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REHABILITATION OF FOREST ECOSYSTEMS TAKING INTO ACCOUNT MODERN INTERNATIONAL ECOLOGICAL TRENDS IN THE CONTEXT OF THE EUROPEAN GREEN DEAL

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ABSTRACT

The forest sector occupies a special place in the 'green' economy. Today, forests are of great importance for biodiversity conservation, climate regulation and water resources. That is, now the forest acts not only as a natural capital that provides society with material resources, but it is also a complex ecosystem capable of generating various ecosystem services. Therefore, our study aimed to outline the scientific and methodological principles of rehabilitation of radioactively contaminated forest ecosystems of Ukrainian Polissia in the context of the EU European Green Deal, taking into account modern environmental and socio-economic features to ensure full integration into the European domain. The article outlines the scientific and methodological principles of rehabilitation of radioactively contaminated forest ecosystems of Ukrainian Polissia in the context of the European Green Deal, taking into account modern environmental and socio-economic features to ensure full integration of the state into the European domain. It was found that the irrational use of forest resources has led to the fact that over the past 40 years there has been a partial loss of forest biodiversity, and broadleaf forests are on the verge of extinction. The Chornobyl accident, which polluted about 3.5 million hectares of Ukraine's forests, has become critical for the country's forestry sector. 1 million 230 thousand ha of the surveyed forested areas had a critical density of radionuclide contamination, 157 thousand ha of which were withdrawn from commercial use due to high ^{137}Cs contamination levels. It was emphasized that deforestation and degradation of forest ecosystems are some of the most pressing environmental problems of our time. The article improves the scientific and methodological principles of rehabilitation of radioactively contaminated forest ecosystems of the Ukrainian Polissia in the context of the European Green Deal taking into account the modern ecological and socio-economic peculiarities to ensure the full integration of the state into the European domain. The revision of the principles and priorities of forest management on the lands affected by the Chornobyl catastrophe and the return of these lands to safe economic use was substantiated taking into account the policies of the EU European Green Deal. It was established that the main actions on rehabilitation of radioactively contaminated forest ecosystems should be focused on the identification of the current radioactive situation in the forests with the aim of the possibility of renewal of forest management activities and production of forest industry products. This will contribute to the improvement of productivity of forest plantations and the renewal of forestry production of the depressed region.

Keywords: 'green' economy, sustainable development, ecosystem services, environmental protection, radioactive contamination, Ukrainian Polissia.

