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DYNAMICS OF FOREST FUND LANDS OF THE MINISTRY OF FORESTRY OF THE REPUBLIC OF BELARUS IN AREAS OF RADIOACTIVE CONTAMINATION

On April 26, 2026, it will be 40 years since the largest man-made disaster of the 20th century – the accident at the Chernobyl Nuclear Power Plant (ChNPP). As a result of this event, 20.1 thousand km² of Belarusian forests were contaminated with radioactive elements, accumulating up to 70% of the radionuclides that fell on the territory of the republic. Radioactive contamination of the land changed the natural properties of forest ecosystems, disrupted established forest management practices, and created a number of restrictions on forestry operations and multiple-use forest management. To ensure radiation safety for forestry workers, the population visiting forests, and consumers of forest products – and to obtain environmentally safe (normatively clean) products – annual updates of the radiation situation in forests have been conducted since 1993.

This article studies the dynamics of changes in the forest fund area of the Ministry of Forestry of the Republic of Belarus in radioactive contamination zones from 1995 to 2025 and provides a forecast for 2046. It also presents the distribution of forestry enterprise territories by radioactive contamination zones as of January 1, 2025.

The radiation situation in the radionuclide-contaminated areas is gradually stabilizing. The amount of cesium-137 in the soil decreases due to radioactive decay (about 2% per year) and absorption by vegetation. Over time, the area of each radioactive contamination zone decreases, with transitions occurring from zones of higher soil contamination density by cesium-137 to zones of lower density. As of January 1, 2025, the forest fund territory classified as radioactive contamination zones amounts to 1,203.0 thousand ha (13.91% of the total forest fund area). The main portion of the radioactive contamination area (842 thousand ha) belongs to Zone I (1–5 Ci/km²). From 1995 (1,747.1 thousand ha) to 2025, the area of radioactive contamination in the Ministry of Forestry's forest fund decreased by 544.1 thousand ha, or 31%. By 2046, it is projected to decrease to 829.3 thousand ha, or 53% relative to the 1995 level. The ability to forecast changes in the area (zones) of radioactive contamination will make it possible to optimize planning of forestry operations in these territories.

Keywords: radioactive contamination, forest fund, radionuclides, cesium-137, radiation safety.

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ДИНАМИКА ЗЕМЕЛЬ ЛЕСНОГО ФОНДА МИНИСТЕРСТВА ЛЕСНОГО ХОЗЯЙСТВА РЕСПУБЛИКИ БЕЛАРУСЬ В ЗОНАХ РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ

26 апреля 2026 г. исполнится 40 лет со дня крупнейшей техногенной катастрофы XX века – аварии на Чернобыльской АЭС (ЧАЭС), в результате которой 20,1 тыс. км^2 лесных насаждений Беларуси оказались загрязнены радиоактивными элементами, аккумулировав до 70% радионуклидов,

выпавших на территорию республики. Радиоактивное загрязнение территорий изменило природные свойства лесных экосистем, нарушило сложившийся режим ведения лесного хозяйства, создало ряд ограничений в процессе лесохозяйственной деятельности и многоцелевого лесопользования. Для обеспечения радиационной безопасности работников лесного хозяйства, населения при посещении лесов, потребителей лесной продукции, а также для получения нормативно чистой продукции с 1993 г. проводится ежегодное уточнение радиационной обстановки в лесах.

В статье исследована динамика изменения площади лесного фонда Министерства лесного хозяйства Республики Беларусь в зонах радиоактивного загрязнения с 1995 по 2025 гг., представлен прогноз на 2046 г. Приведено распределение территорий лесхозов по зонам радиоактивного загрязнения на 01.01.2025.

