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APPROVED
First Deputy Minister of Forestry
of the Republic of Belarus
_____ V. G. Shatravko

REPORT № 6

DEVELOPMENT OF PROPOSALS WITH JUSTIFICATION OF SOCIAL, ECOLOGICAL AND ECONOMIC ASPECTS FOR REMOVAL / NOT REMOVAL OF THE FELLING WASTES IN THE PROCESS OF THINNINGS IN THE STANDS OF 20-40 AND 40-60 YEARS IN ORDER TO STOP DECREASE OF CARBON DIOXIDE SEQUESTRATION BY THE FOREST STANDS OF THE MAIN FOREST SPECIES OF THE REPUBLIC OF BELARUS.

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Project activity 3.1.8: "Undertake monitoring and analysis of stands with and without project thinning and removal of felling waste interventions to assess Greenhouse Gas (GHG) emissions reductions"

Stage 6. Development of proposals with justification of social, ecological and economic aspects for removal/ not removal of the felling wastes in the process of thinnings in the stands of 20-40 and 40-60 years in order to stop decrease of carbon dioxide sequestration by the forest stands of the main forest species of the Republic of Belarus.

Consultant

Educational Institution
"Belarusian State Technological University"

_____I. V. Voitau

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LIST OF AUTHORS

Project manager, Head of the Department of Silviculture of Belarusian State Technological University, PhD (Agriculture), Associate Professor	K. V. Labokha (Overall management, introduction, conclusions, executive summary, all stages)
Experts: Associate Professor of the Department of Forest Protection and Wood Sciences of Belarusian State Technological University, PhD (Agriculture)	A. V. Khvasko (Conclusions, executive summary, stage 4)
Associate Professor of the Department of Forest Management of Belarusian State Technological University, PhD (Agriculture)	A. A. Pushkin (Stage 8)
Senior Lecturer of the Department of Silviculture of Belarusian State Technological University, MSc (Biology), PhD (Agriculture)	Y. A. Larinina (Executive summary, conclusions, stages 1, 3, 6)
Associate Professor of the Department of Forest Management of Belarusian State Technological University, PhD (Agriculture)	V. P. Mashkovskiy (Stage 8)
PhD Student of the Department of Silviculture of Belarusian State Technological University, MSc (Agriculture)	A. O. Luferov (Stage 7)
PhD Student of the Department of Silviculture of Belarusian State Technological University, MSc (Agriculture)	A. A. Pryschepov (Stage 6)
Technical staff: Scientific and technical support of the documents, report design	Y. A. Larinina S. A. Shitikova S. A. Elizarenko
Technical translation:	A. O. Luferov

CONTENT

EXECUTIVE SUMMARY

1. Annual sequestration of CO_2 by forest ecosystem of Belarus, as per different estimations, is equal to 10 and up to 23 million tons. However, the carbon balance of forests is not stable in the temporal aspect, which is associated with the dynamics of the stock of tree stands. Over the past decades, there has been a positive trend due to the predominance of middle-aged forests.

At present there are no data on carbon deposition of felling wastes after intermediate cuts in the forests of Belarus, which are also part of the phyto-mass of the forest ecosystem, as well as their effect on the carbon sequestration capacity of forest stands. Therefore, as a part of the implementation of Project Activity 3.1.8: "Undertake monitoring and analysis of stands with and without project thinning and removal of felling waste interventions to assess Greenhouse Gas (GHG) emissions reductions" it is necessary to develop recommendations for the handling of felling residues during thinning and advance thinning.

The objective of the 6-th stage of Activity 3.1.8 was to develop the proposals with justification of social, ecological and economic aspects for removal / not removal of the felling wastes in the process of thinnings in the stands of 20-40 and 40-60 years in order to stop decrease of carbon dioxide sequestration by the forest stands of the main forest species of the Republic of Belarus.

2. As part of the sixth stage of work on Activity 3.1.8:

- proposals were prepared with the justification of socio-ecological and economic prerequisites for the removal / non-removal of logging residues during thinning and advance thinning in order to prevent a reduction in the absorption of carbon dioxide by forest stands of the Republic of Belarus in the stands of the main forest-forming species (pine, spruce, oak, birch, aspen, black alder);
- algorithms have been developed for choosing the treatment option for logging residues of the main forest-forming species during thinning and advance thinning;
- the analysis of the comments received from the stakeholders was carried out according to the developed guidance methodological document "The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)" and the corresponding adjustments were made to the document.

3. The main results obtained in the development of proposals with the justification of the socio-ecological and economic prerequisites for removing / not removing logging residues during thinning and advance thinning in order to prevent the reduction of carbon dioxide absorption by forest stands of the Republic of Belarus in the stands of the main forest-forming species (pine, spruce, oak, birch, aspen, black alder).

The main factors influencing the choice of method for clearing cutting areas from logging residues (collection and removal of logging residues from the logging site; collecting logging residues in piles and burning; collecting in heaps and leaving for decay; laying of logging residues on portages and subsequent compaction; chopping and scattering on the territory of the cutting area) include:

- type of thinning;
- technology of wood harvesting;
- forest growing conditions (type of forest);
- category of forests;
- requirements for the conservation of biological diversity;
- annual carbon sequestration by ground felling wastes;

- indicators of economic efficiency of various regimes of carrying out intermediate cuts, taking into account the environmental and social consequences of the utilization of biomass of logging residues.

The optimal regime for the management of logging residues should be considered as such a regime of intermediate cuts and the amount of felling wastes under which both the maximum carbon accumulation of the forest ecosystem will be ensured, as well as the proper sanitary and forest pathological condition of the stands and the satisfaction of economic interests in parts of the use of liquid wood and logging residues harvested during thinning.

The results of our studies show that regardless of the technology of harvesting wood in pine stands on dry and fresh sandy soils in pine forests of Lichen, Calluna and Vaccinium, it is most expedient to chop and spread logging residues in the cutting area. Moreover, taking into account primarily the social factor, in recreational forests, the length of logging residues should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

On moist soils in Polytric and Stream-Grassy pine forests, we consider it appropriate to use the combined method: use one part of the logging residues to strengthen the portages, and the other to collect in heaps 0.5–1.0 m high and up to 1.0–1.5 m in diameter and leaving them for decay.

In Mossy, Pteridium, Oxalis and Murtillus pine forests, when applying a harvester and forwarder to the logging operations, it is recommended that the logging residues be laid evenly on the portages, followed by compaction.

In Mossy, Pteridium, Oxalis and Murtillus pine forests when using chainsaws for logging and MPT-461.1 for skidding, it is advisable to use several clearing methods: uniform laying of logging residues on portages with subsequent compaction; grinding and scattering of small logging residues in the cutting area; collection of felling wastes in heaps up to 1.0 m high and with a diameter up to 1.0–1.5 m and leaving them for decay.

In areas with low attendance by the population, after felling, it is allowed to leave large branches and tree tops on cutting areas in the amount of up to 5 m^3 per 1 ha without stacking in heaps.

In winter period, it is possible to collect part of large logging residues in heaps with a diameter of up to 2.0–2.5 m and a height of 1.0–1.5 m and their burning. In all areas of radioactive contamination, burning of logging residues is prohibited.

In the foci of pine stem pests, vascular and necrotic cancer diseases, included in the list of the main forest pests and diseases that can form foci, felling wastes must be burned.

The developed algorithm for choosing the option of handling pine logging residues during thinning and advance thinning is shown in Figure 1.

Corresponding algorithms for choosing the option for handling chopping residues during thinning and advance thinning are developed for the other main forest-forming species (spruce, oak, birch, aspen, black alder).

On fresh soils in Mossy, Pteridium and Oxalis spruce forests, when using a harvester and forwarder in logging operations, it is recommended that the logging residues be laid evenly on portages, followed by compaction. When using MPT–461.1 for skidding and chainsaws for logging, it is recommended that several methods of clearing be used on the cutting site: collecting one part of the logging residues in heaps up to 1.0 meter high and 1.0–1.5 meter in diameter and leaving them for decaying; uniform laying of part of felling wastes on portages with their subsequent compaction.

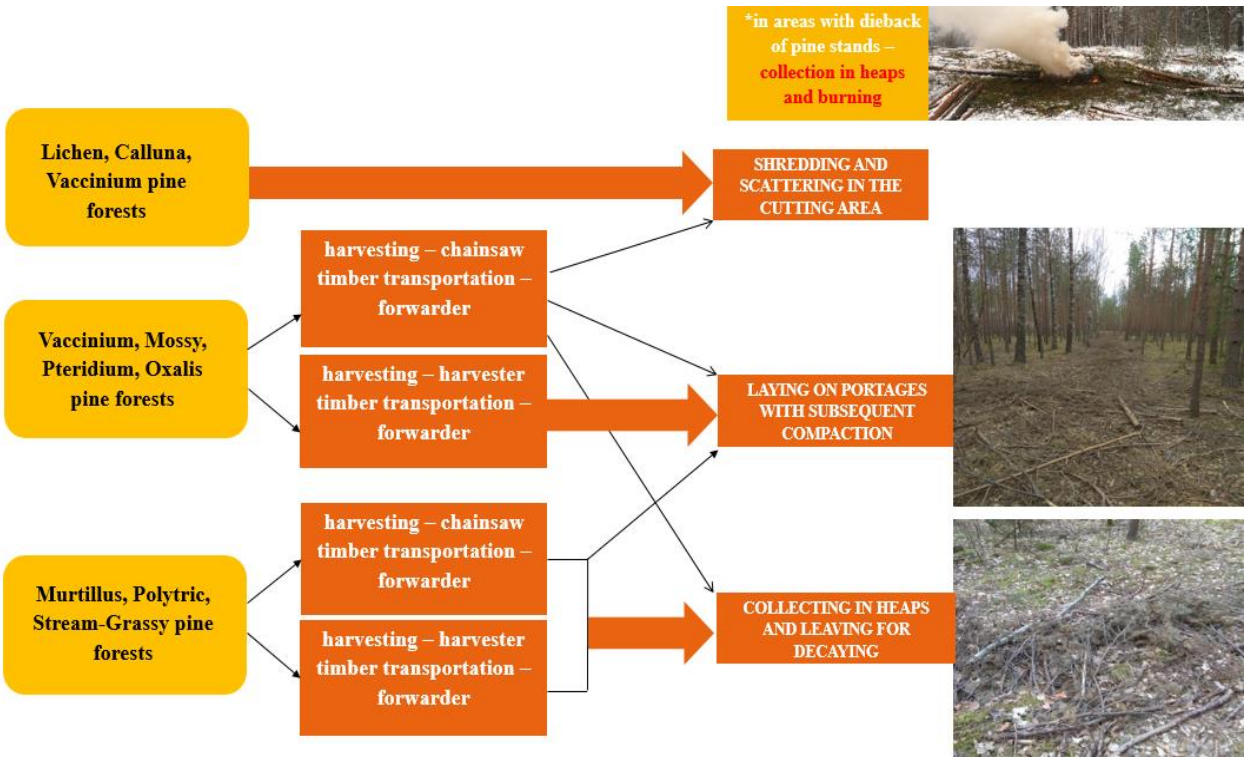


Figure 1 – Algorithm for choosing an option for handling felling wastes in pine stands after thinning and advance thinning

On moist soils in Murtillus, Aegopodium, Tracheophyta and Polytric spruce forests, it is recommended to use one part of the logging residues to strengthen the portages, and the other to collect in heaps 0.5–1.0 m high and up to 1.0–1.5 m in diameter and leaving them for decay.

In Oxalis, Pteridium, Aegopodium, Murtillus and Tracheophyta oak forests, when using chainsaws for logging and MPT-461.1 for skidding, it is advisable to use several clearing methods for thinning: uniform laying of logging residues on portages with subsequent compaction; collecting logging residues in heaps up to 1.0 meter high and 1.0–1.5 meter in diameter and leaving them for decay. When conducting advance thinning, it is necessary to collect felling wastes in heaps up to 1.0-meter-high and with a diameter up to 1.0–1.5 meter and leave them for decay.

On fresh sandy soils in Calluna and Vaccinium birch forests, regardless of the technology of wood harvesting, it is advisable to use chopping and scattering of felling wastes in the cutting area. At the same time, in recreational forests, the length of the felling wastes left should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

On moist soils in Murtillus, Tracheophyta, Polytric, Aegopodium and Stream-Grassy birch forests, it is recommended to use the combined method of clearing cutting areas: one part of the logging residues should be evenly laid on portages with their subsequent compaction, and the other for collection in heaps high 0.5-1.0 m and a diameter of 1.0-1.5 m and leaving them for decay.

When using in Calluna, Vaccinium, Mossy, Pteridium and Oxalis birch forests chainsaw for logging and MPT-461.1 for skidding, several clearing methods can be used on a line: collecting logging residues in heaps up to 1.0 meter high and up to 1.0–1.5 meters in diameter and leaving them for decaying; uniform laying of logging residues on portages, followed by their compaction; chopping and scattering of small logging residues on the cutting area.

In Pteridium, Oxalis, Aegopodium, Tracheophyta, Polytric, and Urtica aspen forests during thinning, the most suitable combined method of handling logging residues is: laying one part of the felling wastes evenly on portages, followed by compaction, the other part – crushing and scattering throughout the cutting area. In this case, the length of the felling residues left should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

When conducting advance thinning (the use of chainsaws for logging and MPT-461.1 for skidder), it is advisable to uniformly lay the logging residues on portages and then compact them.

On moist soils, which are characteristic of the location of black alder stands from an environmental point of view, it is advisable to carry out thinning and advance thinning with chopping and scattering of logging residues across the cutting area. This also corresponds to the forestry practices of industrialists in many forest enterprises of the Republic of Belarus at the present moment, which means that, in this way, the social factor will be taken into account.

The main results obtained by analyzing the comments received from forest fund holders, according to the developed guidance methodological document "The methodology of assessment of carbon sequestration by felling wastes in the process of inter-mediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)".

The guidance methodological document "The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)" passed the established procedure for approval preparation.

The prepared draft recommendations were sent to feedback to stakeholders. A total of 13 reviews were received from forest fund holders in the Republic of Belarus. Five reviews included comments and suggestions for improving the methodological document. According to the above comments and suggestions, the document was amended accordingly.

Thus, as a result of the research carried out in the framework of stage 6 of Activity 3.1.8:

- proposals were prepared on the handling of felling wastes and algorithms were developed for selecting an option for handling logging residues of the main forest-forming species (pine, spruce, oak, birch, aspen, black alder) when carrying out thinning and advance thinning, taking into account the type of care felling and technology for wood harvesting, forest conditions, forest category, requirements for the conservation of biological diversity, the size of annual carbon deposition by ground felling wastes, indicators of economic efficiency of different thinning modes.
- the guidance methodological document "The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)" was finalized in accordance with comments and suggestions from stakeholders.

In connection with the use of modern multioperation machines during intermediate cuttings, we recommend revising the "Guidelines for the organization and conducting of logging in the Republic of Belarus" (2006).

