukraine as of 01.01. 2014 was 9.9 and 20.1% of the total forested area that confirms the high level of their fire hazard.

Except forests of the State Forestry Agency of Ukraine, 13% of forest fund are subordinated to the local governments, 5 – to the Ministry of Agrarian Policy and Food, 2 – to The Ministries of Defense and Emergencies of Ukraine and more than 3% accounts for other land users and are located on reserve lands. As there are no data on distribution of these forests by dominant species, we consider it approximately the same as in the forests of the State Agency of forest resources of Ukraine.

3. Distribution of forested areas by dominant species and age groups, which was subordinated to the State Forest Agency of Ukraine as of 01.01. 2014,

thousands of ha and %

Groups of forest formation	Total	including on age groups				Average age, years	Average stock per 1 ha, m^3
		young forests	middle-aged	immature	mature and over-mature		
Total, ha	6293548,2	1066039,9	2989138	1063275,8	1175094,5	62	240
%	*100,0*	*16,9*	*47,5*	*16,9*	*18.7*	-	-
conifers	2748565,8	623394	1262928,3	562848,3	299395,2	58	277
%	*43,7*	*9,9*	*20,1*	*8,9*	*4,8*	-	-
including							
pine, ha	2179040,9	485811,8	1038654	469927,9	184647,2	57	265
%	*34,6*	*7,7*	*16,5*	*7,5*	*2,9*	-	-
spruce, ha	458564,2	93084	196379,4	77135,7	91965,1	64	336
%	*7,3*	*1,5*	*3,1*	*1,2*	*1,5*	-	-
hardwoods ha	2762654,3	332470,9	1417279,9	363517,1	649386,4	71	226
%	*43,9*	*5,3*	*22,5*	*5,8*	*10,3*	-	-
softwoods ha	739434	105393,1	296650,8	129519,2	207870,9	45	171
%	*11,7*	*1,7*	*4,7*	*2,1*	*3,2*	-	-
other species and shrubs, ha /%	42894,4 / *0,7%*	4781,9 / -	12279 / *0,2%*	10391,2 / *0,2%*	18442 / *0,3%*	60	72

Results. Thus, almost 44% of covered with forest vegetation plots of Ukraine are under coniferous tree species, 79% of them are under piny forest stands, over half of which (over 55%) are young forests and middle-aged tree plantations, which are the most fire hazardous.

Fire resistance of forests largely depends not only on the level of natural fire hazard of forest stands, but also on ensuring the proper carrying out of long-term preventive measures on uncontrolled spread of fire in the forest and conducting of annual elimination of forest combustible materials, primarily on the territory of fire

protection barriers in forest blocks, where stands grow in extremely dry conditions of soil water supply.

Forest fireproof practice has found, that high fire danger occurs on the areas of coniferous forests in the extremely dry piny woods (A_o, A_1), where the most flammable are pure pine forest crops and young stands of low density, under which there is a lot of solar radiation, which causes rapid drying of forest fuels and increase their ability to fire.

In such forest site types the forest stands of Scots pine and Crimean pine (deciduous woody plant species are practically absent here) grow on sandy soils with low soil water supply through rapid filtration of moisture even in the into the conditions of rainfalls. In addition, ground layer of vegetation into extremely dry forests is represented by xerophytic plants, which are the supporters and conductors of burning, and the fallen needles and rapid aging of forest stands in unfavorable conditions promotes outbreak and spread of ground forest fires.

On the territory of fresh piny forests (A_2) except pine birch, rowan, oak as undergrowth can grow. In contrast to the dry piny forests, in fresh piny forests undergrowth of pine occurs, which causes a greater intensity and transition of a ground fire into a crowning one.

In wet piny forests (A_3), which are predominant among piny forests in Ukrainian Polissya, pine mixed with birch grow, temporary vegetation types are represented by birch forests, northern regions – by spruce forests. Soils are moist, mostly podzolized, and sandy with close ground waters, which dry only during periods of prolonged drought.

In the forest stands on the territory of extremely dry piny forests (B_o) pure pine stands grow, in dry soil conditions of soil water supply (B_1) oak-pine stands grow. Fresh pine forests (B_2) are the most common type of forest growth conditions of Ukrainian Polissya. Fire hazard into these stands is largely depend on their density, which grows with its decline.