INTRODUCTION

In the age of globalization, when all processes in the world become interdependent and mutually conditioned, there is an understanding of the depletion of natural resources, ecosystems scarcity, irreversible and rapid environmental changes, which calls into question the future survival of mankind on the planet. The current environmental and economic problems are related to the disruption of the stability of the material, biological, energy and information systems. In this context, the concept of a 'green' economy performs an integrative function, combining the ideas of environmental management with optimal satisfaction of human needs, equitable access to limited resources and environmental protection (Pearce et al., 1991). In world practice, along with the 'green' economy, there are concepts of 'green growth' and sustainable development, the purpose of which is to ensure the rational use of environmental benefits in the organization of economic activity, each of which includes social justice ensuring. The key difference between the 'green' economy and the 'green growth' is seen in the implementation levels: the first one contains a strategic implementation aimed at systemic challenges (higher level), and the second one involves the greening of products, processes, services, technologies (lower level) (Drebot et al., 2014; Furdychko, 2014; Kvasha and Paladchenko, 2014; Ivashchenko, 2021). The transition to a 'green' economy involves complex changes in all sectors of the economy. The primary sector, which includes agriculture, fisheries, forestry and mining, requires the most radical changes, as it is here rather than elsewhere the products to meet the basic needs of mankind are created (Prushkivska et al., 2013). The forest sector holds a special place in the 'green' economy. Today, forests are of great importance for biodiversity conservation, climate regulation and water resources. That is, now the forest acts not only as a natural capital that provides society with material resources but also as a complex ecosystem capable of generating various ecosystem services. The Common International Classification of Ecosystem Services (CICES), prepared under the auspices of the United Nations and proposed in the Millennium Ecosystem Assessment (MEA) report, describes ecosystem services in detail (Corvalán et al., 2005). They are divided into four groups: provisioning - services from products provided by ecosystems; regulation - services of regulatory ecosystem processes; cultural - the contribution of ecosystems to the enrichment of cultural, spiritual and aesthetic aspects of human well-being; maintenance - services that provide basic ecosystem processes (Solovii and Monastyrska, 2008). The functions of forest ecosystems fall into all groups of CICES. The ability of forests to regulate the gas composition of the atmosphere and the water regime of the territory is particularly important in the context of climate change (Symochko& Kalinichenko, 2018; Haghverdi and Kooch, 2020; Başkent, 2021). Last but not least is the ability of forests to positively affect the soil aggregate stability and the aggregate associated carbon (Bai et al., 2020). At the same time, forest ecosystems, despite their complexity and resilience, are among the most affected by both climate change and thoughtless human activity. In addition, if the consequences of the latter are more than obvious, then changes in the course of ecological processes, and as a consequence of changes in the state of ecosystems are not always so obvious, because they are gradual, complex and largely determined by local conditions (Yun and Chun, 2018). That is why the local population and the authorities do not always pay enough attention to this problem, focusing more on urgent short term issues and obvious financial direction. The public does not have a clear understanding of the urgency of climate protection and the global sustainable development agenda, since other issues such as COVID-19 and post-pandemic recovery dominate public discourse (Smyth et al., 2020; Knez et al., 2021; Sulistiawati, 2021). However, countries with developed economies, in particular Western Europe, for objective reasons have traditionally been the flagships in addressing long-term strategic issues, including climate change. The international community is consistently and confidently improving plans to address global challenges and mechanisms for their implementation. More and more countries are adopting (or are in the process of adopting) the necessary regulations and strategies to mitigate the effects of climate change, but the implementation of specific measures is still low. The reasons for this often lie in the lack of commitment of decision-makers, lower levels of economic development, lack of investment, etc. (Knez et al., 2021). That is why it is important to develop local policies and educational plans adapted to the understanding of the general public (Miltiadou et al., 2021). This involves the use of various methods, including incentives for direct producers on the ground (Tadesse, 2021). Researchers agree that the rehabilitation of forest ecosystems should be carried out comprehensively with the involvement of government agencies (Akbar et al., 2021) through stakeholder cooperation and the support of the local community, while the government should act as a regulator, ensuring the development and implementation of a special spatial area management plan. However, existing research on the ways to rehabilitate forest ecosystems, especially those that have been radioactively contaminated and remain degraded, is shown incompletely, in part because a comprehensive radioecological survey of these areas was conducted almost 30 years ago. The study aimed to outline the scientific and methodological principles of rehabilitation of radioactively contaminated forest ecosystems of

Ukrainian Polissiya in the context of the European Green Deal, taking into account modern environmental and socio-economic features to ensure full integration of the state into the European space.

MATERIALS AND METHODS

The theoretical and information basis of the study were the works of Ukrainian and European scientists in the field of economics and forestry, as well as reports of the State Agency of Forest Resources of Ukraine, laws and regulations of both our country and the European Union. The following research methods were used to accomplish this task: monographic (elaboration of scientific publications, regulations, ecosystem services of forest ecosystems), abstract-logical (theoretical generalization and formation of conclusions and recommendations).