INTRODUCTION

Carbon dioxide is a dynamic component of the atmosphere, which is characterized by constant quantitative fluctuations under the influence of natural biogeochemical processes and human activity, primarily as a result of changes in land use (forestry, agriculture, transport, etc.). Carbon fluxes in ecosystems are closely related to the productivity and energy efficiency of ecosystems. At the beginning of 2019, the total area of forest land of the Republic of Belarus is 9598.5 thousand hectares [1]. At the same time, there is a gradual increase in the area of forest land and forest covered land, as well as the total stock of stands and the average stock of stands per hectare.

In the XXI century, in the Republic of Belarus, active work is being done to preserve and increase the carbon-sequestration ability of forests, including the development of new methodological and regulatory documents. Thus, the following recommendations were developed and widely applied: "Recommendations on maintaining a positive balance of stock and emission of carbon dioxide by Belarusian forests and using a forest carbon resource in organizing and managing forestry" (approved by the Ministry of Forestry of the Republic of Belarus on 04.06.2014) "Methodology for assessing the total and annual carbon sequestration by forests of the Republic of Belarus" (approved by the Ministry of Forestry of the Republic of Belarus on 03.03.2011), TCP 17.02-10-2012 (02120) "Environmental Protection and Environmental Management. The order of valuation of ecosystem services and valuation of biological diversity", etc. All of these documents are based on international documents and recommendations, including documents of the UNECE and others.

Annual sequestration of CO_2 by forest ecosystem of Belarus, as per different estimations, is equal to 10 and up to 23 million tons. However, it should be noted that the carbon balance of forests is not stable in the temporal aspect, which is associated with the dynamics of the stock of tree stands. Over the past decades, there has been a positive trend due to the predominance of middle-aged forests.

However, at present there are no data on carbon deposition of felling wastes after intermediate cuts (thinnings in the stands of 21–40 and 41–60 years) in the forests of Belarus, which are also part of the phytomass of the forest ecosystem, as well as their effect on the carbon sequestration capacity of forest stands. Therefore, as a part of the implementation of Project Activity 3.1.8: "Undertake monitoring and analysis of stands with and without project thinning and removal of felling waste interventions to assess Greenhouse Gas (GHG) emissions reductions" it is necessary to develop recommendations for the handling of felling residues during thinning and advance thinning.

- The objectives of the work at the current stage are:

Development of proposals with justification of social, ecological and economic aspects for removal / not removal of the felling wastes after thinning and advance thinning in order to stop decrease of carbon dioxide sequestration by the forest stands of the main forest species of the Republic of Belarus.

LIST OF MAIN TERMS AND DEFINITIONS

Tree stand – a set of trees, which are the main component of forest stand [2].

Total carbon sequestration – balance "absorption-emission" of carbon by forests, $_{T}C$ [3].

Clearing of cutting areas – the final logging operation to remove felling wastes from the cutting area or to bring them into a state that provides conditions for the renewal and growth of tree species, the prevention of fires and diseases [4].

Felling wastes – logging residues consisting of limbs, branches, needles, foliage, tops of trees, stumps, roots, parts of trunks formed during intermediate and final cuttings [5].

Thinning – care felling, carried out in order to create favorable conditions for the correct formation of the trunk and crown of the best trees (carrying out in pine, spruce and oak stands of 21–40 years, birch and black alder stands of 21–30 years, aspen stands of 11–20 years) [4, 6].

Advance thinning – care felling, carried out in order to create favorable conditions for increasing the growth of the best trees (carrying out in pine, spruce and oak stands of 41 and more years, birch and black alder stands of 31 and more years, aspen stands of 21 and more years) [4, 6].

Intermediate cuttings – care felling, selective sanitary felling, reconstruction cutting, cutting of other low-value stands, as well as re-novation cutting and re-formation cutting [2].

Liquid wood – a term used in the practice of forestry production, implying a combination of commercial wood and firewood.

Pine – Scots pine *(Pinus sylvestris)*
Spruce – European spruce (*Picea abies*)
Oak – English oak *(Quercus robur*)
Birch – European white birch *(Betula pendula*)
Aspen – European aspen (*Populus tremula)*
Black alder – European alder (*Alnus glutinosa*)

CO_2 – Carbon dioxide
C – Carbon
°C – degrees Celsius;
№ – number;
% – percent;
ha – hectare;
m^3/ha – cubic meter per hectare;
km – 10^3 m, kilometer;
m – meter;
kg – 10^3 g, kilogram;
t – the tonne, 1000 kg.

1 FACTORS INFLUENCING THE METHOD OF CLEARING CUTTING AREAS FROM FELLING WASTES

Clearing of logging sites from logging residues is carried out simultaneously with intermediate cuttings and (or) after its completion before the survey of cutting areas.

It is possible to use the following methods of clearing cutting areas from felling wastes during thinning and advance thinning:

- collection and removal of logging residues from the cutting area;
- collecting logging residues in heaps and burning;
- collecting in heaps and leaving for decay;
- laying of logging residues on portages with subsequent compaction;
- chopping and scattering throughout the cutting area.

The choice of a method for clearing cutting areas from logging residues in accordance with Chapter 9 of the Felling Rules in the Republic of Belarus [4] depends on the type of logging, the technology of logging, forest growing conditions (forest type), the category of forests and the requirements for preserving biological diversity.

The purpose of the implementation of Activity 3.1.8 BFDP / GEF / CQS / 16/29: "Undertake monitoring and analysis of stands with and without project thinning and removal of felling waste interventions to assess Greenhouse Gas (GHG) emissions reductions" is to determine the optimal thinning and advance thinning mode (without thinning; thinning with leaving felling wastes; thinning with removal of felling wastes) and the optimal amount of felling wastes left after intermediate cuts in the stands of the main tree species (pine, spruce, oak, birch, black alder, aspen). At the same time, the optimal mode is understood as the regime of thinning and the amount of logging residues under which maximum carbon accumulation by the forest ecosystem will be ensured, on the one hand, and the proper sanitary and forest stands pathological state, as well as the satisfaction of economic interests in terms of the use of harvested logging liquid wood and logging residues – on the other hand.

When carrying out care cuttings, the carbon sequestration capacity of forest stands naturally decreases due to the removal of part of the stem wood. Branches are the only type of logging residues whose handling affects carbon conservation in the forest ecosystem. The carbon deposition by roots, needles and foliage is the same for all variants of handling logging residues [8]. The decrease in the carbon sequestration capacity of the stands during thinning and advance thinning depends on the prevailing tree species and the chosen method of handling felling wastes.

Therefore, in order to ensure maximum carbon accumulation in the forest ecosystem at the sites of intermediate cuttings (thinning and advance thinning), additionally, when choosing a method for clearing cutting areas from felling wastes, it is necessary to take into account the annual deposition of carbon by ground logging residues, indicators of economic efficiency of different thinning regimes in the stands of the main tree species, taking into account the environmental and social consequences of the utilization of felling wastes' biomass.

The average annual carbon deposition by ground felling wastes is shown in Figure 1.1.

When *thinning* is carried out, logging residues of birch have the greatest average annual carbon sequestration capacity when they are collected in heaps and left for decaying (1.28 tC / ha per year), and smallest – logging residues of black alder when laid on portages with subsequent compaction by forestry equipment (0.33 tC / ha per year).

When *thinning* is carried out, the highest average (over the rotation period) carbon content is observed in birch logging residues when they are collected in piles or shafts and left to decay (1.28 tC / ha); the smallest content – logging residues of black alder when laid on portages with subsequent compaction by forestry equipment (0.33 tC / ha per year).

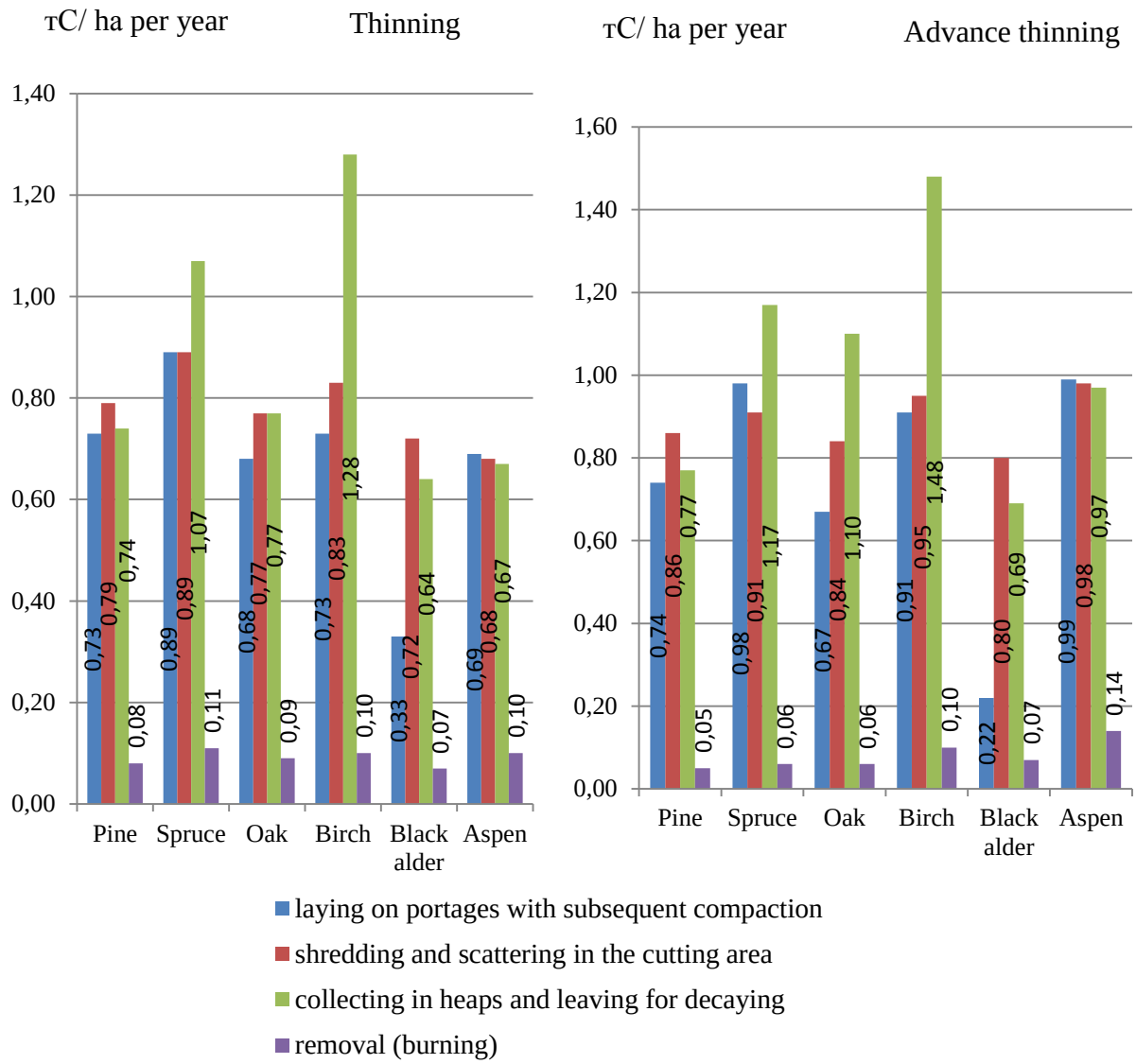


Figure 1.1 – Average annual carbon sequestration by ground felling wastes after thinning and advance thinning in the forests of the Ministry of Forestry of the Republic of Belarus, tC / ha

A similar pattern is also characteristic of *advance thinning*. The highest average annual accumulation of carbon by birch felling wastes when collected in piles and left for decaying is 1.48 tC / ha per year, the smallest average annual accumulation of carbon by felling wastes of black alder when laid on portages with subsequent compaction is 0,22 tC / ha per year. The average annual accumulation of carbon by logging residues during their removal (burning) is extremely small and is in the range of 0.05–0.14 tC / ha per year, depending on the tree species and type of logging.

When choosing a method of handling logging residues, it is also necessary to take into account the results of a sociological survey of the population visiting forest lands. Table 1.1 shows the results of our research on the most preferred methods for utilizing felling wastes after logging, depending on the place of residence and the method of handling logging residues. A sociological study was conducted independently and on a voluntary basis. Residents of various settlements were asked to choose one of four options for handling logging residues after logging.

Table 1.1 – The results of a sociological survey, % of all respondents

Place of residence	The method of handling felling wastes			
	collecting in heaps and leaving for decaying	shredding and scattering in the cutting area	burning	removal from the cutting area and processing
village	–	20,0	–	80,0
agro-town	12,5	25,0	12,5	50,0
urban village	37,5	–	25,0	37,5
city of district subordination	21,5	10,5	5,2	63,2
city of regional subordination	67,0	–	–	33,0
capital	25,0	25,0	–	50,0
average value	21,2	13,5	7,7	57,7

The majority of the surveyed population (57.7%), regardless of their place of residence, considers it most appropriate to collect and remove logging residues from the cutting area, and subsequently process them to wood chips.

This opinion of residents of the capital and cities is due to the fact that they most often visit forest stands near settlements (recreational forests) for rest and harvesting non-timber forest products.

At the same time, the villagers explain the need for removal of logging residues from the cutting area due to the limited mobility of trees because of the remaining twigs and branches after felling during the collection and harvesting of wild berries and mushrooms, medicinal raw materials.

Also, residents of small settlements (village, agro-town) suggested allowing them to collect branches for their own needs, in particular for use as fuel.

Among the surveyed population, 21.2% support the collection of logging residues into small heaps and leaving them in the forest for decay, and 13.5% support chopping felling wastes and scattering them in the forest.

According to the population, this method of clearing the cutting areas will not significantly hinder movement in the forest, and decaying residues that have decayed over time will increase soil fertility, which will favorably affect the increase in stocks of berries and mushrooms in the forest stand.

In 7.7% of cases, residents of agro-towns, urban-type towns, and cities of district subordination favored burning logging residues in the cutting area, which was associated with the prevention of stem pest reproduction. However, it should be noted that this was the population of the southern regions of the republic, where in recent years there has been a massive drying out of pine stands, which is widely covered in local and republican media.

According to the Ministry of Forestry in 2018, about 2 million cubic meters of wood chips were exported. The price of this type of timber for export amounted to 51,03 BYN (at about 21,34 euros). The cost of production and shipment for export (shipping to wagons, transport charges, etc.) amounted to 44,78 BYN (at about 18,73 euros). Profitability was 14%.

The price of chips from barked wood today in the foreign market varies from 220 to 300 euros per cubic meter.

The average price of wood chips in the domestic market was 28,60 BYN (at about 11,96 euros). The average cost of chip production was 27,80 BYN (at about 11,63 euros). Profitability

was 2.8%. It should be noted that we are talking about wood chips, produced primarily from wood.

The cost of production of wood chips from **felling wastes in the areas of intermediate cutting** is on average about 34,00 BYN (at about 14,22 euros), according to our estimates. In addition, it is necessary to take into account such a factor as the remnants of wood in the forests of the republic in the amount of 1.7 million cubic meters.