Радиационная обстановка на загрязненной радионуклидами территории постепенно стабилизируется. Запас цезия-137 в почве снижается за счет радиоактивного распада (около 2% в год) и поглощения растительностью. Со временем уменьшаются площади каждой зоны радиоактивного загрязнения, происходит переход из зоны с большей плотностью загрязнения почв цезием-137 в зону с меньшей плотностью. По состоянию на 1 января 2025 г. территория лесного фонда, отнесенная к зонам радиоактивного загрязнения, составляет 1203,0 тыс. га (13,91% от общей площади лесного фонда). Основная часть территории радиоактивного загрязнения (70%) отнесена к I зоне (1–5 Ки/км^2). Площадь радиоактивного загрязнения лесного фонда Минлесхоза за период с 1995 (1747,1 тыс. га) по 2025 гг. уменьшилась на 544,1 тыс. га, или на 31%. К 2046 г. прогнозируется уменьшение площади лесов в зонах радиоактивного загрязнения до 829,3 тыс. га, или на 53%, по отношению к площади в 1995 г. Возможность прогнозирования изменения площади (зон) радиоактивного загрязнения позволит оптимизировать планирование лесохозяйственных работ на данных территориях.

Ключевые слова: радиоактивное загрязнение, лесной фонд, радионуклиды, цезий-137, радиационная безопасность.

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Introduction. On April 26, 2026, it will be 40 years since the largest man-made disaster of the 20th century – the accident at the Chernobyl Nuclear Power Plant (ChNPP), as a result of which about one-quarter of the territory of Belarus was exposed to radioactive contamination. To varying degrees, 52 administrative districts of Belarus were affected (4 in Brest Region, 1 in Vitebsk Region, 20 in Gomel Region, 3 in Grodno Region, 10 in Minsk Region, and 14 in Mogilev Region). Taking into account the proportion of contaminated land, collective radiation dose, loss of agricultural land, number of liquidated farms and enterprises, and the resettled population, 21 districts were identified as the most contaminated with radionuclides: Brest Region: Luninets, Pinsk, and Stolin Districts; Gomel Region: Bragin, Buda-Koshelevo, Vetka, Dobrush, Yelsk, Kalinkovichi, Korma, Lelchitsy, Narovlya, Rechitsa, Rogachev, Khoiniki, and Chechersk Districts; Mogilev Region: Bykhov, Kostyukovichi, Krasnopolye, Slavgorod, and Cherikov Districts. Radioactive contamination disrupted established modes of use for agricultural land and forests, reduced their resource potential, complicated the technological processes of economic activity, and led to additional financial expenditures for radiation control and monitoring of radioactive contamination parameters in farmland, forest areas, natural resources, and production outputs [1–4].

A total of 20.1 thousand km² of Belarusian forests were contaminated with radioactive elements, accumulating up to 70% of the radionuclides that fell on the republic's territory. Forests contaminated with radionuclides represent a long-term source of radiation hazard. Important properties of forest ecosystems – such as the large absorbing surface area of forest vegetation and other forest components, the inclusion of radionuclides into the nutrient cycle of forest ecosystems, high stability of forest stands, and their ability to securely retain radionuclides – allow forests to serve as a powerful biogeochemical barrier preventing the spread of radionuclides. The distinct features of forests as both an object of contamination and a source of radiation hazard lie in their large biomass, biodiversity, and longevity [1–4].

Main Section. Radioactive contamination of territories altered the natural properties of forest ecosystems, disrupted the established system of forest management, and created a number of restrictions on forestry operations and multiple-use forest utilization.

To ensure radiation safety for forestry workers, the population visiting forests, and consumers of forest products – and to obtain environmentally safe (normatively clean) products – it became necessary to refine the understanding of the radiation situation and to develop regulatory documentation governing activities in radioactive contamination zones [1–4].

In 1989, systematic work began to establish a radiation control service to monitor the radiation situation on forest fund lands. Regional radiation control laboratories and radiation control posts were created within State Forestry Production Associations (SFPA) and in contaminated state forestry enterprises across the republic.

A comprehensive field radiation survey of forest fund lands was carried out in 1991–1992. The survey revealed that the forest fund area affected by the Chernobyl NPP accident amounted to 20.1 thousand km^2. The main share of radionuclide-contaminated forests was under the jurisdiction of the Ministry of Forestry – 17.47 thousand km^2, and the Ministry of Natural Resources and Environmental Protection [5].