RESULTS AND DISCUSSION

In 2017, the procedure for the development and approval of the United Nations Strategic Plan for Forests 2030, UNSPF for 2017-2030 (2017) was completed. The Strategic Plan was preliminarily adopted at a special session of the Forum in January 2017, as well as by a resolution by the UN General Assembly A/RES/71/285 (2017) and a resolution of the UN Economic and Social Council E/RES/2015/33 (2015). The Strategic Plan identifies 6 global goals and 26 related objectives aimed at improving sustainable forest management worldwide. As of 2021, 19 countries, including Ukraine, have announced their voluntary national commitments to achieve global goals and objectives. The Strategic Plan outlines an overall approach to environmentally sustainable management policies for all types of forests and promotes the 2030 Sustainable Development Goals and other international commitments, as well as the United Nations Forest Instrument, UNFI, which formulates a series of agreed strategies and actions at both international and national levels (The European Communities, 2008; Appropriate environmental management in the Nordic Partnership countries: a work in progress, 2012). To maintain their function for both biodiversity and climate, all forests must be preserved in proper condition. Therefore, in 2021, the European Commission adopted 'The EU Biodiversity Strategy Until 2030: Bringing Nature Back Into Our Lives' (COM (2020) 380 final) (Kuzemko, 2020). The document aims to achieve the global goals set by the European Green Deal (EGD) and the UN Framework Convention on Biodiversity (CBD), and in some respects to surpass them. EU countries seek not only to preserve biodiversity and the range of ecosystem services provided by natural complexes but also to become a world leader in nature conservation and restoration over the next decade. The European Commission also undertook to adopt some important documents that will determine the legal basis for the implementation of measures envisaged by the Strategy and the attached Action Plan, including the new EU Forest Strategy for 2030, the flagship initiative of the EGD. The Strategy will help to reduce greenhouse gas emissions by at least 55% by 2030 and minimize climate change in the EU by 2050. However, after analyzing all the above documents, we can conclude that the EGD does not take into account many of the benefits that forests provide to society and the contribution that the forest sector can make to the Strategy itself (Fig. 1).

Figure 1. European Green Deal and the place of forest policy in it.
*Note: * areas related to forest policy in Ukraine in one way or another*

There are several potential solutions to this problem in the scientific literature related to the coordination of green policy goals, forest management, impact on costs, harmonization of relevant information and its accessibility, knowledge acquisition and communication. However, given the disclosure of the role of forests in EGD, many of the problems identified by researchers in the forest and related sectors remain prevalently unchanged, such as inconsistent sectoral policies and a lack of coordination and integration. Mentions of these and similar problems can be traced in official documents up to 1998, suggesting that we may not have made great strides in it. The obvious reason for this is certain internal problems of forest management in the EU's forest policy itself, which cannot be solved without changing tools and mechanisms. In this case, simply having a common forest agenda is not enough, especially when it comes to the impact on the European Union as a whole. And even if some legal obstacles are not taken into account, the lack of a clear delineation or focus of the European Green Deal on specific measures complicates the strategic vision of the future of forests in the document. All of that leads to the conclusion that to increase the relevance and efficiency, it is necessary to adapt the EGD to certain local conditions and within certain areas, as well as to harmonize relevant sectoral documents, such as the Forest Strategy.

However, all these difficulties do not undermine the value of the EGD as a constituent strategic document in any way. Moreover, they only actualize the urgent need to implement some of its points with the utmost regard to local conditions. Since 2020, Ukrainians have felt the force of natural disasters caused by climate change. Thus, the largest dust storms since 1926 took place (including such a storm in Polissia for the first time in history); powerful tornadoes took place in eastern Ukraine for the first time; floods in Transcarpathian and Ivano-Frankivsk regions became the largest in a long time, and the spring drought in Polissia became the largest in the history of meteorological observations. In addition, forest fires caused by the drought in Polissya became record-breaking in immensity and intensity (it should be noted here that the vast majority of burned forest areas fell on the territory contaminated by radiation as a result of the 1986 Chornobyl accident).