Thus, at the current price of wood chips 28,80 BYN (at about 12,05 euros) the production of wood chips from logging residues in the areas of intermediate cuts **is not economically feasible and the loss ratio is 18%.**

2 PROPOSALS FOR PINE STANDS FOR CHOOSING THE OPTION OF HANDLING LOGGING RESIDUES DURING THINNING AND ADVANCE THINNING

The area of pine forests of the Ministry of Forestry as of 01.01.2019 is 3 671 939 ha [1]. During field forest inventory work, forest types that correspond to fifth and lower bonitet classes are excluded from the design of intermediate cuttings. The typological structure of pine forests, where intermediate cuttings are possible, is presented in Figure 2.1.

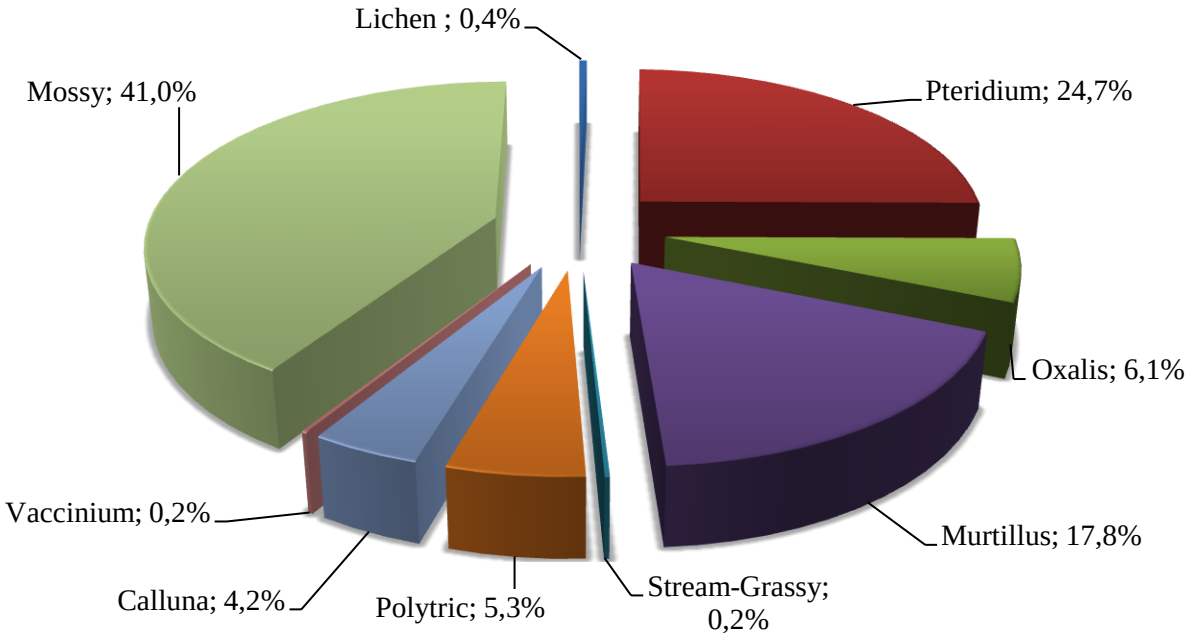


Figure 2.1 – Typological structure of pine forests, where intermediate cuttings are possible

The predominant types of forests are Mossy (41.0%), Pteridium (24.7%) and Murtillus (17.8%) pine forests.

We determined the carbon reserves for the stands of the main forest-forming species for the forests of the Ministry of Forestry, taking into account their average taxation indicators for the age periods corresponding to the ages of thinning and advance thinning. Therefore, the report in Figures 2.1, 2.4, 2.7, 2.10, 2.13 and 2.16 presents the typological structure of the main forest-forming stands **for the Ministry of Forestry only** (based on the data of the State Forest Cadaster of the Republic of Belarus as of 01.01.2019).

The type of forest is an important forest taxation indicator, which is determined by soil-hydrological and climatic conditions. The zonal expression of the geomorphological and soil-climatic conditions of Belarus affected the composition of forest vegetation, which also has a zonal character. In the direction from north to south, there is a change of oak-dark coniferous forests with deciduous. On the territory of the country passes the northern border of the range of the hornbeam. The strip between the northern border of the continuous distribution of the common hornbeam and the southern border of the continuous distribution of European spruce is the territory where the forests of the East European type are replaced by the forests of the West European type, which gave rise to the Belarusian geobotany to divide the territory of Belarus into three geobotanical subzones: the subzone of oak-dark coniferous forests subzone of hornbeam-oak-dark coniferous forests and subzone of broad-leaved-pine forests. The boundaries of the selected geobotanical subzones almost coincide with the boundaries of agroclimatic regions and with the soil and climatic zoning of the country.

Subzones are subdivided into geobotanical districts (allocated 7), which in turn are divided into geobotanical areas (allocated 25). Geobotanical subzones are determined by the latitudi-

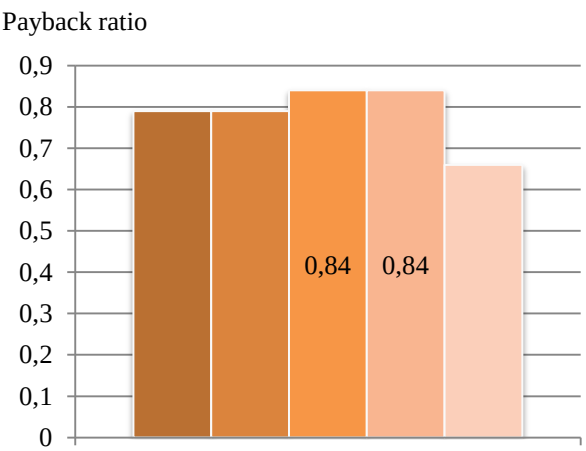
nal and climatic zonality of the vegetation cover. Within the subzones, the orographic, edaphic, and longitudinal-climatic features of individual territories, which determine intrazonal differences in the composition of forests, reflect geobotanical districts. The main taxonomic unit of geobotanical zoning is a geobotanical region, covering a certain complex of forests. The boundaries of the districts are determined by phytocenotic features, among which the leading is the typological structure of forests.

Therefore, it is desirable to represent the geographical distribution of various types of forests taking into account geobotanical zoning.

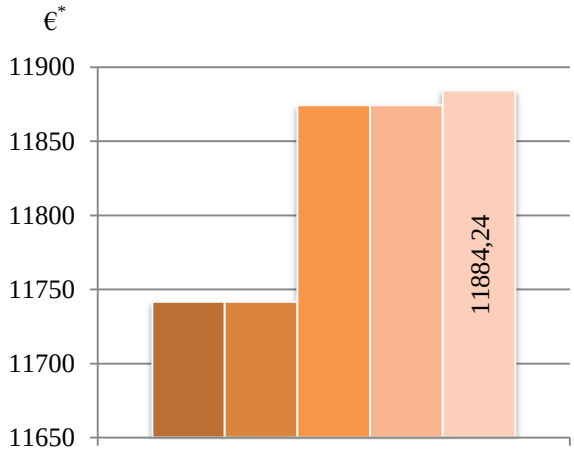
In the practice of accounting for the forest fund of the republic, the territorial principle is used (accounting is done for administrative regions and forest fund holders). Therefore, studies taking into account geobotanical zoning according to the characteristics of the pine formation are given as of 01.01.2009 in the monograph "Gradual logging in the pine forests of Belarus", BSTU, Minsk, 2013 (authors Labokha K.V., Shiman D.V.). Table 2.8 of the monograph (pp. 44–45) shows the distribution of Belarusian pine forests by forest type. Studies on the typological structure of the main forest-forming tree species (spruce, oak, birch, black alder, aspen) have not been conducted in the republic over the past decade.

To determine the most optimal way of utilizing logging residues in pine forests in order to reduce GHG emissions and enhance the carbon sequestration capacity of forests, it is necessary to take into account the type of logging and its economic efficiency indicators, forest category, forest growing conditions, timber harvesting technology and requirements for the conservation of biological diversity.

Figure 2.2 shows the indicators of economic efficiency of thinning and advance thinning in pine stands, depending on the method of handling logging residues ***(the methodology and calculations are given in the report of 4 stage [7])***.



Payback of thinning with various methods of handling felling wastes



Valuation of accumulated CO2 by stands for the rotation period of thinning

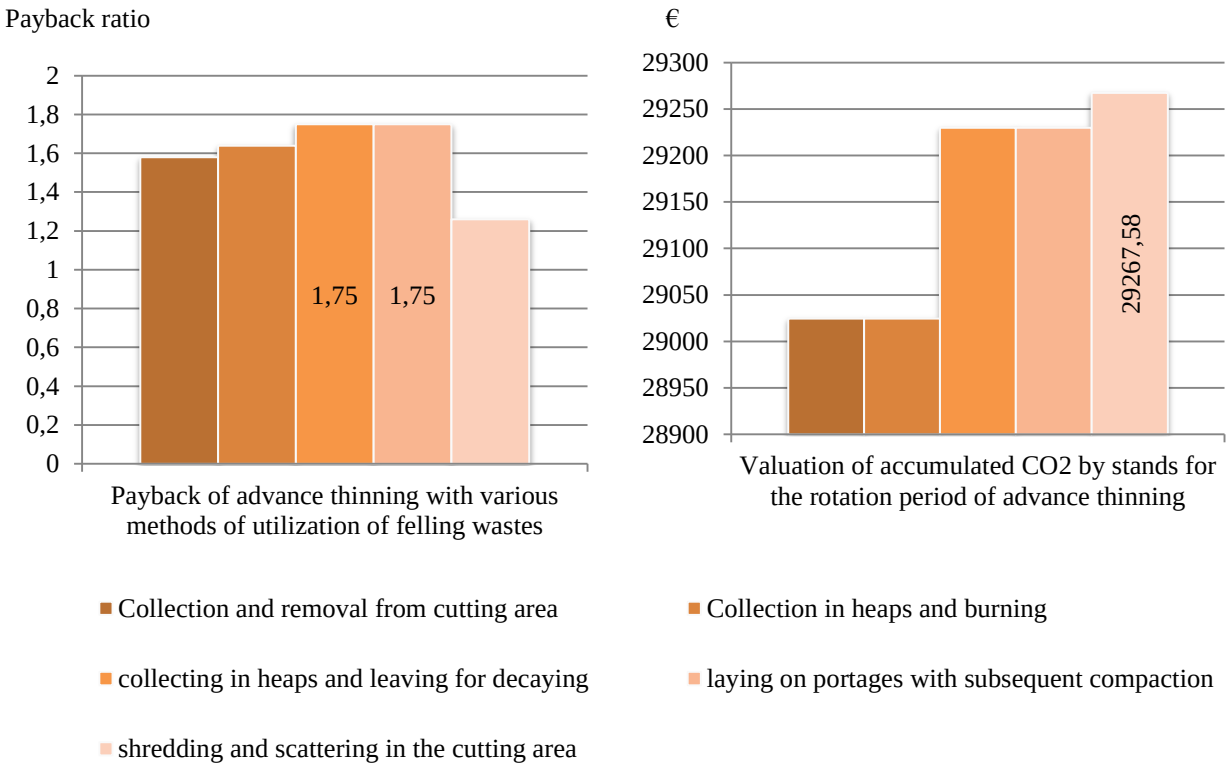


Figure 2.2 – Indicators of economic evaluation of the appropriateness of using felling wastes in pine stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The payback of *thinning* in pine forests with various methods of utilization of felling wastes is as follows:

- when collecting and removal of logging residues from the cutting area: 0.79;
- when collecting logging residues in heaps and burning: 0.79;
- when collecting in heaps and leaving for decaying or laying on portages with subsequent compaction: 0.84;
- when chopping and scattering in the cutting area: 0.66.

The payback of *advance thinning* in pine forests is:

- when collecting and removal of logging residues from the cutting area: 1.58;
- when collecting logging residues in heaps and burning: 1.64;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 1.75;
- when chopping and scattering in the cutting area: 1.26.

The results of our research show that in pine stands it is most expedient to carry out felling with the collecting of logging residues in piles and leave them for decaying or laying on portages with subsequent compaction: the payback ratio for thinning is 0.84, for advance thinning – 1.75.

But in order to obtain the maximum additional income from the sale of emission reduction units (ERU GHG), it is advisable to carry out felling in pine stands, followed by chopping and scattering felling wastes along the cutting areas.

Although the other methods for clearing cutting areas (collecting logging residues in piles and leaving them to decay or laying on portages with subsequent compaction) also will allow the carbon sequestration capacity of logging residues to remain as long as possible.

At the same time, it is advisable, when carrying out intermediate cuttings in pine stands, to leave the biomass of logging residues at the places of logging in order to increase soil fertility and preserve biological diversity [10–14].

The selection algorithm for handling pine felling wastes during thinning and advance thinning is shown in Figure 2.3.

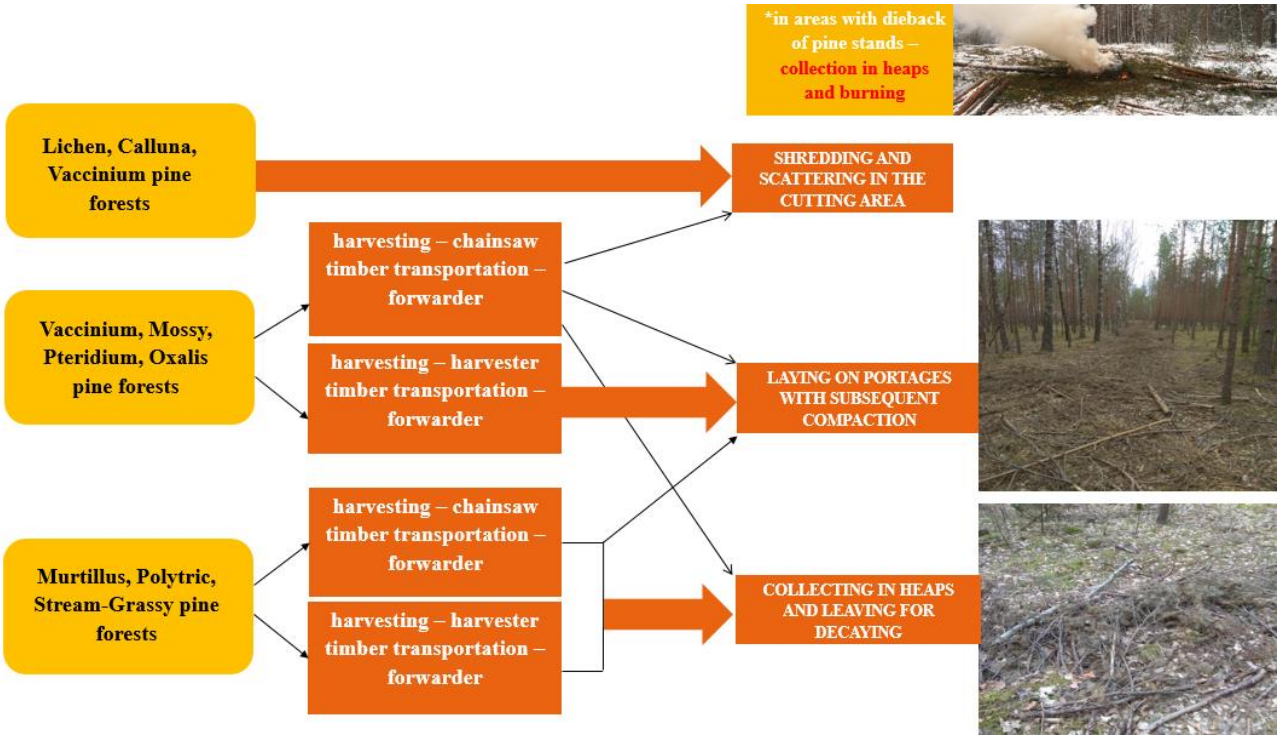


Figure 2.3 – Algorithm for choosing an option for handling felling wastes in pine stands after thinning and advance thinning

The results of our studies show that regardless of the technology of harvesting wood in pine stands on dry and fresh sandy soils in pine forests of Lichen, Calluna and Vaccinium, it is most expedient to chop and spread logging residues in the cutting area. Moreover, taking into account primarily the social factor, in recreational forests, the length of logging residues should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

On moist soils in Polytric and Stream-Grassy pine forests, we consider it appropriate to use the combined method: use one part of the logging residues to strengthen the portages, and the other to collect in heaps 0.5–1.0 m high and up to 1.0–1.5 m in diameter and leaving them for decay.

