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# ECONOMIC ASSESSMENT OF CLIMATE-RELATED DISASTER LOSSES IN THE FORESTRY SECTOR IN BELARUS: CURRENT STATUS AND AREAS FOR IMPROVEMENT BASED ON INTERNATIONAL EXPERIENCE

FINAL REPORT



Minsk 2018

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## Abbreviations

SFE	State Forestry Enterprise
SEFE	State Experimental Forestry Enterprise
SPFA	State Production Forestry Association
SSFE	State Specialized Forestry Enterprise
IPCC	Intergovernmental Panel on Climate Change
PLC	Public limited company
CS	Corporate standard
PB	Payroll budget
SPF	Social Protection Fund



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Many important details of this review have arisen from the discussions with the representatives of governmental bodies and industries who made important comments during working meetings and the workshop hosted by Belarusian State Technological University and organizations under the Ministry of Forestry of the Republic of Belarus between October 2 and October 3, 2018.

## Executive Summary

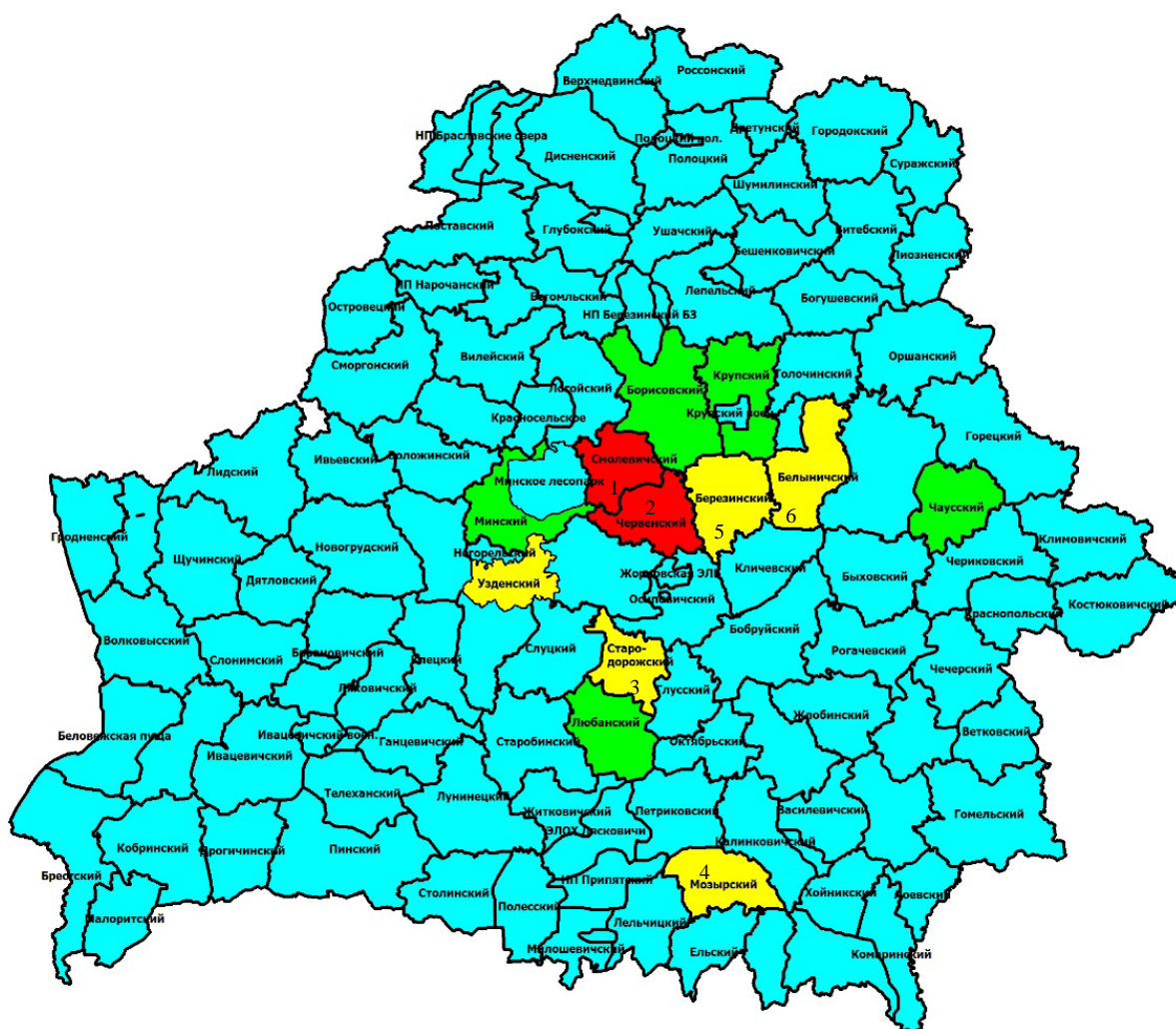
This report has been drawn up within the study “Assessing the current losses and improving the economic analysis of the costs of the on-going climate related catastrophic forestry events based on international experience” funded by The Global Facility for Disaster Reduction and Recovery (GFDRR). This report was largely encouraged by the need to support the forest sector of Belarus to recover from the forestry catastrophic event of 2016 and to increase the resilience of Belarusian forests to future windblows and other adverse weather effects.