Ukraine is not an EU member but is inextricably linked with its western neighbours by common climate processes and changes in biodiversity status (Kuzemko, 2020). Therefore, the President of Ukraine V. Zelensky at the All-Ukrainian Forum ‘Ukraine-30. Ecology’ signed the Decree ‘On some measures for the preservation and reproduction of forests’ (2021). The document launches the initiative of large-scale afforestation of Ukraine - ‘Green Country’, or ‘Large-scale afforestation of Ukraine’ at the national level from 2021. The initiative is aimed at solving problematic issues of forest management, primarily protection, preservation, use and reproduction of forests. The national initiative ‘Green Country’ provides for preservation and reproduction of forests, including self-seeding ones, increasing the area of forests, stimulation of afforestation, conservation and restoration of natural ecosystems; improving the management system of state forestry enterprises; involvement of schoolchildren, students and public organizations in afforestation, preservation and restoration of forests. On June 11, 2021, the draft Law "On Amendments to Certain Legislative Acts Concerning Forest Conservation" was registered with the number 5650. This bill should regulate the preservation of self-seeding forests, withdrawal of unproductive and degraded lands from circulation and reservation. It is well known that forests are the most biodiversity-rich terrestrial ecosystems. The total forest area belonging to the forest fund of Ukraine is 10.4 million hectares, including 9.6 million hectares covered with forest vegetation. Despite the low forest land percentage - 15.9%, Ukraine ranks 7th in Europe in terms of forest area and 6th in terms of timber reserves (Fig. 2).

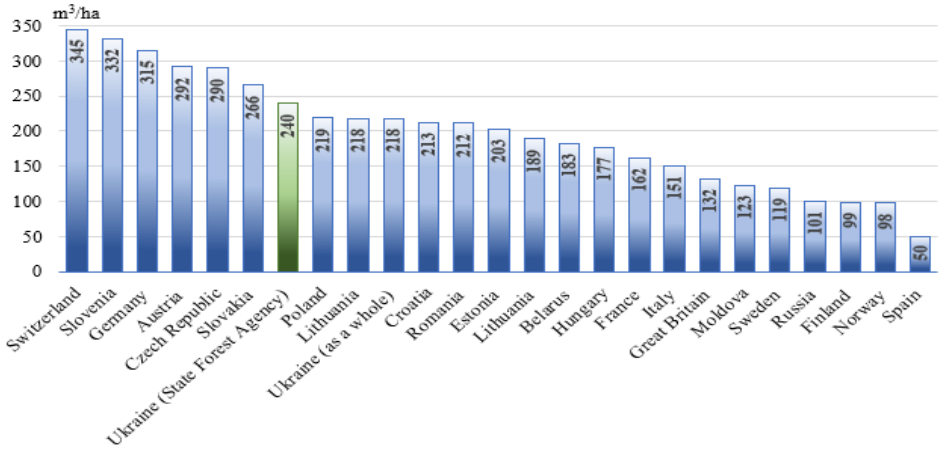

Figure 2. Average growing stock in some European countries, m^3/ha.

Forests on the territory of Ukraine are located unevenly and are mainly concentrated in Polissia and the Ukrainian Carpathians. Ukraine's forests are formed by more than 30 tree species, among which pine, oak, beech, spruce, birch, alder, ash, hornbeam, and fir dominate. Coniferous plantations occupy 43% of the total area, in particular, pine - 35%. Hardwood plantations make up 43%, in particular oak and beech - 37%. The age structure is dominated by middle-aged plantations, the share of ripe and overripe plantations is 18.7%. The average age of forests is over 60 years, there is a gradual ageing of forests, which leads to the deterioration of their sanitary state (State Agency of Forest Resources of Ukraine, 2020). As a result, our country, along with Great Britain, the Netherlands, Spain, and Italy, belongs to forest-deficient countries, so its policy in this area is aimed at restoring forest resources.
Studies conducted by specialists from various research institutions (Furdychko O., Kurbet T., Landin V., Krasnov V., Dankevich S.), prove that forest degradation and reduction of forest plantations area are caused by the simultaneous action of various interrelated factors (Dankevych, 2021). In his works, J. Henyk proves that the influence of any factor, whether anthropogenic or natural, leads to certain negative consequences in the development of forest ecosystems, and a combination of several factors enhances the effect of each in particular (Fig. 3).