In Mossy, Pteridium, Oxalis and Murtillus pine forests, when applying a harvester and forwarder to the logging operations, it is recommended that the logging residues be laid evenly on the portages, followed by compaction.

In Mossy, Pteridium, Oxalis and Murtillus pine forests when using chainsaws for logging and MPT-461.1 for skidding, it is advisable to use several clearing methods: uniform laying of logging residues on portages with subsequent compaction; grinding and scattering of small logging residues in the cutting area; collection of felling wastes in heaps up to 1.0 m high and with a diameter up to 1.0–1.5 m and leaving them for decay.

In areas with low attendance by the population, after felling, it is allowed to leave large branches and tree tops on cutting areas in the amount of up to 5 m^3 per 1 ha without stacking in heaps.

In winter, it is possible to collect part of the large logging residues in heaps with a diameter of up to 2.0–2.5 meters and a height of up to 1.0–1.5 meters with subsequent burning. In all areas of radioactive contamination, burning of logging residues is prohibited.

In accordance with paragraph 45 of the Sanitary Rules in the forests of the Republic of Belarus [9] care felling is primarily carried out in forest stands with impaired stability. When intermediate cuts, it is mandatory to cut down trees populated by stem pests, affected by diseases, drying out and shrinking trees.

According to paragraph 47 of the Sanitary Rules [9], in foci of pine stem pests, vascular and necrotic cancer diseases included in the list of main forest pests and diseases that can form foci, felling wastes are subject to mandatory burning.

3 PROPOSALS FOR SPRUCE STANDS ON THE CHOICE OF A METHOD FOR CLEARING CUTTING AREAS DURING THINNING AND ADVANCE THINNING

The area of spruce forests of the Ministry of Forestry as of 01.01.2019 is 720,700 ha. The typological structure of spruce forests where intermediate cuttings are possible is presented in Figure 2.4.

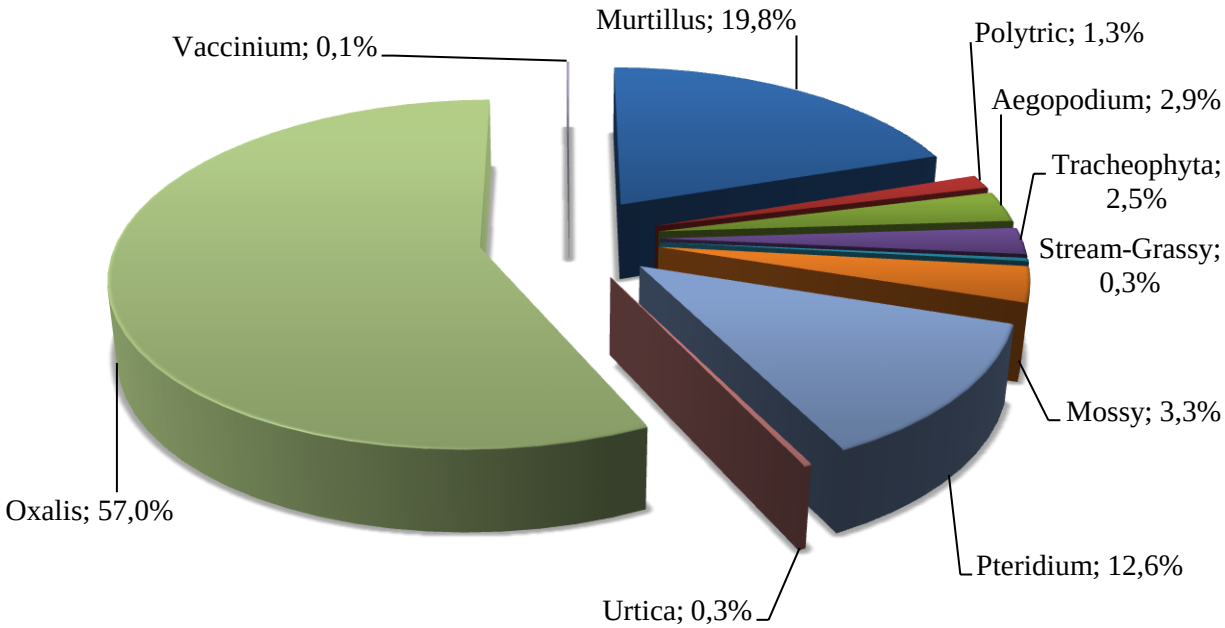


Figure 2.4 – Typological structure of spruce forests, where intermediate cuttings are possible

The predominant types of forests are Oxalis (57.0%), Murtillus (19.8%) and Pteridium (12.6%) spruce forests.

Figure 2.5 shows the indicators of economic efficiency of thinning and advance thinning in spruce stands, depending on the method of handling logging residues.

The payback of *thinning* in spruce forests with various methods of utilization of logging residues is as follows:

- when collecting and removal of logging residues from the cutting area: 0.51;
- when collecting logging residues in heaps and burning: 0.50;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 0.51;
- when chopping and scattering in the cutting area: 0.46.

The payback of *advance thinning* is:

- when collecting and removal of logging residues from the cutting area: 1.03;
- when collecting logging residues in heaps and burning: 1.08;
- when collecting in heaps and leaving for decaying or laying on portages with subsequent compaction: 1.15;
- when chopping and scattering in the cutting area: 0.92.

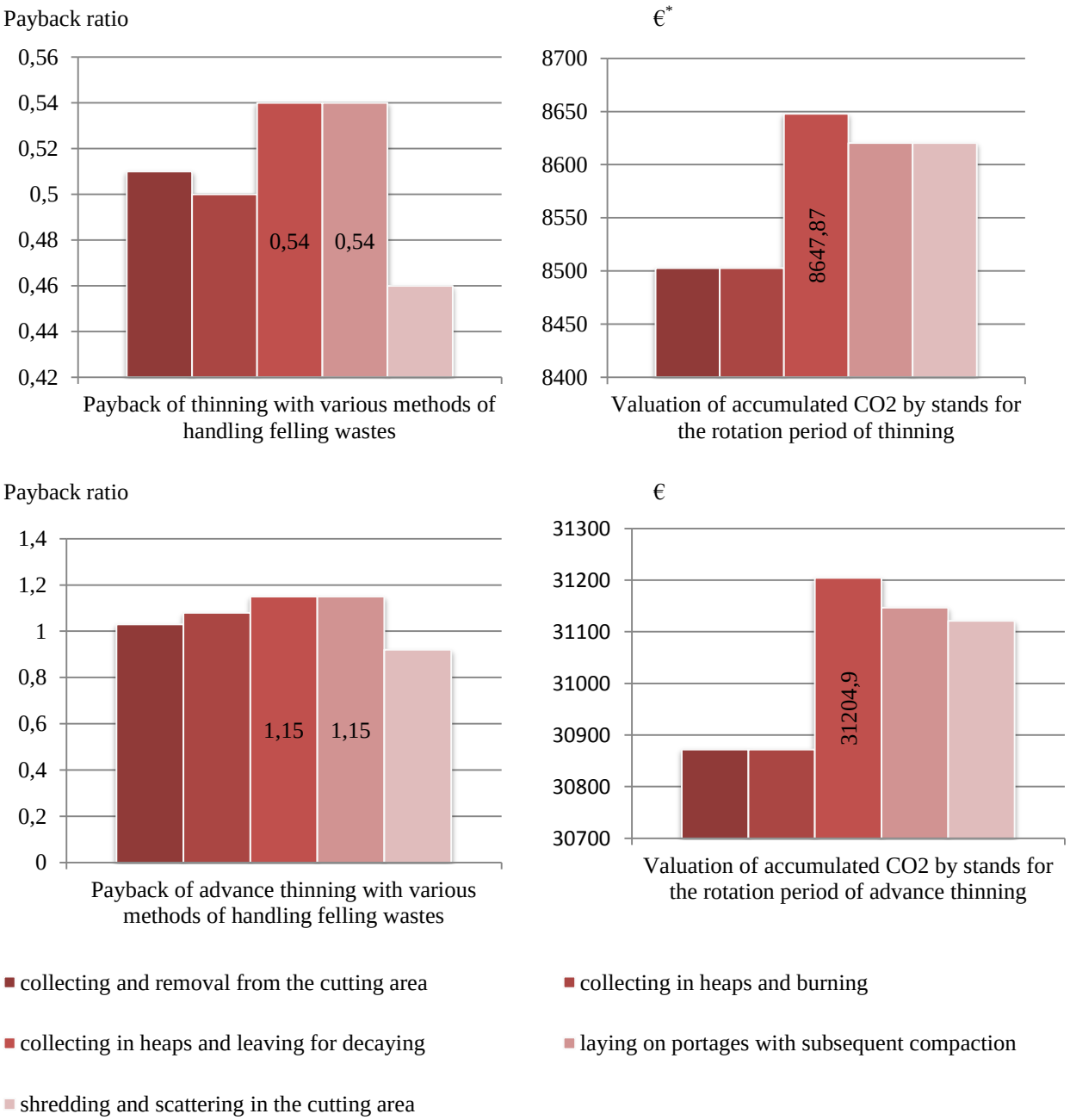


Figure 2.5 – Indicators of economic evaluation of the appropriateness of using felling wastes in spruce stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The highest payback ratio for thinning is 0.54, for advance thinning – 1.15 when cutting with the collecting of logging residues in piles and left for decaying or laying on portages with subsequent compaction. Thinning in spruce stands as well as advance thinning with chopping up of felling wastes and scattering in the cutting area do not pay off.

The highest cost of CO_2 accumulated by the forest stand during the thinning rotation period is 8,647.87 €, on average for a year – 1,441.31 € for collecting felling wastes in piles and leaving for decay, during advance thinning – 31,204.90 and 2,600.41 € respectively.

The algorithm for choosing the option of handling felling wastes in spruce stands during thinning and advance thinning is shown in Figure 2.6.

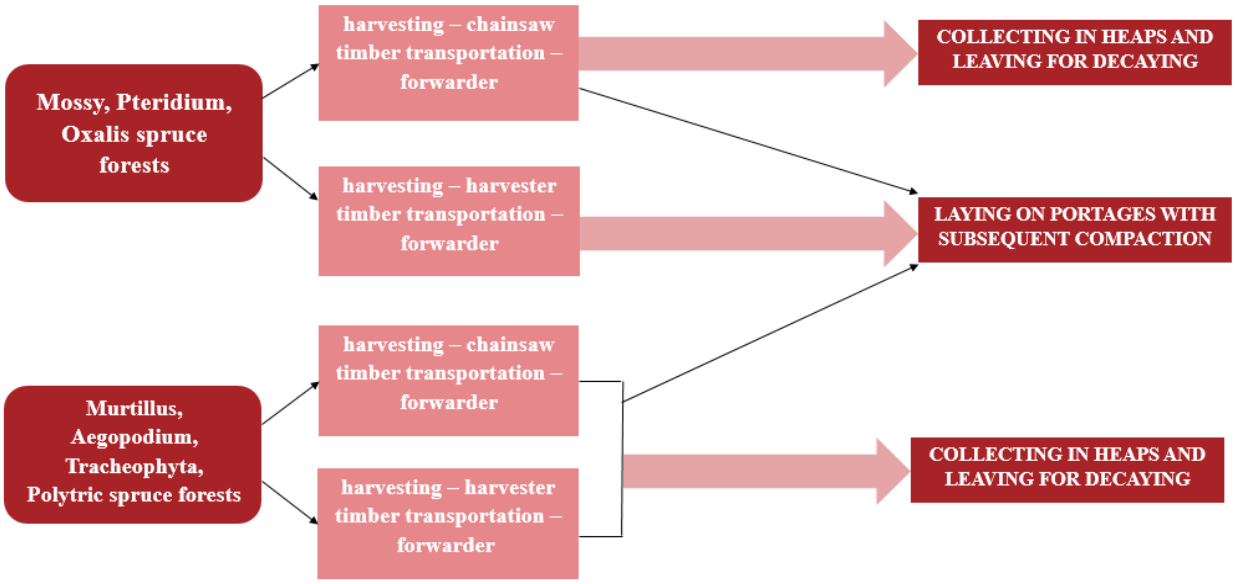


Figure 2.6 – Algorithm for choosing an option for handling felling wastes in spruce stands after thinning and advance thinning

On fresh soils in Mossy, Pteridium and Oxalis spruce forests, when using a harvester and forwarder in logging operations, it is recommended that the logging residues be laid evenly on portages, followed by compaction. When using MPT-461.1 for skidding and chainsaws for logging, it is recommended that several methods of clearing be used on the cutting site: collecting one part of the logging residues in heaps up to 1.0 meter high and 1.0–1.5 meter in diameter and leaving them for decaying; uniform laying of part of felling wastes on portages with their subsequent compaction.

On moist soils in Murtillus, Aegopodium, Tracheophyta and Polytric spruce forests, it is recommended to use one part of the logging residues to strengthen the portages, and the other to collect in heaps 0.5–1.0 m high and up to 1.0–1.5 m in diameter and leaving them for decay.

4 PROPOSALS FOR OAK STANDS FOR CHOOSING THE METHOD OF UTILIZATION OF FELLING WASTES DURING THINNING AND ADVANCE THINNING

The area of oak forests of the Ministry of Forestry as of 01.01.2019 is 254,379 ha. The typological structure of oak forests, where intermediate cuttings are possible, is presented in Figure 2.7.