The system of radioactive contamination control for the forest fund includes two subsystems: radiation control and radiation monitoring. Radiation control – a set of activities aimed at measuring and monitoring radiation levels to assess the safety of people and the environment. Radiation monitoring – a continuous system of observation and control over the levels of radiation and radioactive contamination of the environment, including air, water, soil, food, humans, and facilities [5].

Since 1993, radiation control and monitoring have been carried out in forests located in radioactive contamination zones. This monitoring is conducted in accordance with the technical codes of established practice: TKP 498–2013 “Radiation Monitoring of the Forest Fund. Establishment of a Permanent Observation Point. Procedure”, TKP 499–2013 “Radiation Monitoring of the Forest Fund. Examination of a Permanent Observation Point. Procedure”. To study the “behavior” of radionuclides in forest ecosystems, 102 permanent sample plots – Permanent Observation Points (hereinafter POP) for radiation monitoring in forests – were established within Ministry of Forestry organizations during 1993–1995 [5–8]. Figure 1 shows the distribution of radiation monitoring departments, posts and POP in forests across Belarus.

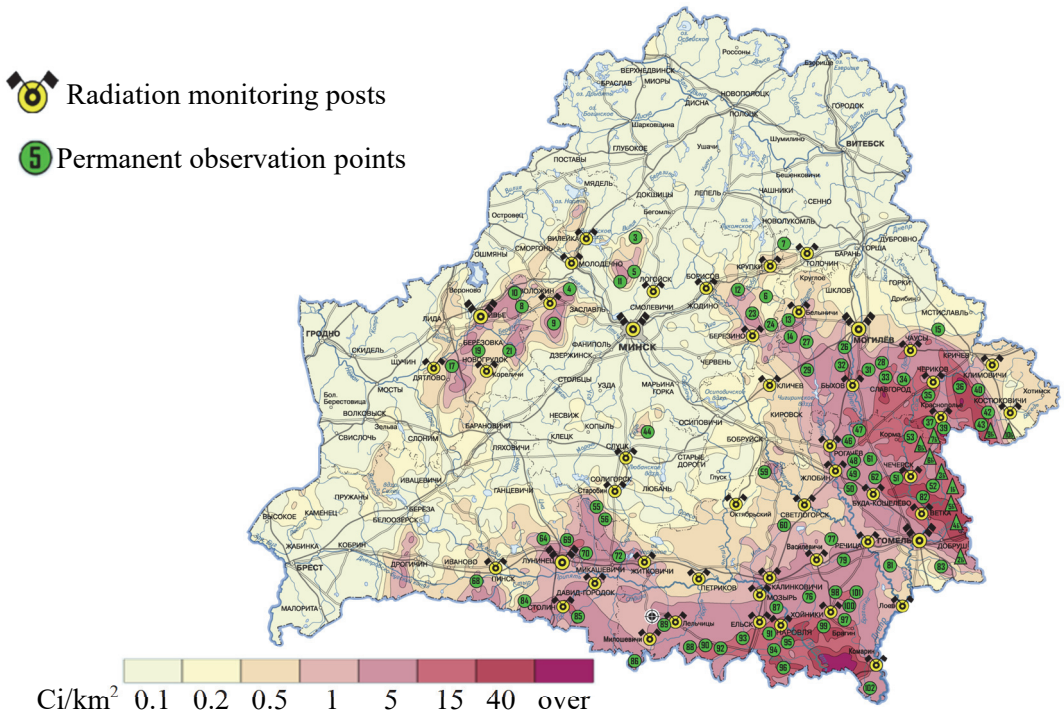

Figure 1. Distribution of radiation monitoring posts and POP in forests

When organizing the radiation monitoring network in forests, the needs of the forestry sector for sufficient and objective information on radionuclide levels in the main forest resource – wood – as well as on the processes of change in wood contamination over time, were taken into account.

As part of the annual radiation surveys at the Permanent Observation Points (POP), studies are conducted on how various factors influence the uptake of radionuclides from soil into trees, considering forest type, forest growth conditions, and edaphotopes.