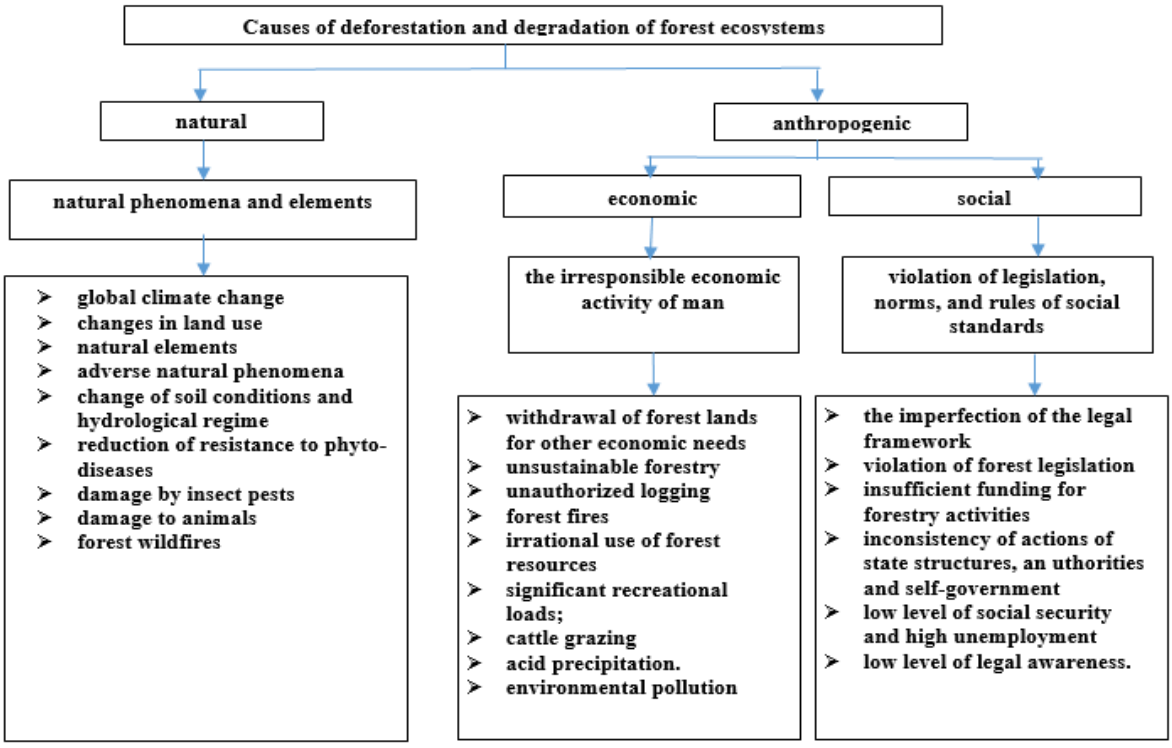

Figure 3. The main causes of deforestation and degradation of forest ecosystems.

It can be maintained that the partial reduction in forest area is due to changes in climatic conditions. However, mostly these are the consequences of human economic activity. The microclimate in the territory of fellings and fires changes, lighting and warming of the ground surface enhance, wind velocity increases, water reserves in the upper layer of the soil significantly reduce, the water cycle is changing, etc.
Many forests in Ukraine have been destroyed as a result of the construction of water reservoirs, railways and roads, or conversion of forested areas into agricultural land. Unsustainable use of forest resources has led to the fact that deciduous forests are on the verge of extinction. Due to afforestation over the last 40 years, forest diversity has been partially lost. Artificial coniferous plantations, which are very dangerous in the context of fire safety, have been created on hundreds of thousands of hectares.
According to the Global Forest Watch platform (Forest Monitoring Designed for Action), during 2001-2020, Ukraine lost 1.08 million hectares of forest plantations, their area decreased by 9.7% compared to 2000 (Henyk, 2011).
During 19 years, 0.26% of forest plantations were lost as a result of logging, and 418.44 hectares of forests were destroyed on average as a result of fires (Fig. 4).