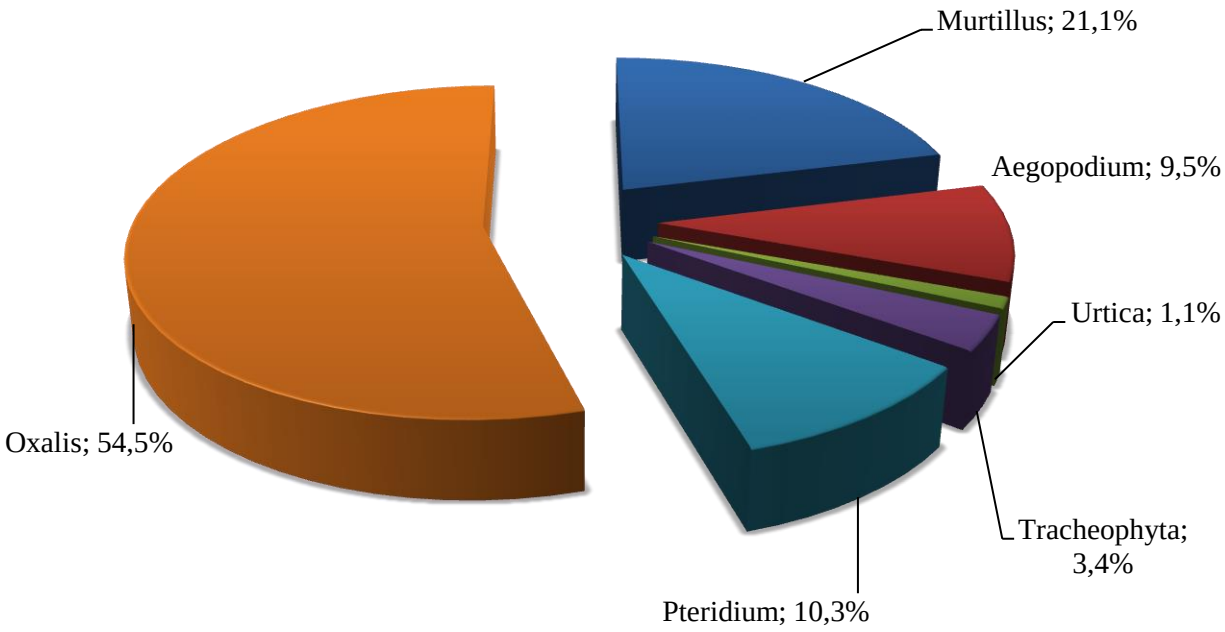


Figure 2.7 – Typological structure of oak forests, where intermediate cuttings are possible

The predominant types of forests are Oxalis (54.5%), Murtillus (21.1%) and Pteridium (10.3%) oak forests.

Figure 2.8 shows the indicators of economic efficiency of thinning and advance thinning in oak stands, depending on the method of handling logging residues.

The payback of *thinning* in oak stands with various methods of disposal of logging residues is as follows:

- when collecting and removal of logging residues from the cutting area: 0.42;
- when collecting logging residues in heaps and burning: 0.42;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 0.44;
- when chopping and scattering in the cutting area: 0.36.

The payback of *advance thinning* is:

- when collecting and removal of logging residues from the cutting area: 1.15;
- when collecting logging residues in heaps and burning: 1.18;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 1.27;
- when chopping and scattering in the cutting area: 0.93.

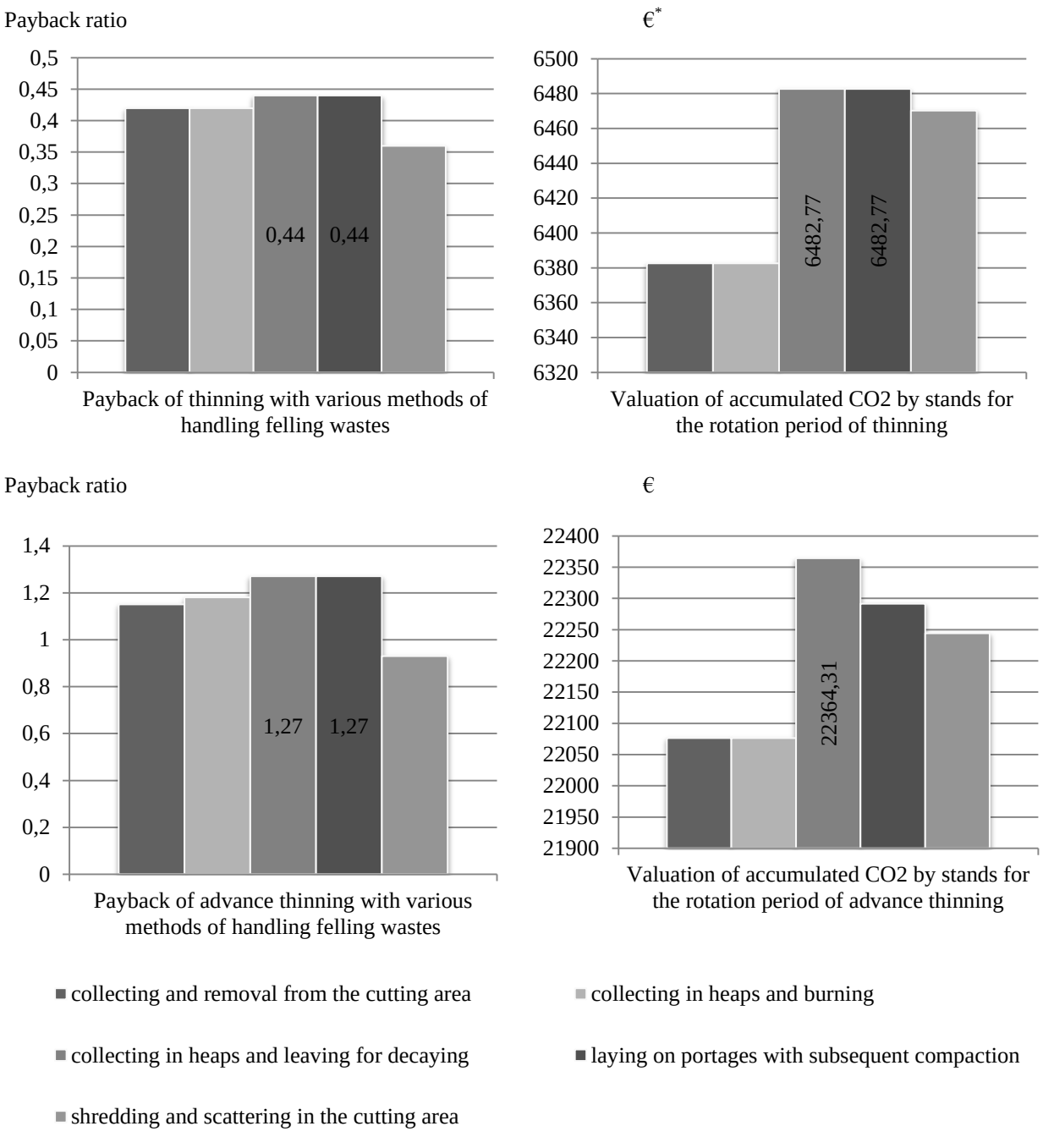


Figure 2.8 – Indicators of economic evaluation of the appropriateness of using felling wastes in oak stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The highest payback ratio for thinning is 0.44, for advance thinning – 1.27 when cutting with the collecting of logging residues in piles and left for decaying or laying on portages with subsequent compaction. Thinning in oak stands and advance thinning with shredding of logging residues and scattering in the cutting area do not pay off.

The highest cost of accumulated CO_2 by forest stand over the thinning period is 6,382.77 €, on average per year – 1,080.46 € when collecting logging residues in piles and leaving for decaying or laying on portages with subsequent compaction, during advance thinning –

22,364.31 and 2,033.12 € for the collecting of logging residues in piles and left for decay.

Thus, in order to obtain the maximum additional income from the sale of emission reduction units (ERU GHG) in oak stands, it is advisable to carry out thinning with the collecting of logging residues in piles and leaving them to be rotted or laid on portages with subsequent compaction, and advance thinning – ***with the collecting of logging residues in piles and leaving them to decay.***

The algorithm for choosing the option of handling felling wastes in oak stands during thinning and advance thinning is shown in Figure 2.9.

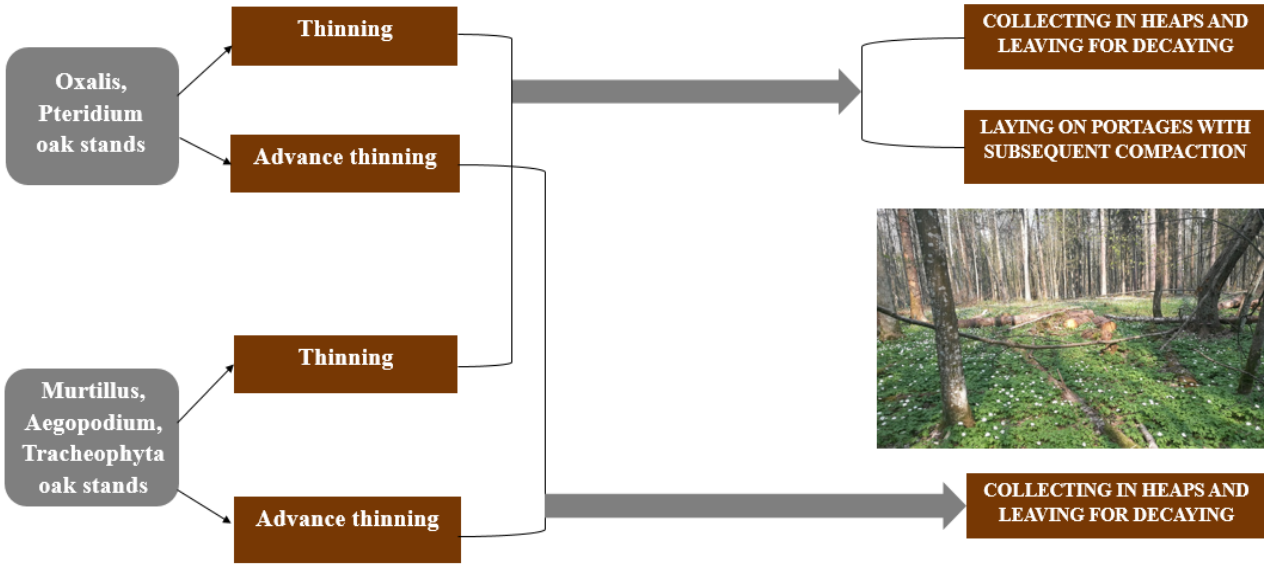


Figure 2.9 – Algorithm for choosing an option for handling felling wastes in oak stands after thinning and advance thinning

In Oxalis, Pteridium, Aegopodium, Murtillus and Tracheophyta oak forests, when using chainsaws for logging and MPT-461.1 for skidding, it is advisable to use several clearing methods for thinning: uniform laying of logging residues on portages with subsequent compaction; collecting logging residues in heaps up to 1.0 meter high and 1.0–1.5 meter in diameter and leaving them for decay. When conducting advance thinning, it is necessary to collect felling wastes in heaps up to 1.0-meter-high and with a diameter up to 1.0–1.5 meter and leave them for decay.

5 PROPOSALS FOR BIRCH STANDS TO CHOOSE A METHOD FOR CLEARING CUTTING AREAS DURING THINNING AND ADVANCE THINNING

The area of birch forests of the Ministry of Forestry as of 01.01.2019 is 1,682.271 ha. The typological structure of birch forests, where intermediate cuttings are possible, is presented in Figure 2.10.

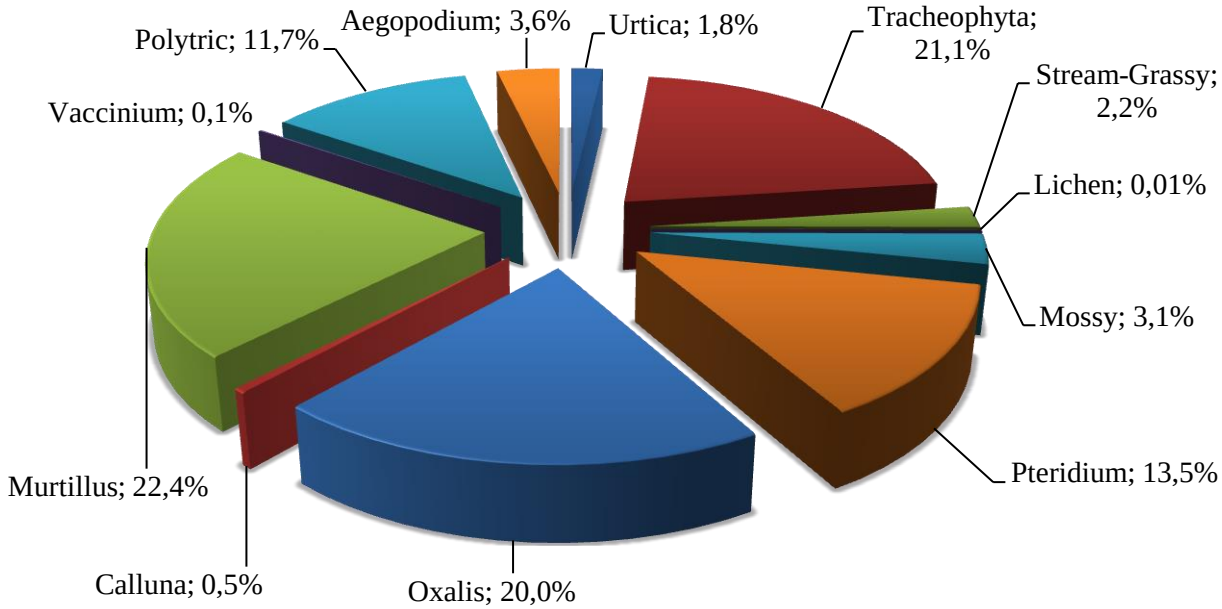


Figure 2.10 – Typological structure of birch forests, where intermediate cuttings are possible

The predominant types of forests are Murtillus (22.4%), Tracheophyta (21.1%), Oxalis (20.0%) and Pteridium (13.5%) birch forests.

Figure 2.11 shows the indicators of economic efficiency of thinning and advance thinning in birch stands, depending on the method of handling felling wastes.

The payback of *thinning* in birch stands with various methods of utilization of logging residues is as follows:

- when collecting and removal of logging residues from the cutting area: 0.51;
- when collecting logging residues in heaps and burning: 0.50;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 0.53;
- when chopping and scattering in the cutting area: 0.49.

The payback of *advance thinning* is:

- when collecting and removal of logging residues from the cutting area: 0.86;
- when collecting logging residues in heaps and burning: 0.87;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 0.93;
- when chopping and scattering in the cutting area: 0.72.