The procedure for classifying forest fund territories into radioactive contamination zones (zoning) and the legal regime in such territories are determined in accordance with the requirements of the Law of the Republic of Belarus "On the Legal Regime of Territories Affected by Radioactive Contamination as a Result of the Chernobyl NPP Disaster" [9].

The following zoning of radioactive contamination in the forest fund is applied, based on the soil contamination density by cesium-137:

Zone I – contamination density 1–5 Ci/km^2;

Zone II – 5–15 Ci/km^2;

Zone III –15–40 Ci/km^2;

Zone IV – 40 Ci/km^2 and over.

The basis for assigning a forest quarter to a specific contamination zone is the contamination density established from radiation survey results of forest fund lands, conducted in accordance with technical code of established practice TKP 240–2010 "Radiation Control. Survey of Forest Fund Lands. Procedure" [10].

The radiation control service of the Ministry of Forestry is managed by the State Forestry Protection and Monitoring Institution "Bellesozashchita", which includes 35 accredited (certified) units. Results of radioactive contamination control are stored systematically in the information system "Radioactive Contamination of Forests" – RadFor. This system enables automated collection, storage, processing, and analysis of results, forecasting of radiation trends, and generation of reports and documentation. In forestry enterprises, a geo-information service "RadForInfo" within RadFor is used to provide real-time data on the radiation situation for any selected forest quarter on the map, including forecasts for future dates [11, 12].

At present, a large volume of data has been accumulated on the specifics of radioactive contamination in forest ecosystem components – including forest fund lands, forest plots and resources, forest products and their derivatives, forestry facilities and workplaces, as well as agricultural raw materials, fodder, food products, and medicinal-technical raw materials.

This has enabled the development of short-term and long-term forecasts of radioactive contamination dynamics in forests and forest products, as well as recommendations for forest management in different contamination zones. The main directions for sustainable forestry development have been identified.

Analysis of accumulated data shows that the radiation situation in forests is characterized by a gradual decrease in cesium-137 levels in soil (about 2% per year) and a reduction in gamma radiation dose rate (2.0–4.4% per year). The decline in cesium-137 levels is due to radioactive decay and absorption by vegetation, while the decrease in gamma dose rate is also influenced by the migration of cesium-137 deeper into the soil and shielding by upper soil layers and litter [5, 6, 13].

Over time, the area of each radioactive contamination zone decreases, with territories transitioning from zones of higher soil contamination density to those of lower density. In 1995, the share of forests under the Ministry of Forestry that were contaminated amounted to 25.6% of the total forest fund area, while by 2025, it had decreased to 13.9% [5].

Figure 2 shows the change in the forest fund area of the Ministry of Forestry in radioactive contamination zones from 1995 to 2025.

Over the 39 years since the Chernobyl Nuclear Power Plant accident, significant changes have occurred in the radiation situation in the affected territories. As of January 1, 2025, the area of the forest fund classified as radioactive contamination zones amounts to 1,203.0 thousand ha. Since 1995 (when it was 1,747.1 thousand ha), the area of radioactive contamination within the Ministry of Forestry's forest fund has decreased by 544.1 thousand ha, or 31%.