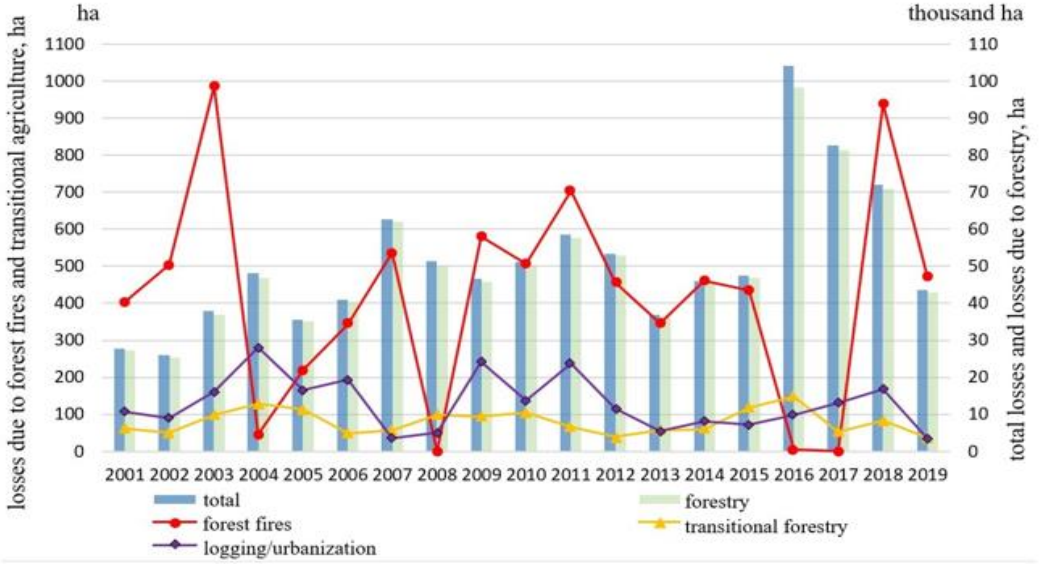

Figure 4. Loss of forest stands in 2001–2019 (according to Global forest watch).

The probability of forest fires and the damage caused by them is the highest for young and middle-aged coniferous stands of the south, east and Polissya of Ukraine. Forest fires are one of the most dangerous phenomena that lead to significant economic losses and adverse environmental effects.

Until recently, it was believed that forests as extremely complex ecosystems are characterized by high resistance to man-made pollution of air and soil mantle. However, over the past two decades research has worsened forecasts of the dynamic resilience of forest ecosystems to long-term pollutant uptake (Cherniavskyi et. al., 2011). An assessment of the impact of various components on Europe's forests shows that the degradation process covers 20-25% of the continent's forests (FAO, 2020).

After the Chornobyl nuclear disaster in 1986, radioactive contamination of forests was detected in 18 regions of Ukraine. In total, almost 3.5 million hectares of Ukraine's forests were contaminated with radionuclides. 1 million 230 thousand ha of forests from the surveyed forested areas had a critical density of radionuclide contamination, of which 157 thousand ha were withdrawn from commercial use due to high levels of ^{137}Cs pollution. The largest areas of contaminated forests are in the Zhytomyr - 974.3, Rivne - 728.8, Chernihiv - 725.5 and Kyiv regions - 416.4 thousand hectares. According to research (Chobotko et al., 2016; Landin et al., 2020; Orlov et al., 2002), the density of radioactive contamination in forests remains on average 25–30% higher than in nearby located non-green areas. Radionuclides that have migrated to forest litter and soil are firmly fixed and/or involved in the biological cycle, which makes it possible to predict the radiation situation stability in these areas. Thus, forest ecosystems in the absence of natural phenomena (fires, windbreaks), which violate their integrity, serve as a powerful barrier to secondary radioactive contamination of adjacent areas (Krasnov et al., 2007).