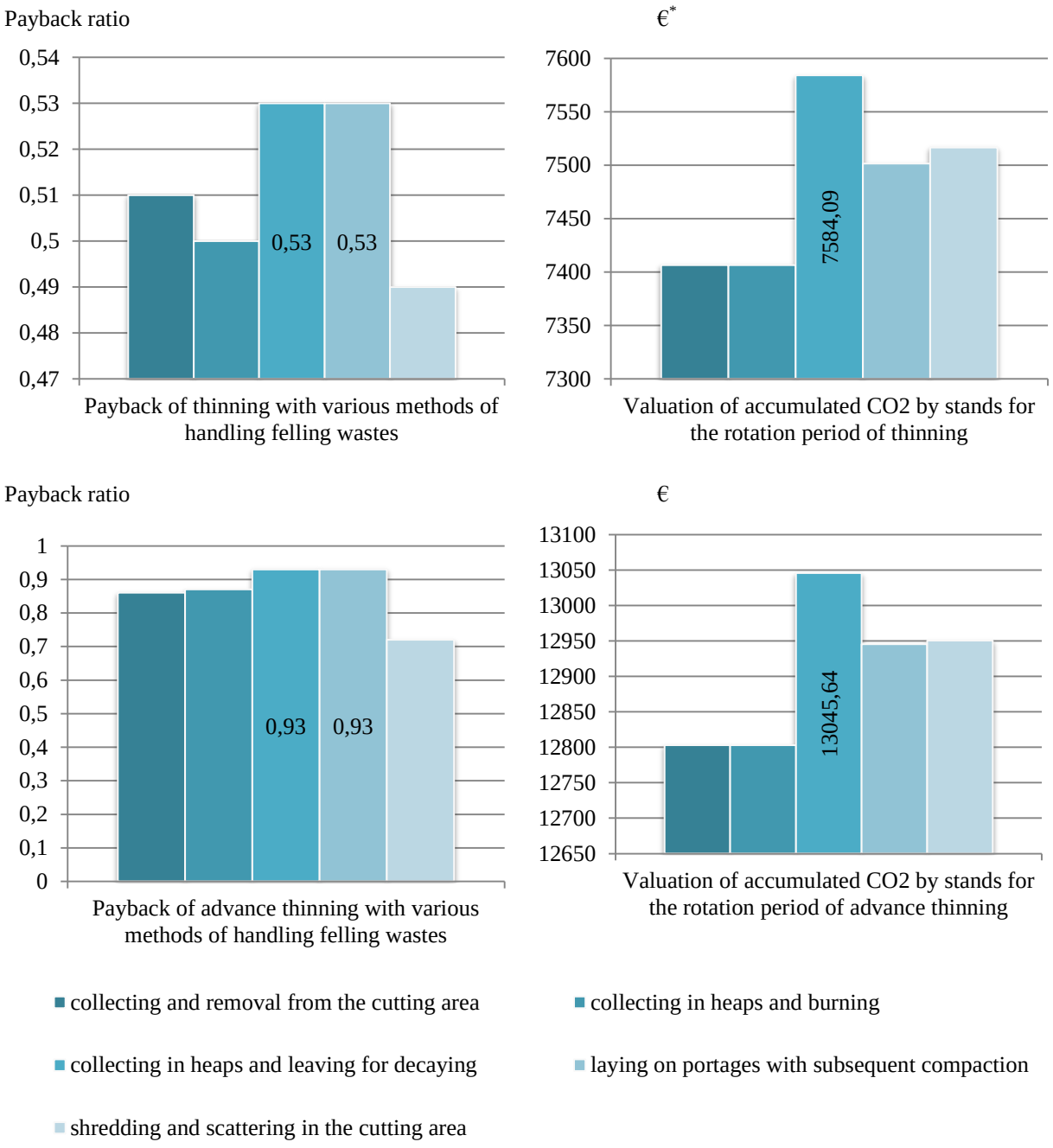


Figure 2.11 – Indicators of economic evaluation of the appropriateness of using felling wastes in birch stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The highest payback ratio for thinning is 0.53, for advance thinning – 0.93 when cutting with the collecting of logging residues in piles and left for decaying or laying on portages with subsequent compaction. In general, in birch stands, due to the large yield of low-cost wood, thinning and advance thinning do not pay off.

The highest cost of CO_2 accumulated by the stand over the thinning rotation period is 7,584.09 €, on average for a year – 1,264.02 €, for advance thinning – 1,3045.64 and 1,863.66 € when collecting felling wastes in heaps and leaving them for decaying.

Thus, in order to obtain the maximum additional income from the sale of emission reduction units (ERU GHG) in birch stands, it is advisable to carry out thinning and advance thinning with ***the collecting of logging residues in heaps and leaving them for decay.***

The algorithm for choosing the option of handling felling wastes in birch stands during thinning and advance thinning is shown in Figure 2.12.

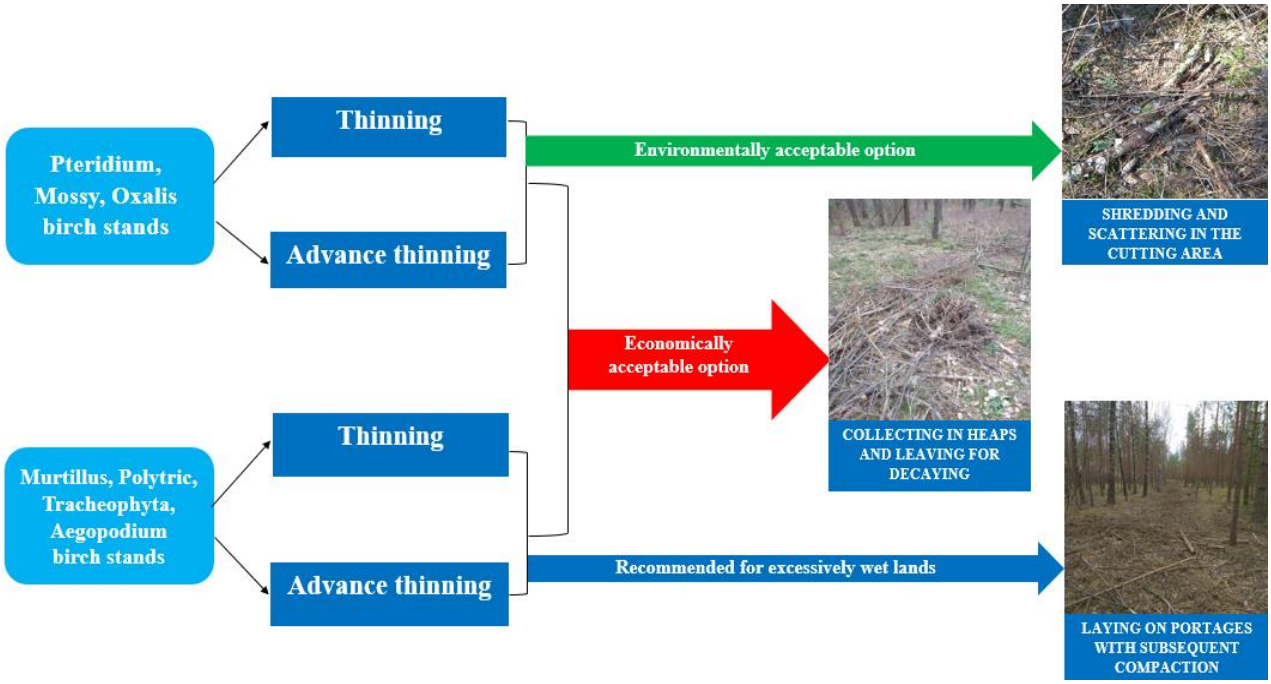


Figure 2.12 – Algorithm for choosing an option for handling felling wastes in birch stands after thinning and advance thinning

On fresh sandy soils in Calluna and Vaccinium birch forests, regardless of the technology of wood harvesting, it is advisable to use chopping and scattering of felling wastes in the cutting area. At the same time, in recreational forests, the length of the felling wastes left should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

On moist soils in Murtillus, Tracheophyta, Polytric, Aegopodium and Stream-Grassy birch forests, it is recommended to use the combined method of clearing cutting areas: one part of the logging residues should be evenly laid on portages with their subsequent compaction, and the other for collection in heaps high 0.5-1.0 m and a diameter of 1.0-1.5 m and leaving them for decay.

When using in Calluna, Vaccinium, Mossy, Pteridium and Oxalis birch forests chainsaw for logging and MPT-461.1 for skidding, several clearing methods can be used on a line: collecting logging residues in heaps up to 1.0 meter high and up to 1.0–1.5 meters in diameter and leaving them for decaying; uniform laying of logging residues on portages, followed by their compaction; chopping and scattering of small logging residues on the cutting area.

This corresponds to the current forestry practice of forest management in many forest enterprises of the Republic of Belarus.

6 PROPOSALS FOR ASPEN STANDS FOR THE SELECTION OF A METHOD FOR UTILIZING FELLING WASTES DURING THINNING AND ADVANCE THINNING

The area of aspen forests of the Ministry of Forestry as of 01.01.2019 is 174 102 ha. The typological structure of aspen stands, where intermediate cuttings are possible, is presented in Figure 2.13.

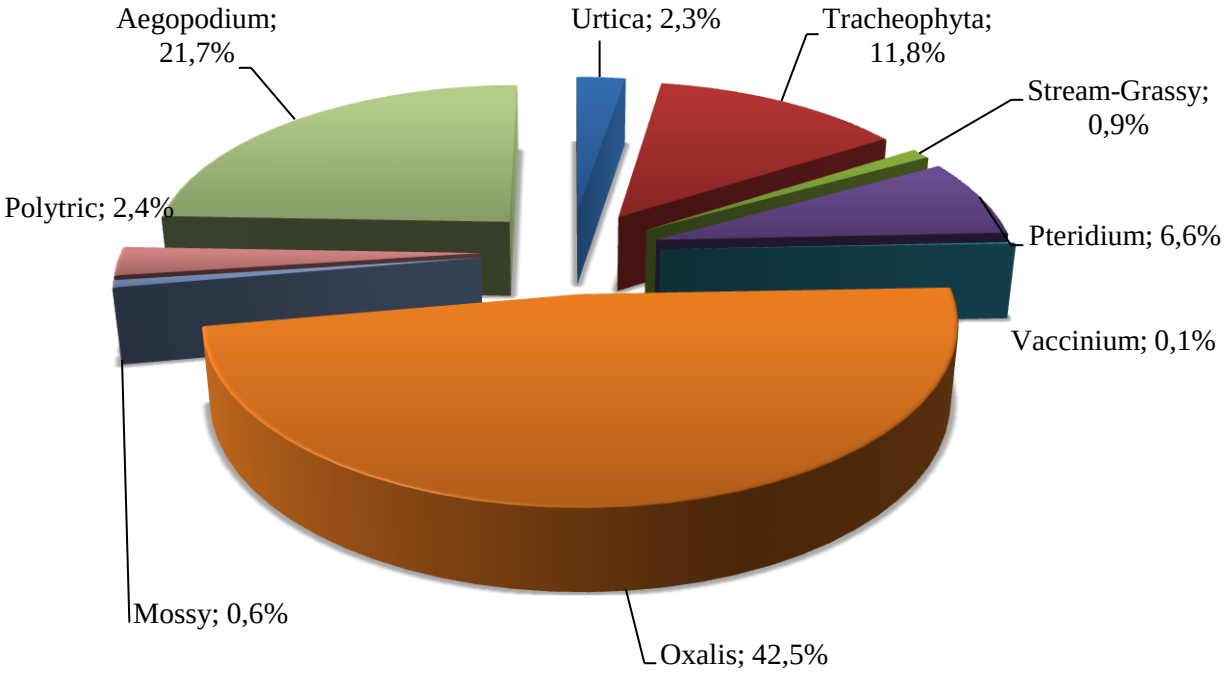


Figure 2.13 – Typological structure of aspen forests, where intermediate cuttings are possible

The predominant types of forests are Oxalis (42.5%), Aegopodium (21.7%) and Tracheophyta (11.8%) aspen forests.

Figure 2.14 shows the indicators of economic efficiency of thinning and advance thinning in aspen stands, depending on the method of handling felling wastes.

The payback of *thinning* in aspen stands with various methods of disposal of logging residues is as follows:

- when collecting and removal of logging residues from the cutting area: 0.34;
- when collecting logging residues in heaps and burning: 0.34;
- when collecting in heaps and leaving for decaying or laying on portages with subsequent compaction: 0.36;
- when chopping and scattering in the cutting area: 0.29.

The payback of *advance thinning* is:

- when collecting and removal of logging residues from the cutting area: 0.75;
- when collecting logging residues in heaps and burning: 0.77;
- when collecting in heaps and leaving for decaying or laying on portages with subsequent compaction: 0.83;
- when chopping and scattering in the cutting area: 0.31.

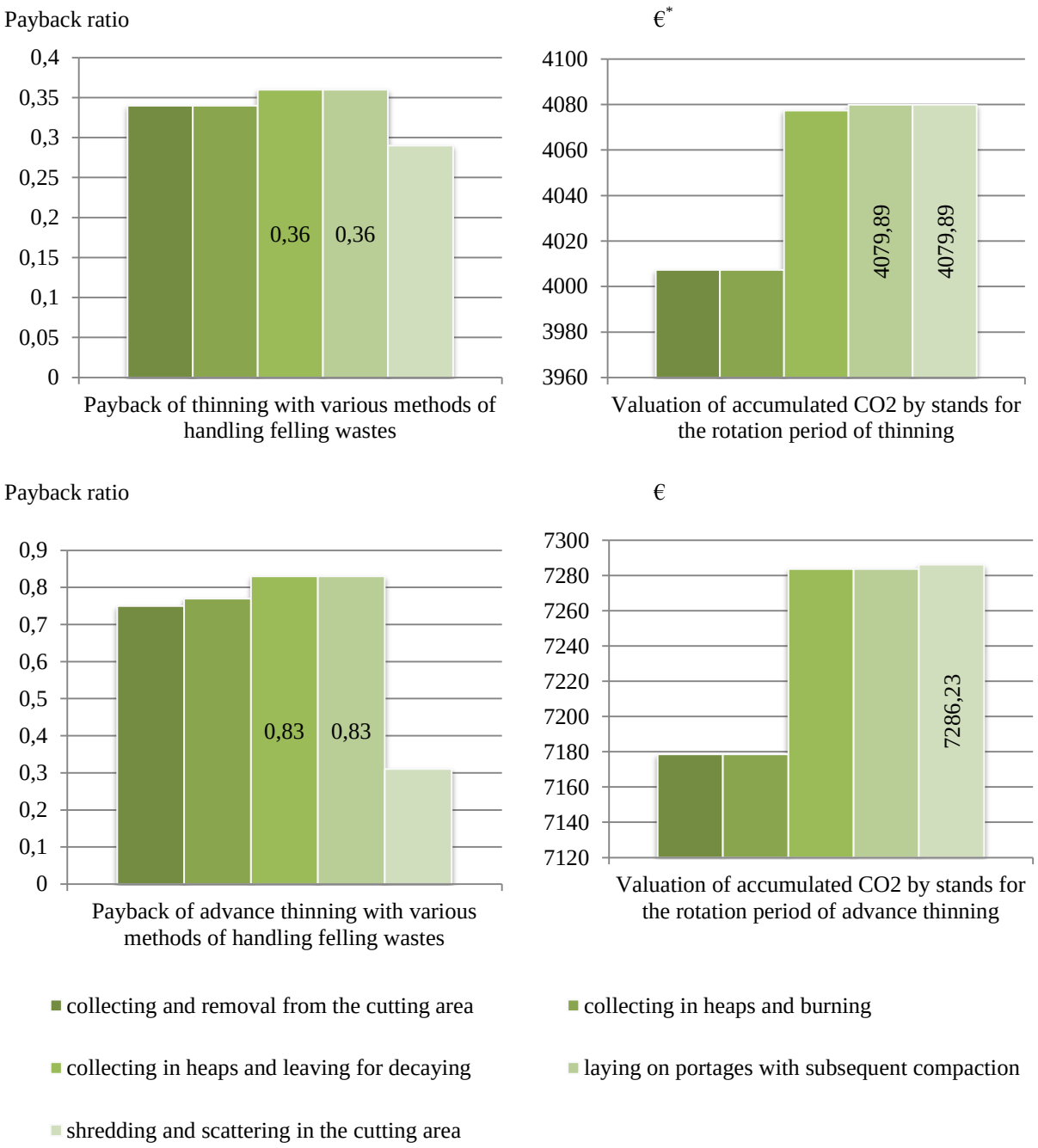


Figure 2.14 – Indicators of economic evaluation of the appropriateness of using felling wastes in aspen stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The highest payback ratio for thinning is 0.36, for advance thinning – 0.83 when cutting with the collecting of logging residues in heaps and left for decaying or laying on portages with subsequent compaction. In general, in aspen stands, due to the large yield of low-cost wood intermediate cuttings does not pay off.