The goal of the study was to improve economic assessment of the impact of catastrophic weather events on Belarusian forests. The study was carried out based on analysis of available research from the countries that have considerably advanced in this area, and were developed with regard to the practices existing in the forest sector of the Republic of Belarus. The work involved meetings with the authorities and professionals of the Ministry of Forestry of the Republic of Belarus, visits to forestry enterprise with relevant study of methods for economic assessment of costs and the recovery operations after natural disasters.

In Belarus as well as in Europe there is a tendency towards the increasing number and intensity of natural disasters in forests. Therefore, the damage incurred by the adverse weather effects is also increasing. The impact of various negative factors affecting the forest sector of Belarus over 2012-2016 can be described as follows: windblows and snowbreaks – 53.9 thousand ha (79.65%); forest fires – 7.3 thousand ha (10.75%); forest diseases – 4.5 thousand ha (6.71%); other factors (excessive humidity, pests, damage by wildlife) – about 2 thousand ha (2.89%). Thus, strong winds and fires are the most hazardous factors. It should be noted that about 80% of adverse weather effects occur during warm seasons. Besides, pine stands diebacks and stand damage by forest pests have become factors of great concern in Belarusian forests over the recent years.

In addition, windblows have caused damage ranging from 500 to 2300 thousand m<sup>3</sup> of timber since 2005. The 2016 windblow has happened to be the most large-scale catastrophic event over the past 15 years. Forest stands of most forestry enterprises were affected by the windblow to a greater or lesser extent (Figure 1). Major damage was registered in state experimental forestry enterprise “Starodorozhskiy opytniy leskhoz”, state forestry enterprise “Berezinskiy leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz” (Table 1). The heaviest windblow impact affected mainly the eastern regions of the country. The storm was centered in the forested areas of state forestry enterprises “Smolevichi leskhoz” and “Cherven leskhoz” (Figure 2).

The area of the most affected territories where forest stands were almost completely destroyed amounted to nearly 14 thousand ha that is comparable to the area of 26 000 football fields. The total area of damaged stands (various damage degree, incl. small damage) was 110 thousand ha. The timber losses amounted to approx. 6 million m<sup>3</sup> or 25-30% of the annual timber harvest.



- forestry enterprises with damaged wood volume less than 50 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume from 50 to 100 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume from 100 to 300 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume over 300 thousand m<sup>3</sup>.