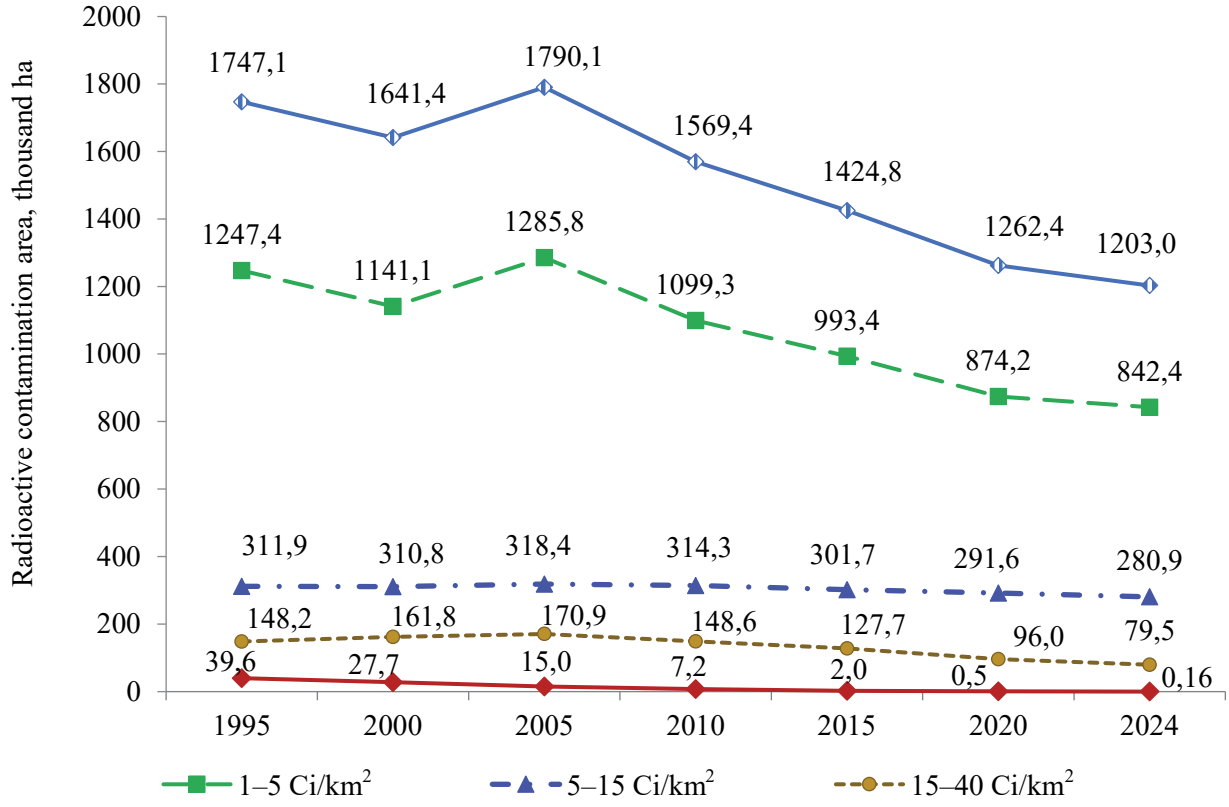

Figure 2. Distribution of the Ministry of Forestry's forest fund lands by zones of radioactive contamination (1995–2024)

The distribution of the Ministry of Forestry's forest fund lands by zones of radioactive contamination as of January 1, 2025, is shown in Figure 3 [5].

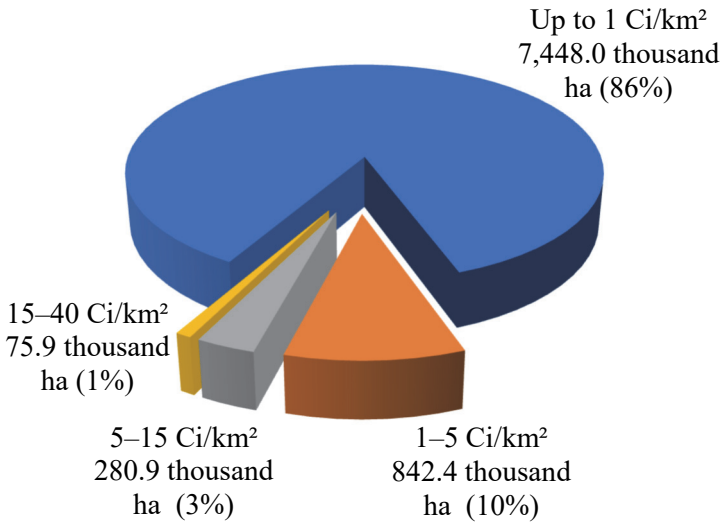

Figure 3. Distribution of the forest fund lands of the Ministry of Forestry by zones of radioactive contamination as of January 1, 2025

In 43 forestry enterprises across the republic, areas of the forest fund are classified as radioactive contamination zones. Table 1 presents the distribution of the forestry enterprises of the Ministry of Forestry of the Republic of Belarus by zones of radioactive contamination (as of January 1, 2025) [5].