The highest cost of CO_2 accumulated by the forest stand over the thinning rotation period is 4,079.89 €, on average per year – 1,080.46 € when laying on portages, followed by compac-

tion or grinding and scattering throughout the cutting area, during advance thinning – 7,286.23 € and 1,457.25 € when laying on portages with subsequent compaction.

Thus, in order to obtain the maximum additional income from the sale of emission reduction units (ERU GHG) in aspen stands, it is advisable to carry out thinning ***with the laying of logging residues on portages, followed by compaction or grinding and scattering across the territory of the cutting area***, and for advance thinning – ***with laying of logging residues on portages followed by compaction.***

The selection algorithm for handling felling wastes in aspen stands during thinning and advance thinning is shown in Figure 2.15.

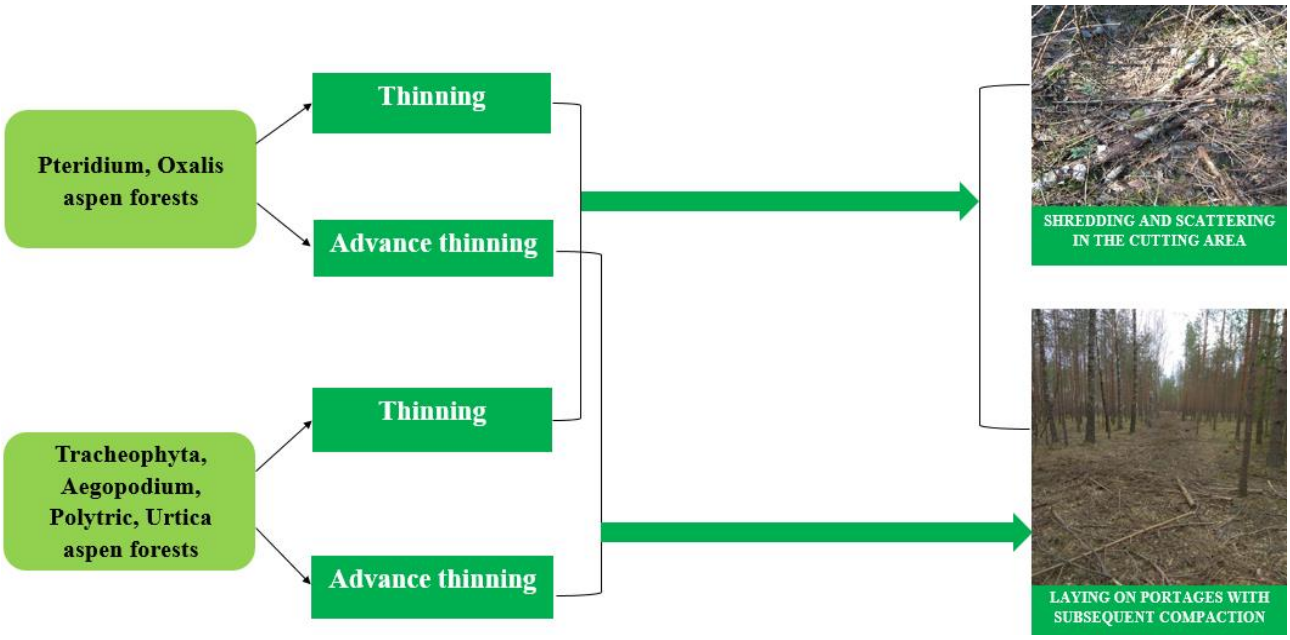


Figure 2.15 – Algorithm for choosing an option for handling felling wastes in aspen stands after thinning and advance thinning

In Pteridium, Oxalis, Aegopodium, Tracheophyta, Polytric, and Urtica aspen forests during thinning, the most suitable combined method of handling logging residues is: laying one part of the felling wastes evenly on portages, followed by compaction, the other part – crushing and scattering throughout the cutting area. In this case, the length of the felling residues left should not exceed 1.0 m with a diameter in the upper section of not more than 6.0 cm.

When conducting advance thinning (the use of chainsaws for logging and MPT-461.1 for skidder), it is advisable to uniformly lay the logging residues on portages and then compact them.

This corresponds to the current forestry practice of forest management in many forest enterprises of the Republic of Belarus.

7 PROPOSALS FOR BLACK ALDER STANDS FOR CHOOSING THE OPTION OF HANDLING LOGGING RESIDUES DURING THINNING AND ADVANCE THINNING

The area of black alder forests of the Ministry of Forestry as of 01.01.2019 is 626 590 ha. The typological structure of black alder forests, where intermediate cuttings are possible, is presented in Figure 2.16.

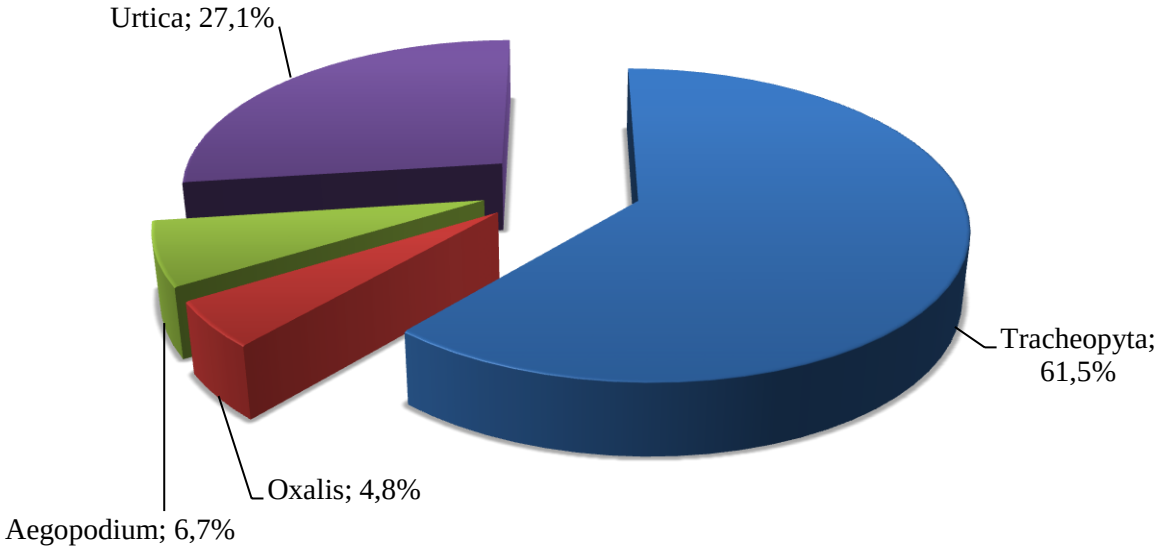


Figure 2.16 – Typological structure of black alder forests, where intermediate cuttings are possible

The predominant types of forests are Tracheophyta (61.5%) and Urtica (27.1%) black alder forests.

Figure 2.17 shows the indicators of economic efficiency of thinning and advance thinning in black alder stands, depending on the method of handling logging residues.

The payback ratio of *thinning* in black alder stands with different methods of utilization of logging residues is as follows:

- when collecting and removal of logging residues from the cutting area: 0.81;
- when collecting logging residues in heaps and burning: 0.80;
- when collecting in heaps and leaving for decaying or laying on portages with subsequent compaction: 0.85;
- when chopping and scattering in the cutting area: 0.68.

The payback ratio of *advance thinning* in black alder forests is as follows:

- when collecting and removal of logging residues from the cutting area: 0.76;
- when collecting logging residues in heaps and burning: 0.77;
- when collecting in piles and leaving for decaying or laying on portages with subsequent compaction: 0.81;
- when chopping and scattering in the cutting area: 0.63.

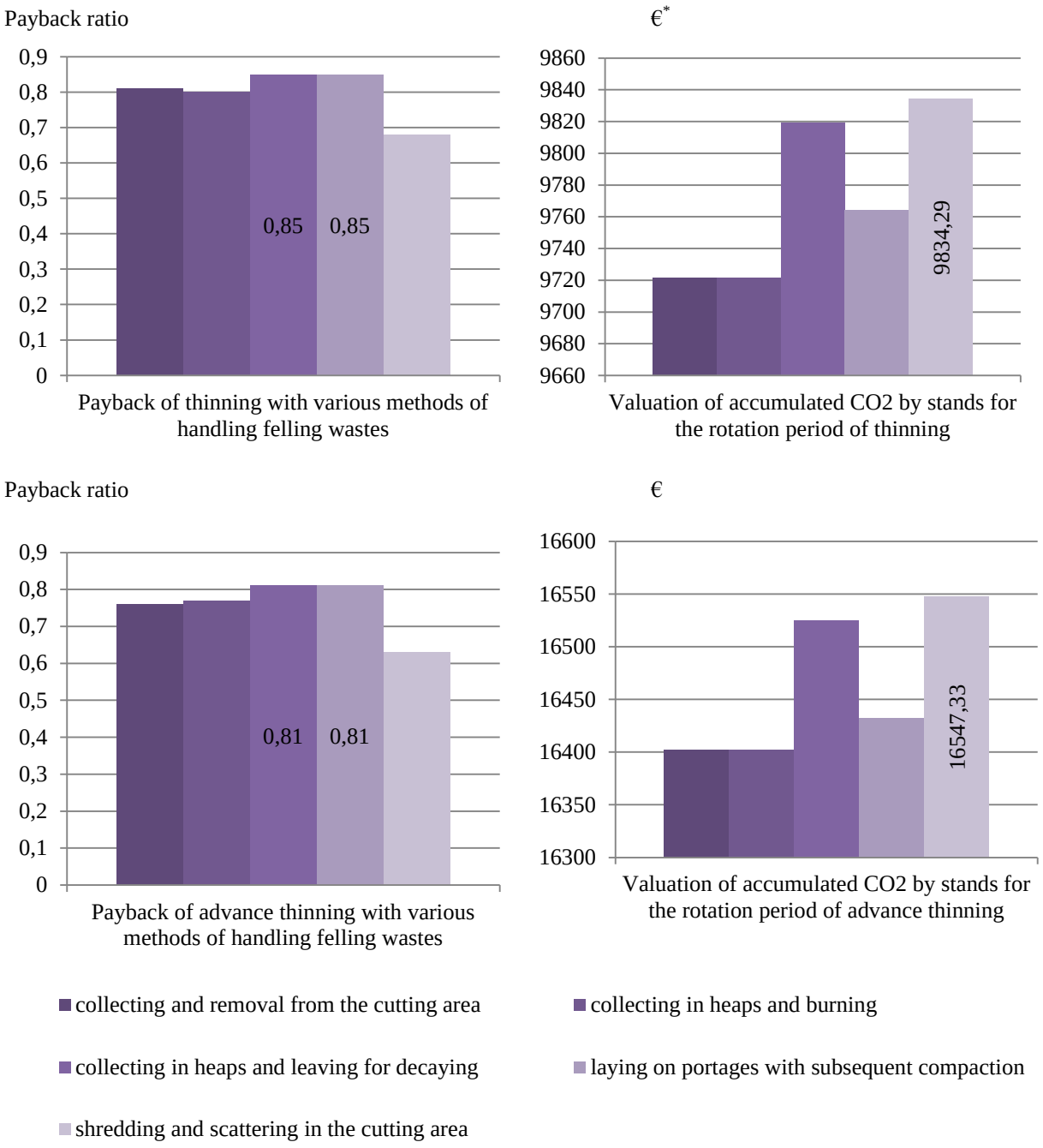


Figure 2.17 – Indicators of economic evaluation of the appropriateness of using felling wastes in black alder stands

** The possible revenues from the sale of emission reduction units (ERU GHG) for the rotation period of thinning and advance thinning operations are calculated taking into account the average world price of the emission allowance of 1 ton of CO_2 (adopted at € 25.03 according to the European Climate Exchange on the date of the assessment (30.09.2019)).*

The highest payback ratio for thinning is 0.85, for advance thinning – 0.81 when cutting with the collecting of felling wastes in piles and left for decaying or laying on portages with subsequent compaction.

Despite the fact that the payback ratios during intermediate cuttings with subsequent collection and removal of logging residues from the cutting area also have not the lowest values (for thinning – 0.81, for advance thinning – 0.76), this option of handling felling wastes should be immediately eliminated due to the inaccessibility of black alder plots (in many cases), which

may result in additional transportation costs.

In general, in black alder stands, due to the large yield of low-cost firewood, intermediate cuttings, as a rule, does not pay off.

The highest cost of CO_2 accumulated by the forest stand during the thinning rotation period is 9,834.29 € (annual average 1,404.90 €) when chopping and scattering felling wastes across the cutting area; for advance thinning – 1,6547.33 € (on average for a year – 2,068.42 €).

Thus, in order to obtain the maximum additional income from the sale of emission reduction units (ERU GHG) in black alder stands, it is expedient to carry out thinning and advance thinning with ***chopping and scattering of logging residues across the cutting area.*** This corresponds to the forestry practices of managers in many forest enterprises of the Republic of Belarus at the moment, and therefore, the social factor will also be taken into account.

The algorithm for choosing the option of handling felling wastes in black alder stands during thinning and advance thinning is shown in Figure 2.18.