On the territory of wet pine forests (B_3) on sandy, loamy, less often clay-loam soils pine plantations with impurity of birch, oak and alder in the first layer and with impurity of alder and spruce in the second one.

Ground fires in such circumstances of place growth are possible only if ground layer of vegetation dries to dryness, and crowning fires are possible if there is spruce in the second layer.

In the tree stands on the territory of extremely dry oak forests (C_o, C_1) pine (less often – oak) grow in the first layer. The second layer in extremely dry conditions is not available, in dry conditions it can consist of oak. Wild fires occur in pine plantations in circumstances of extremely dry oak forests, and the occurrence of fires in hardwood forests in the conditions of dry oak forests is possible only during prolonged drought.

Fresh and wet oak forests (C_2, C_3) are widespread in Polissya and Forest-Steppe of Ukraine on weakly podzolic sod loamy, sandy soils with layers of clay chernozemic sand loams. In such conditions of habitat there are pine, oak, beech and hornbeam in the first layer, in the second – birch and aspen, in the third layer – maple, lime, apple and pear. At thinned second and third layers dense undergrowth consisting of rough spindle tree and European spindle tree, dogwood, Tatarian maple and red elderberry occur. Fire danger in fresh and moist oak forests may occur under conditions of prolonged drought in late summer and autumn.

In extremely dry and dry oak forests ($Д_o$, $Д_1$), where oak, less ash grow, ground fires can occur only at a prolonged drought, in fresh and humid oak forests ($Д_{2,}$, $Д_3$) fire hazard is negligible.

In the Ukrainian Carpathians fire hazard can occur in sparse woodlands or in natural young growths if there is dry grass and forest litter. In the foothills and mountains of the Crimea Crimean pine plantations as well as tree and shrubbery vegetation, which were formed in the place of forests and sparse forests are characterized by the greatest fire hazard.

To increase the level of fire resistance of Ukrainian forests one should carry out long-term silvicultural fire-prevention measures:

- regulation of species composition of forest stands by introducing birch into pine stands in the conditions of fresh and moist pine forests, other deciduous tree species in complex piny forests;

- removal of fire hazardous undergrowth;

- providing of forest fuels cleaning, primarily on the territory of fire barriers and crown rising of pine trees to a height of 2 m by removing the lower branches in extremely dry and dry piny forests, where deciduous tree species into the plants composition are impossible.

To prevent the spread of forest fires in large areas the territory of forest plantations of I-III classes of natural fire hazard must be split into basic blocks of 350 to 700 ha, as well as additional units of 150 to 350 ha with the system of fire protection barriers, taking into account the possibility to use rivers, drainage canals, rocky ridges and sandy deposits, existing hardwood and mixed stands as fire barriers for this purpose. The minimum and maximum area of blocks is established depending upon the level of forestry management in selected areas and forest-pirology characteristics of the territory of forest fund.

Action of fire protection barriers lies in the fact that there are no conditions for primary fire on their surface, and the fire of movable ground fire does not find materials to sustain combustion. Fire barriers are constructed as combined fire barriers consisting of fire breaks and forest strips, grown if possible of deciduous tree species, such as oak, ash, maple and birch, and in the southern regions of Ukraine – of robinia, honey locust etc. The entire area of fire protection barriers should be free of combustible materials and dissected with a network of mineralized strips.

In extremely dry conditions of habitat, where introduction of tree species into plantings of fire barriers is impossible because of forest growth conditions, in stands of softwoods is necessary to provide cutting of coniferous undergrowth and underwood and seasonable territory cleaning of forest stands across the entire width of barriers from debris and cleaning the trunks of trees from the branches to a height of 2 m. In addition, along fire breaks through each 20-30 m it is necessary

to lay out mineralized stripes if there is a living ground cover of mosses and lichens – 1-1.5 m wide; heather and berry-bearing plants – 1,5 -2,5 m and high grass cover - 2.5 to 4 m.

Mineralized strips are constructed using forest plows PCL-70, PLP-135, plows for agricultural purposes, tillers, bulldozers, specialized tractor fire-break makers PF-1 etc.

Practice of forest fire extinguishing proved that flame of crown fire without support of ground fire can spread only at a distance of 80 - 150 m. It should be noted that this condition does not operate in the mountains and because of fire spreading up the hill.