Table 1. **Distribution of Forestry Enterprises of the Ministry of Forestry of the Republic of Belarus by Zones of Radioactive Contamination (as of January 1, 2025)**

Name of Forestry Enterprise	Total area, thousand ha	Area of soil contamination with cesium-137, thousand ha					
		Total	Including zones and sub-zones, Ci/km^2				
			1–2	2–5	5–15	15–40	>40
Vetkovsky	103.0	103.00	0.21	17.44	64.04	21.34	–
Chechersky	106.9	106.90	5.15	55.88	35.83	10.03	–
Krasnopolsky	86.4	86.40	8.55	32.19	27.38	18.12	0.16
Cherikovsky	103.8	87.50	19.84	30.19	29.34	8.13	–
Narovlyansky	70.7	70.10	8.70	23.49	36.56	1.35	–
Yelsky	88.8	74.20	21.85	41.09	11.22	–	–
Khoiniki	66.4	64.00	29.43	25.56	8.74	0.28	–
Komarinsky	50.4	44.10	23.97	16.57	3.60	–	–
Buda-Koshelevo	52.4	25.10	3.88	11.48	8.05	1.66	–
Bykhovsky	113.6	68.50	44.40	21.98	2.02	0.10	–
Gomelsky	118.0	42.80	7.60	6.45	18.59	10.15	–
Lelchitsy	121.5	55.40	42.28	12.81	0.33	–	–
Rogachevsky	79.0	31.30	6.00	24.77	0.48	–	–
Kostyukovichi	104.5	39.80	3.34	5.91	22.18	8.38	–
Stolin	94.4	32.90	17.22	13.93	1.74	–	–
Chausy	67.4	31.50	18.78	11.73	0.98	–	–
Miloshevichi	102.9	22.20	18.38	3.87	–	–	–
Vasilevichi	90.4	18.60	16.85	1.78	–	–	–
Rechitsa	64.7	10.90	8.23	2.66	–	–	–
Belynichi	97.6	20.80	14.49	6.34	–	–	–
Mozyr	97.3	15.70	15.25	0.45	–	–	–
Klimovichi	94.9	18.10	4.07	5.31	8.71	–	–
Loev	45.2	7.10	3.48	2.85	0.79	–	–
Kalinkovichi	102.7	21.80	20.22	1.60	–	–	–
Polessky	105.7	10.50	8.51	2.01	–	–	–
Luninets	146.7	19.60	15.02	4.47	0.07	–	–
Ivye	89.1	6.60	6.42	0.15	–	–	–
Mogilev	87.3	12.50	9.33	3.00	0.18	–	–
Berezinsky	111.8	12.30	10.59	1.69	–	–	–
Zhlobin	85.2	11.80	11.27	0.52	–	–	–
Klichev	109.1	3.00	3.00	–	–	–	–
Novogrudok	100.4	3.40	2.82	0.61	–	–	–
Zhitkovichi	118.2	4.50	3.55	0.96	–	–	–
Volozhin	83.9	6.10	3.80	2.24	0.11	–	–
Starobin	100.8	5.00	4.80	0.21	–	–	–
Pinsk	92.0	3.40	3.31	0.08	–	–	–
Krupki	124.3	1.40	0.57	0.80	–	–	–
Dyatlovo	85.0	0.20	0.20	–	–	–	–
Logoisk	115.1	2.10	0.94	1.16	–	–	–
Gorki	73.3	1.20	0.37	0.79	–	–	–
Svetlogorsk	105.4	0.20	0.04	0.17	–	–	–
Slutsk	62.4	0.21	0.21	–	–	–	–
Molodechno	49.7	0.30	0.17	0.09	–	–	–
Total	3,968.3	1,203.01	447.09	395.28	280.94	79.54	0.16

The degree of danger posed by a forest as a source of external and internal radiation exposure primarily depends on the soil contamination density with cesium-137 (^{137}Cs) – the main dose-forming long-lived radioisotope of Chernobyl origin. An important characteristic of a radionuclide

is its half-life – the period of time during which, as a result of radioactive decay, the number of nuclei of that radionuclide decreases by half. For cesium-137, the half-life is 30 years [14]. In 2016, the first half-life period of cesium-137 was reached, leading to a change in the area of each zone of radioactive contamination. The second half-life period of cesium-137 will occur in 2046. The forecast of the distribution of soil contamination area with cesium-137 across the State Forestry Production Association (SFPA) of the Ministry of Forestry for 2046 is presented in Table 2.