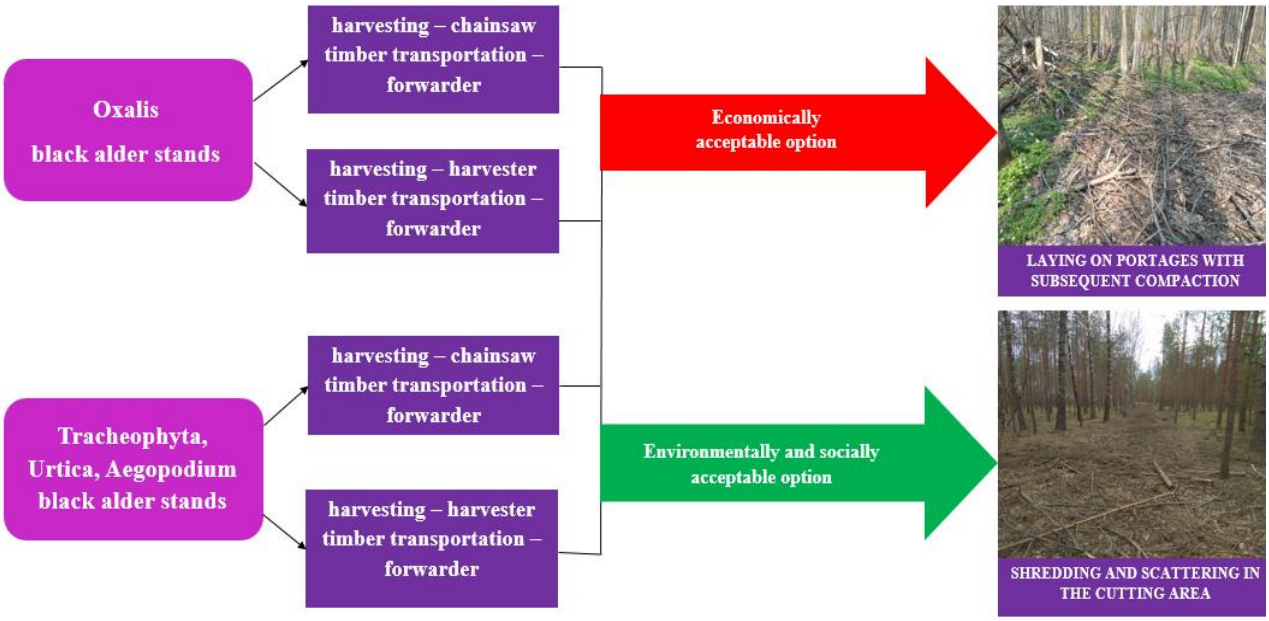


Figure 2.18 – Algorithm for choosing an option for handling felling wastes in black alder stands after thinning and advance thinning

The felling wastes of black alder, crushed and scattered throughout the cutting area under moist and humid conditions, which are characteristic of the location of black alder forests, will quickly decompose and decay, positively affecting soil fertility and microorganism reproduction. Thereby, compliance with the environmental factor will be achieved when using logging residues of black alder after intermediate cuttings.

8 COORDINATION AND DISCUSSION OF THE METHODOLOGY FOR EVALUATING CARBON SEQUESTRATION BY FELLING WASTES WHEN CARRYING OUT THINNING AND ADVANCE THINNING IN THE STANDS OF THE MAIN FOREST-FORMING TREE SPECIES OF THE REPUBLIC OF BELARUS

The methodological document "The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)" passed the established procedure of preparation for approval.

The methodology is based on current regulatory documents, legal acts on forestry, in particular:

GOST 17.6.1.01-83 Nature protection. Forest conservation and protection. Terms and definitions / Approved by the resolution of the Gosstandard of the Republic of Belarus of December 17, 1992 No. 3, reprint (January 2011), 2011. – 12 p.

GOST 18486-87 Forestry. Terms and definitions / Introduced into operation on the territory of the Republic of Belarus since December 17, 1992 by the Resolution of the Committee on Standardization, Metrology and Certification under the Council of Ministers of the Republic of Belarus dated December 17, 1992 No. 3, 1992. – 20 p.

Methodology for assessing the total and annual carbon sequestration by forests of the Republic of Belarus / approved and enforced by order of the Ministry of forestry of the Republic of Belarus dated March 28, 2011, No. 81 / L. N. Rozhkov [et al.]. – Minsk: BSTU; Belgosles, 2011. – 19 p.

Felling rules in the Republic of Belarus / Decree of the Ministry of Forestry of the Republic of Belarus dated December 19, 2016 No. 68. – Minsk: Ministry of Forestry, 2016. – 17 p.

Forest Code of the Republic of Belarus / dated December 24, 2015 No. 332-Z: Adopted by the House of Representatives on December 3, 2015, approved by the Council of the Republic of Belarus on December 9, 2015; Changes and additions: Law of the Republic of Belarus dated December 18, 2018 No. 152-Z.

STB 1681-2006 Sustainable forest management. Forest inventory. General requirements / Approved and enforced by resolution of the Gosstandard of the Republic of Belarus of October 16, 2006 No. 46, 2007. – 12 p.

STB 1688-2006 Sustainable forest management. Requirements for forest management engineering / Approved and enforced by resolution of the State Standard of the Republic of Belarus of November 15, 2006. No. 54, 2007. – 20 p.

STB 1708-2006 Sustainable forest management. Basic Provisions / Approved and enforced by resolution of the State Standard of the Republic of Belarus dated December 18, 2006 No. 63. Reprint (May 2014) with Amendment No. 1 approved in December 2010 (IU TNPA No. 11-2010), by Change No. 2, approved in December 2013 (IU TNPA No. 12-2013), 2013. – 72 p.

STB 1361-2002 "Sustainable forest management. Intermediate cuttings. Technology requirements" / approved and enforced by Decree of the Gosstandard of the Republic of Belarus of December 9, 2002 No. 54. Reprint (May 2011) with Amendment No. 1 approved in April 2007 (IU TNLA No. 4-2007), Amendment No. 2 approved in February 2011 (IUTNPA No. 2-2011), 2003. – 26 p.

TCP 622-2018 (33090) "Technical requirements for forest inventory. Allocation and taxation of cutting areas in the forests of the Republic of Belarus" / Approved and enforced by Decree of the Ministry of Forestry of the Republic of Belarus dated July 12, 2018. No. 9.

The prepared draft recommendations were sent to stakeholders for feedback. According to the above comments and suggestions, the document was amended accordingly.

Comments and (or) proposals for the draft guidance document "The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)" are given in Table 8.1.

Table 8.1 – Summary of reviews on the guidance document “The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)”

Name of organization, letter number and date	Comment and (or) proposal	Developer Conclusion
1	2	3
Republican Scientific Research Unitary Enterprise "Bel NIC" Ecology", No. 01-14/1151 of 11/22/2019	No comments or proposals	–
Forest inventory republican unitary enterprise “Belgosles”, No. 04/1123 dated 11/22/2019.		
State Scientific Institution “Institute of Experimental Botany named after V.F. Kuprevich NAS of Belarus", No. 255-01-15/1135 of 11/18/2019		
Ministry of Defense of the Republic of Belarus, No. 10/1706 dated 11/26/2019		
Ministry of Emergency Situations of the Republic of Belarus, No. 1/63/4439 of 11/26/2019		
The State Inspectorate for the Protection of the Fauna and Flora under the President of the Republic of Belarus, No. 04-03-04/2169 dated 11/21/2019	Not subject to approval by the State Inspectorate in accordance with applicable law	–
Republican Center for Advanced Training of Executive Officers and Forestry Specialists, No. 01-08/892 of November 26, 2019	At the moment, the Center does not have specialists on the research topic and cannot give a professional assessment of the methodological document	–
Mogilev State Forest Management Board, No. 1490 dated 11/22/2019	In section 1 “Scope”, it is necessary to change the edition of the second part. Instead of “The methodology is intended for use by legal entities engaged in forestry and harvesting timber during thinning and advance thinning in the forests of the Republic of Belarus”, write “The methodology is intended for use in the development of regulatory documents governing the rules, methods of cutting and clearing of cutting areas from logging residues. "	Partially adopted taking into account article 20 of the Forest Code of the Republic of Belarus.

Continuation of table 8.1

1	2	3
Minsk State Forest Management Board, No. 3442 dated 11/15/2019	The 2nd paragraph of 1st part "The scope" shall be stated in the following edition: "The methodology is intended for use in the field of forestry". The proposed edition will allow the use of a methodological document by all stakeholders.	Not accepted. The new edition of the Methodology sets out more specifically.
Grodno State Forest Management Board, No. 05-1-4/2122 dated 11/20/2019	The developed Methodology does not take into account sanitary requirements when carrying out logging in pine stands. In accordance with paragraph 45 of the Sanitary Rules in the forests of the Republic of Belarus, approved by Decree of the Ministry of Forestry of the Republic of Belarus dated December 19, 2016 No. 79 (hereinafter referred to as the Rules), thinning is carried out primarily in forest stands with impaired stability. When thinning, they are required to cut down trees populated by stem pests, affected by diseases, drying out and shrinking trees. Paragraph 47 of the Rules prescribes in the foci of stem pine pests, vascular and necro-cancerous diseases included in the list of the main pests and forest diseases that can form foci, logging residues are subject to mandatory burning. Consequently, legal entities engaged in forestry and harvesting timber during thinning and advance thinning in pine stands, when choosing a method for clearing cutting areas, are forced to be primarily guided by the sanitary condition of the forest stands. The implementation of the Methodology in practice is possible if the existing approaches to sanitary requirements are changed during logging, which will require additional study of this issue and its discussion with forest protection specialists.	Accepted. Section 1 "Scope" is proposed to be supplemented with the paragraph "The provisions of the methodology are applicable subject to the priority observance of the Sanitary Rules in the forests of the Republic of Belarus".

Continuation of table 8.1

1	2	3
Ministry of Natural Resources and Environmental Protection of the Republic of Belarus, No. 11-14-1/5323 of 11/27/2019	In the section 1 “Scope” it is proposed to review the circle of people to whom the presented methodology is intended, depending on who it will be used in practice. We believe that legal entities involved in forestry need a scientifically based decision-making algorithm for choosing a method of handling felling wastes, where carbon deposition will be one of the factors that must be taken into account. We consider it possible to set out in the draft Methodology a part of this algorithm regarding the decision to choose a method for handling logging residues depending on their carbon deposition. In the section 3 “Terms and definitions”, the definitions of the terms “tree stand” and “intermediate cuttings” should be brought into line with the definitions of the concepts “tree stand” and “intermediate cuttings” according to Article 1 of the Forest Code of the Republic of Belarus.	Partially accepted. The choice of the method of handling felling wastes in each case, except for carbon deposition, will depend on many factors: the sanitary condition of the stands, places of growing conditions, the amount of logging residues, the availability of infrastructure and the economic feasibility of their processing, the proximity of cutting areas to settlements and roads, use forests for recreational purposes, etc. In each particular case, the manager (forester) needs to make a decision on the treatment of logging residues, taking into account the whole complex of factors, the formalization of which by a single algorithm is not possible. Terms and definitions are brought into line with the Forest Code in the new edition of the guidance methodological document.
Office of the President of the Republic of Belarus, No. 22-10/3041 of December 6, 2019	No comments or proposals	_

Continuation of table 8.1

1	2	3
State Scientific Institution “Forest Institute of the NAS of Belarus”	On section 1 "Scope" there are the following remarks. The scope is not clearly defined. The second paragraph should be adjusted, the conditions for the application of the guidance methodological document have to be determined. Section 3, “Terms and Definitions,” has the following remarks. The term “basic wood density” is not used in the text of the document; other terms given in section 3 do not have references to the source from which they are taken. Section 4, “General Provisions”, has the following remarks. Paragraph 3 shows the CO_2 deposition figures without reference to the sources. The carbon dioxide label is not printed correctly. In paragraph 4, the first sentence contradicts the second. In the penultimate paragraph, carbon sequestration by felling wastes should be given in t / ha, since the annual volumes of felling in the Ministry of Forestry are variable. According to section 5, “The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen),” there are the following observations. The determination of the amount of deposited carbon is calculated by the formula, the key indicator of which are conversion coefficients. However, the methodology does not set out the principles for their calculation. Paragraph 3 (p. 6) needs to be edited. The method for clearing cutting areas from logging residues is not depending of carbon deposition. When calculating the amount of carbon deposited over a period of time *t*, the proposed method does not take into account the peculiarities of the increase in the mass of branches, but it is based (maybe?) on the assessment of cut down timber reserves.	Partially accepted. The general provisions of the Methodology show both the average content of deposited carbon with felling wastes in *t / ha*, and, in general, for all forests of the Ministry of Forestry of the Republic of Belarus. The developed draft Methodology is intended for practical use and does not provide for the reduction and explanation of the calculations of used conversion coefficients. The developed draft Methodology is intended for the assessment of deposited carbon by felling wastes and does not provide for the assessment of carbon accumulations by the growing phytomass of the forest stand (these calculations are presented in the reporting materials).

CONCLUSION

In accordance with the schedule and terms of reference as a result of the sixth stage of Actevity 3.1.8: “Undertake monitoring and analysis of stands with and without project thinning and removal of felling waste interventions to assess Greenhouse Gas (GHG) emissions reductions”:

- Proposals were prepared for the handling felling wastes and algorithms were developed for choosing the treatment of logging residues of the main forest-forming species (pine, spruce, oak, birch, aspen, black alder) after thinning and advance thinning, taking into account the type of thinning and timber harvesting technology, forest conditions, forest categories, requirements for the conservation of biological diversity, the size of annual carbon deposition by ground felling wastes, indicators of economic efficiency of different regimes of thinning.

- Algorithms have been developed for choosing the treatment option for felling wastes of the main forest-forming species during thinning and advance thinning;

- An analysis of the comments and suggestions received from forest fund holders was carried out according to the developed methodological document “The methodology of assessment of carbon sequestration by felling wastes in the process of intermediate cuts for the main forest species (pine, spruce, oak-tree, birch, black alder, aspen)” and corresponding adjustments were made to the document.

In connection with the use of modern multioperation machines during intermediate cuttings, we recommend revising the “Guidelines for the organization and conducting of logging in the Republic of Belarus” (2006).

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4 Felling rules in the Republic of Belarus: Decree of the Ministry of Forestry of the Republic of Belarus dated December 19, 2016. No. 68. – Minsk: Ministry of Forestry, 2016. – 17 p.

5 STB 1361-2002 "Sustainable forest management. Intermediate felling. Technology requirements" / approved and enforced by resolution of the Gosstandard of the Republic of Belarus dated December 9, 2002, No. 54. Reprint (May 2011) with Amendment No. 1 approved in April 2007 (IU TNPA No. 4-2007), Amendment No. 2 approved in February 2011 (IU TNPA No. 2-2011), 2003. – 26 p.

6 GOST 18486-87 Forestry. Terms and definitions / Entered into force on the territory of the Republic of Belarus on December 17, 1992 by the Resolution of the Committee on Standardization, Metrology and Certification under the Council of Ministers of the Republic of Belarus dated December 17, 1992. No. 3, 1992. – 20 p.

7 Analysis of ecological, social and economic consequences of utilization of biomass of felling wastes at the sites of intermediate cuts (thinnings in the stands of 20-40 and 40-60 years) for the Republic of Belarus, with due regard to the sanitary conditions of the stands and avoiding of development of pathological processes in the stands, and necessity to use felling wastes at the productions on manufacturing of biofuel and biomaterials: : Report No. 4 / Belarussian State Technological University; project manager K. V. Labokha. – Minsk, 2019. – 139 p.

8 Analysis and monitoring (in case of establishment of pilot sites) of the carbon sequestration capacity of the pine, spruce, birch, oak-tree, black alder and aspen stands where: intermediate cuts are not done; intermediate cuts are done (thinnings in the stands of 20-40 and 40-60 years) without removal of felling wastes; intermediate cuts are done with removal of felling wastes: report No. 3 / Belarussian State Technological University; project manager K. V. Labokha. – Minsk, 2019. – 82 p.

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