The recommended width of main fire protection barriers of deciduous woody species or with their predominance of 120-150 m, a width of coniferous is 260-320 m, including a road or a fire break. One fire protection barrier may include areas of deciduous and coniferous plantations in various combinations. The most fire hazardous of conifers forest areas inside the main block in turn should be divided into additional blocks 150-350 ha in area by internal fire barriers. Railways and highways can serve as the axis of the internal fire protection barriers, on either side of which there are strips 30-50 m wide with predominance of hardwoods or 100 m wide – of coniferous woody species. The width of the internal fire protection barriers of hardwood is 60-100 m, of softwoods is 200 m (in barriers of coniferous tree species the territory is removed from the clutter, pine seedlings, hazard undergrowth, the removal of lower branches to a height of 2 m is provided and through each 20-30 m mineralized strips are laid). Internal fire barriers with a predominance of hardwoods tree species is advisable to construct along compartment lines, in this case mineralized strips are laid on either side of the glade through each 10-15 m.

Areas of coniferous plantations of high fire danger classes are separated from human settlements, country sites and forest boundaries by fire resisting borders 200-300 m wide. Fire resistance boundaries of hardwoods or with their

predominance are formed by cuttings, formation and improvement of forests, construction of forest plantations or reconstruction of existing forest plantations.

In conditions of fire protection barriers on the coniferous forests stands, where according to forest growth conditions it is impossible to introduce hardwoods into plantations, the works on cleaning the territory from undergrowth of conifers, removal of lower branches to a height of 2 m and laying of mineralized stripes in every 50 m are carried out in the stripes of coniferous forests of 200-300 m wide. It is also advantageous to analyze the current state of forest plantations in state forestry and game management enterprises of Ukraine in the context of forestry and determine potential productivity of forests for each of them [2] using the coefficients of ecological compliance (according to Lositskyi K.B. and Chuenkov V.S.), adaptive potential of forestry [1], provide the design, approval and implementation of silvicultural measures to increase the productivity of forests by planting establishments, which by their species composition, productivity and quality are most fully meet the objectives of economy, form required wood assortments in the age of technical maturity, most effectively serve protective functions, use natural soil trophicity, provide the highest annual growth in these environmental conditions, will be the most resistant to the abiotic and biotic factors. A long-term plan for such measures considering turnover of main loggings of major tree species and reforestation in their territories for a given state forestry enterprise should be approved in the prescribed manner regional offices of forestry and game management.

After that in each state forestry enterprise, considering specific forest growth conditions, primarily of forest stands, which grow in extremely dry pine forests and pine forests (A_0, B_0), where only pine plantings with an admixture of deciduous trees can be grown, a long-term plan of fire protection measures connected with the construction of fire protection barriers and considering current opportunities on their establishment and perspective works on increasing of forest productivity and quality and reforestation in such territories, must be approved. It

is expected that the average annual temperature by 2020 will increase from 7.5 to 9.0° C, and in 2080 - 13.5º C compared with 1950-2000 years [1].

During one period of revision in forestry enterprises it is impossible to provide creation of completed fire-protection network from basic and additional barriers which would prevent the uncontrolled spread of forest fires on the territory of the forest fund not only due to the lack of money but also due to the fact that the places of such establishments must be designed by Ukrainian Design and Research Institute of Forestry «Ukrdiprolis» or Ukrainian State Design Forest Inventory Production Association «Ukrderzhlisproekt» in accordance with the turnover terms of main tree species loggings and increasing the potential of forest productivity considering the impact of expected climate changes in Ukraine and approved by regional offices of forestry and game management for the long term (on average for 50 years).

Conclusions

To increase the level of fire resistance and productivity of forests of Ukraine may provident:

- long-term silvicultural activities, in particular the introduction of a pine plantations deciduous tree species, cutting of undergrowth;
- creating of a network of fire barriers that pine plantations are divided into basic blocks area 350-700 ha and extra – 150-350 ha;
- arrangement of fire-resistant forest edges of a width of 200-300 m, which is separated by pine plantations from populated areas, suburban areas and forest estates;
- analysis of the current state of forest and their potential productivity and ensuring the implementation of silvicultural activities aimed at creating the future of business-appropriate planting.

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