According to the forecast presented in Table 2, the area of forests in zones of radioactive contamination in 2046 will amount to 829.3 thousand ha.

Table 2. **Forecast of the distribution of soil contamination area with cesium-137 across the SFPA of the Ministry of Forestry for 2046**

Name of SFPA	Area of soil contamination with cesium-137, thousand ha
Brest	26.3
Vitebsk	0.0
Gomel	536.4
Grodno	2.2
Minsk	8.3
Mogilev	256.1
Total	829.3

Between 1995 and 2046, a reduction of 917.8 thousand ha, or 53%, in the area of radioactive contamination of the Ministry of Forestry's forest fund is projected. This reduction is due to the decrease in soil contamination density with cesium-137 as a result of radioactive decay and redistribution of the radionuclide among forest ecosystem components.

Planning of forestry activities and forest use is carried out within the established zones of radioactive contamination, using the results of radiation monitoring. The ability to forecast changes in the area (zones) of radioactive contamination will make it possible to optimize forestry planning in these territories [15].

At present, to ensure stable development of forestry in radioactive contamination zones, a special system of forest management has been organized. This system provides for the long-term, effective implementation of forestry measures, safe working conditions, and the production of radiation-safe (standard-compliant) products [16–18]. Priority attention is given to the following tasks:

– improvement of the forest fire protection system to prevent forest loss and possible secondary radioactive contamination of adjacent territories as a result of forest fires;

– reforestation and afforestation;

– restoration of forest infrastructure (forest roads, access routes, compartment lines, fire observation posts, firebreaks, etc.);

– improvement of protective measures;

– radiation monitoring and control;

– improvement of the forest utilization system to ensure compliance with radiation safety norms and regulations;

– creation and implementation of specialized (mobile) multi-operation logging complexes;

– improvement of the regulatory and legal framework, provision of accessible and updated information for specialists and the public regarding changes in the radiation situation; improvement of training and professional development of forestry specialists [1–3, 19, 20].

Conclusion. In Belarus, forests are one of the main renewable natural resources and an important part of the nation's wealth. Radioactive contamination of forest lands has led to a decrease in the potential of forest areas in terms of their ecosystem functions, the consumer properties of forest products, and the possibilities for multipurpose forest use.

Since 1993 and up to the present time, annual radiation control and monitoring have been carried out in the forest fund territories of the Ministry of Forestry affected by radioactive contamination. As of January 1, 2025, the area of the forest fund classified as zones of radioactive

contamination amounts to 1,203.0 thousand ha (13.91% of the total forest fund area). The main part (70%) of the contaminated area belongs to Zone I (1–5 Ci/km^2).

Between 1995 (1,747.1 thousand ha) and 2025, the area of radioactive contamination within the Ministry of Forestry's forest fund decreased by 544.1 thousand ha, or by 31%. The radiation situation in forests is characterized by a gradual decrease in the cesium-137 content in soils (about 2% per year) and in gamma radiation dose rate (2.0–4.4% per year). The main factor driving these positive changes is natural radioactive decay. By 2046, the area of forests in zones of radioactive contamination is projected to decrease to 829.3 thousand ha, or by 53% compared to 1995.

To restore the socio-economic importance of forests and to maintain their biological and fire resistance in areas contaminated with radionuclides, a set of measures is being implemented to ensure public health protection and sustainable, environmentally safe forest management. These measures are mandatory, long-term in nature, and require significant additional resources. The ability to forecast changes in the area (zones) of radioactive contamination will help optimize the planning of forestry activities in these territories.

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