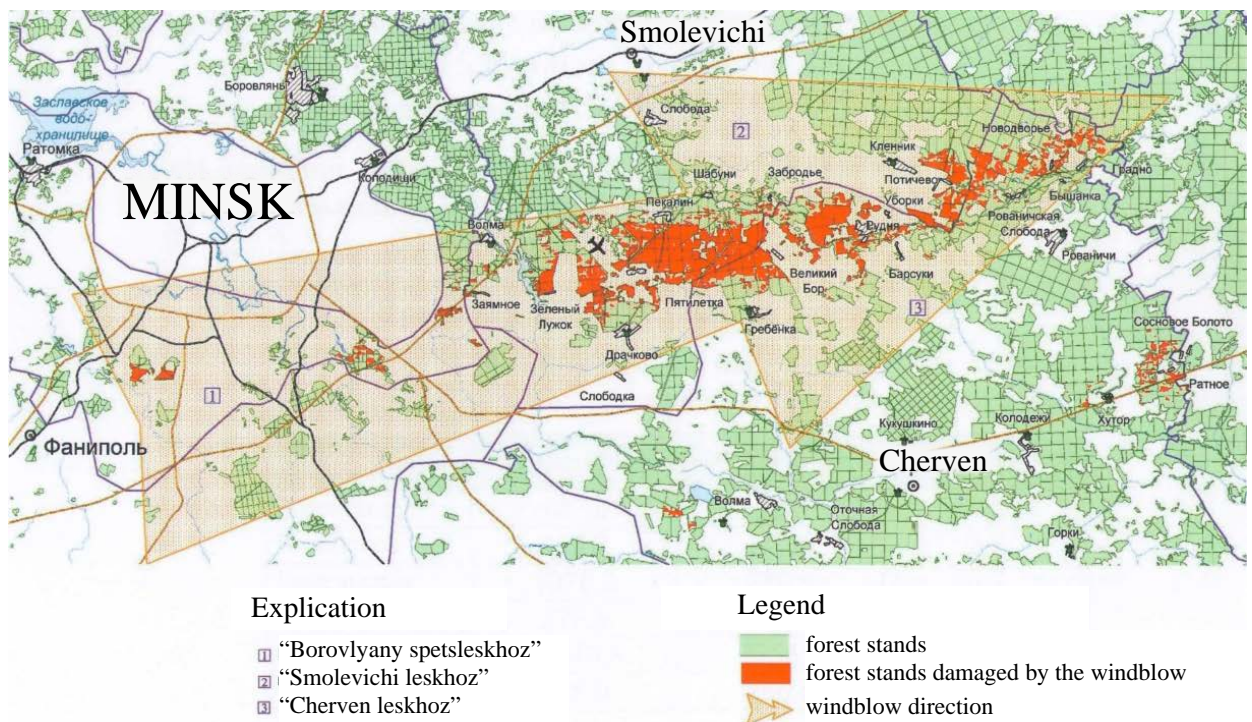
**Figure 1 – Map of forest fund damage incurred to the organizations under the Ministry of Forestry of the Republic of Belarus:**

*Source:* authors' development based on the data of the Ministry of Forestry of the Republic of Belarus

**Table 1 – Timber losses and area of the affected forested lands in the forestry enterprises most greatly affected by the 2016 windblow**

The name of the forestry enterprises	Timber losses, thousand m <sup>3</sup>	Damaged area, ha	Rate of the total forested area, %
State forestry enterprises "Smolevichi leskhoz"	1720,0	8796	23,0
State forestry enterprises "Cherven leskhoz"	1589,3	11955	16,3
State experimental forestry enterprise "Mozyr opytny leskhoz"	231,3	3133	3,6
State experimental forestry enterprise "Starodorozhskiy opytny leskhoz"	220,1	6601	10,2
State forestry enterprise "Berezinskiy leskhoz"	134,0	2680	2,8

The name of the forestry enterprises	Timber losses, thousand m <sup>3</sup>	Damaged area, ha	Rate of the total forested area, %
State forestry enterprise “Belynychy leskhoz”	104,0	1713	1,8