In the 35 years since the Chernobyl accident, the radiation situation in contaminated areas has changed significantly due to the redistribution of radionuclides between components of forest ecosystems and the irreversible fixation of radionuclides in the soil absorption complex and due to physical decay (Table 1).

According to our calculations, the area of forest land with a density of ^{137}Cs pollution over 37 kBq/m^2 compared to 1992 should be reduced by 374.6 thousand hectares, ie they are allowed to carry out all forestry activities without restrictions. The area of forests that belonged to the zone of unconditional resettlement (> 555 kBq/m^2) should also be reduced by 17.5 thousand hectares and now it is necessary to carry out priority forestry measures in these areas.

In general, the forest area in Ukraine, which according to the current legislation does not belong to the radioactively contaminated areas (up to 37 kBq/m^2), increased by 23.3% compared to the 1992 survey. Accordingly, the forest areas belonging to one or another contamination zone have been redistributed. The forest area where forestry activities are prohibited (over 555 kBq/m^2) decreased from 40.8 thousand hectares to 22.4 thousand hectares, which is 55.0%

compared to 1992. The forest area where certain restrictions on the use of wood have been introduced (over 185 kBq/m^2) has decreased by 60% compared to 1992.

Table 1. Dynamics of forest land areas contaminated with ^{137}Cs, thousand hectares

Regional departments of forestry and hunting	Years	Pollution ^{137}Cs density zones, kBq/m^2								Change in an area with <37 kBq/m^2
		<37,0	37,1-74,0	74,1-185,0	185,1-370,0	370,1-555,0	555,1-1110,0	>1110,0		
Volyn	1992	136,2	36,9	5,3	–	–	–	–		
	2020*	156,1	16,7	3,0	–	–	–	–		+19,9
Vinnytsia	1992	185,1	23,8	6,8	0,5	–	–	–		
	2020*	205,2	8,3	1,4	–	–	–	–		+20,1
Zhytomyr	1992	292,4	182,5	158,3	50,3	16,4	27,0	5,4		
	2020*	441,9	131,8	77,3	27,3	16,6	14,8	2,7		+149,5
Kyiv	1992	178,0	129,3	38,2	13,0	5,5	4,2	4,1		
	2020*	234,0	68,5	18,9	8,7	3,9	2,7	2,2		+56,0
Rivne	1992	293,6	215,3	151,6	10,7	0,3	–	–		
	2020*	387,5	130,9	117,5	3,1	0,5	–	–		+93,9
Sumy	1992	109,4	8,0	4,5	–	–	–	–		
	2020*	114,2	4,9	1,9	–	–	–	–		+4,8
Cherkasy	1992	176,0	31,1	7,3	0,6	0,04	–	–		
	2020*	188,1	18,9	4,5	0,3	–	–	–		+12,1
Chernihiv	1992	273,8	47,4	23,1	3,3	0,9	0,1	–		
	2020*	292,1	14,9	10,4	0,6	–	–	–		+18,3
Total by the State Forest Agency	1992	1644,5	674,3	395,1	78,4	23,14	31,3	9,5		
	2020*	2019,1	394,9	234,9	40,0	21,0	17,5	4,9		374,6

*Note: * calculated by the authors according to the data (Landin, 2013).*

The decay of radionuclides has led to even greater differentiation of the density of radioactive soil contamination in forests, especially in areas less affected by the Chornobyl accident. Thus, in the Rivne region the maximum density of radioactive soil contamination currently does not exceed 370 kBq/m^2, and in the Volyn region – 74 kBq/m^2. However, even now there is a fairly large area of forests that have high levels of radionuclide contamination. Therefore, the methodology of rehabilitation of these forest ecosystems should be based on well-known principles in the theory and practice of safe living and management in radioactively contaminated areas that meet the Radiation Safety Standards of Ukraine (NRBU-97) and the Basic Sanitary Rules (OSP-2006) environmental trends and in the context of EGD.

To achieve the goals of rehabilitation of radioactively contaminated forest ecosystems scientists from various institutions, including The Institute of Agroecology and Environmental Management of NAAS, Polissya Branch of Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky (URIFFM), Ukrainian National Forestry University, Polissya National University, etc. proposed the main goals for the rehabilitation of forest ecosystems, which should be aimed at determining the current radiation situation in forests. In particular, it is advisable to conduct a gradual and phased survey of forests to restore or remove some restrictions on forest use and forest management activities. The next logical step is to create an updated modern electronic database of forest plantations, as the electronic database with primary materials of radioactive contamination of Polissian forests was created in 1991-1992. Initially, it is recommended to conduct surveys of areas with the highest density of radioactive contamination of the soil and follow the required sequence of forest rehabilitation: 1) ^{137}Cs soil contamination over 15 Ki/km^2; 2) ^{137}Cs soil contamination over 7–15 Ki/km^2; 3) ^{137}Cs soil contamination less than 7 Ki/km^2. This thesis is very important, as the sanitary condition of the forests of Ukrainian Polissya is unsatisfactory, and their productivity is gradually declining. (Krasnov, 2015). The creation of such an electronic bank should be the first step towards quality accounting of forest ecosystem biodiversity within national economic planning. This database should be a complete complement to the System of Environmental-Economic Accounting (SEEA) - an integrated and comprehensive statistical database for organizing data on habitats and landscapes, measuring ecosystem services, tracking changes in ecosystem assets and

linking this information to economic and other human activities, adopted by the United Nations on March 11, 2021 (System of environmental economic accounting. Ecosystem Accounting; Global Assessment of Environmental Economic Accounting and Supporting Statistics 2020; United Nations Committee of Experts on Environmental-Economic Accounting, 2017). A key aspect of ecosystem accounting is that it allows expressing the contribution of ecosystems to the well-being of society in monetary terms.

A separate important issue is the conduct of systematic radiological control of forest food resources (mushrooms, berries) obtained in radioactively contaminated areas, and the relevant comprehensive radiological survey of contaminated areas to determine the boundaries of radiation-critical areas, the use of which threatens to obtain forest products that are excessively contaminated with radionuclides. The next step is to establish the feasibility of economic use of these lands and possibly change their zoning and status based on expected contamination levels.

CONCLUSIONS

The Polissia region of Ukraine, which suffered the most from the Chornobyl accident, has many unresolved environmental and economic problems that require the coordinated participation of central and local authorities, local governments, research institutions and the general public. Forestry is one of the key industries in the region and at the same time the ones that suffer the most from a complex of negative factors, such as radiation pollution, climate change, uncontrolled anthropogenic activities. It is traditional for the north of Ukraine, as Ukrainian Polissia accounts for almost 40% of the state's forests. This issue has become especially relevant in the context of Ukraine's declaration of accession to the European Green Deal and other international commitments, including the United Nations Forest Instrument (UNFI), which formulate some agreed strategies and measures at the international and national levels.

Currently, among the main obstacles to full-scale rehabilitation of forest ecosystems in Ukraine, and especially in the Polissya region, are the lack of relevant legislation, regulations and legal mechanisms, imperfect logistics system and low pay of staff, lack of professional staff and more. Given this, there is a need to review the principles and priorities of forestry in the lands affected by the Chornobyl disaster and return these lands to safe economic use. In modern conditions, special attention should be paid to measures that have a biological and environmental focus and do not require significant changes in current technologies. However, the application of such measures requires a scientifically sound comprehensive analysis of radio-capacity and, consequently, radiation criticality of forest ecosystems in the affected region. The main actions on the rehabilitation of forest ecosystems should be aimed at determining the current radiation situation in forests to be able to resume forest management activities and obtain forestry products. This will help improve the productivity of forest plantations and restore forestry production in the Chornobyl-affected region. The long-term task is the comprehensive rehabilitation of the affected region, optimization of forestry activities taking into account the restoration of the natural structure of landscapes, ensuring the biodiversity of ecosystems, as well as climate change.

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