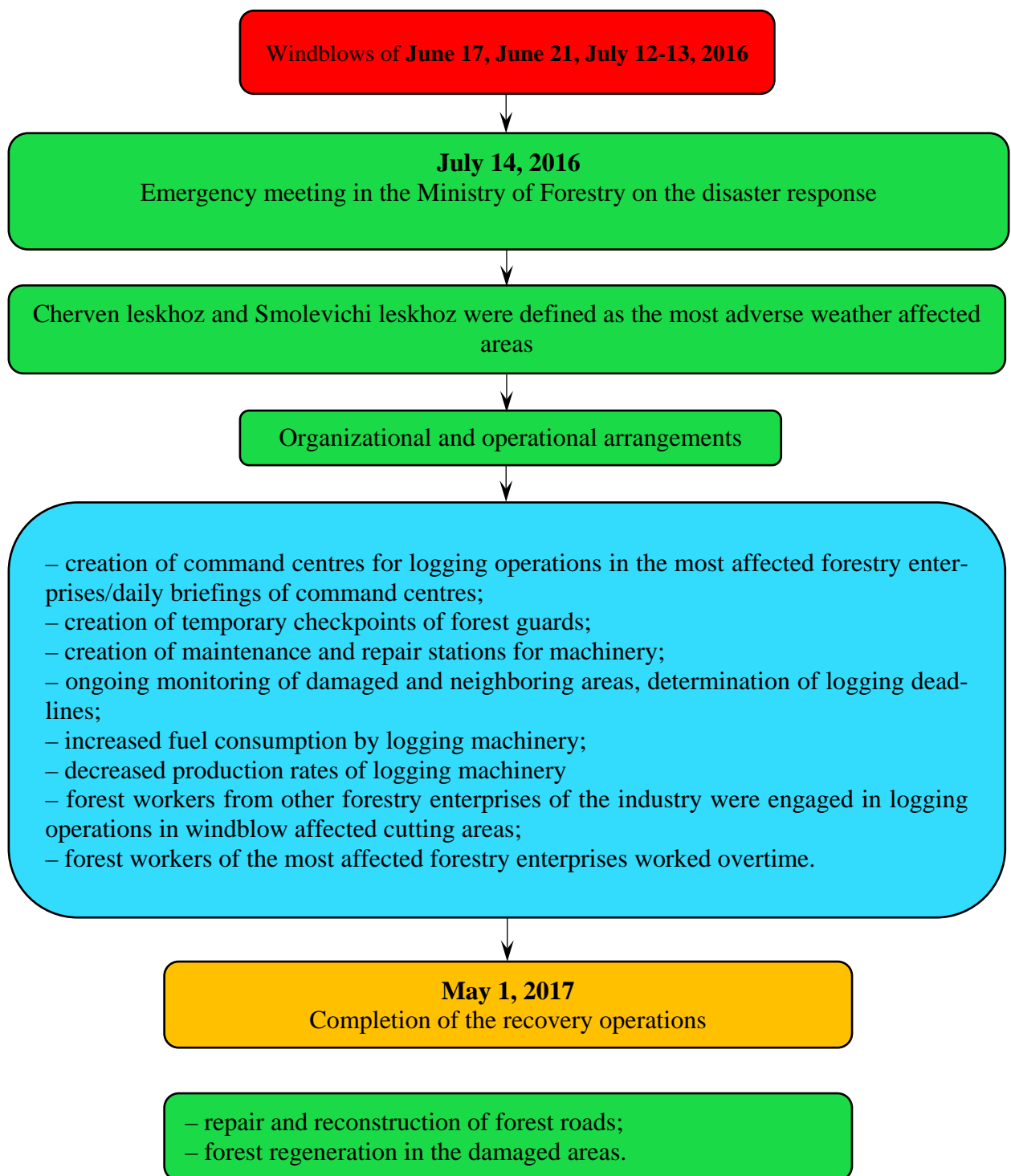


**Figure 2 – Map of forested stands most heavily damaged by the windblow of July 13, 2016**  
*Source: data of the Ministry of Forestry of the Republic of Belarus*

The emergency meeting of July 14, 2016 in the Ministry of Forestry came to a decision to mobilize all the forestry enterprises and other organizations of various ownership forms in order to eliminate the windblow damage in the most affected areas and to prevent degradation of the timber quality. It was decided to involve multifunction machinery to ensure maximum labour safety during the recovery operations. Since the first days after the windblow more than 500 workers were involved in the inspection of damaged forest stands in the forestry enterprises of the Minsk region. Scaled-up estimation of the scope of damaged forested areas was done by aerial survey and air drones. Final update was done during allocation of sites for cutting operations by forestry enterprises specialists.

Figure 3 illustrates the actions taken to ensure smooth work and timely rectification of the windblow consequences.

Special command centres coordinating the recovery operations in the windblow areas were established at the forestry enterprises that were most greatly affected by the catastrophic event. They were coordinating the harvesting operations that were done by joint forces of several forestry enterprises. The command centres regularly held briefings to discuss the harvesting technology, to analyze the result and to monitor the living conditions of the workers.

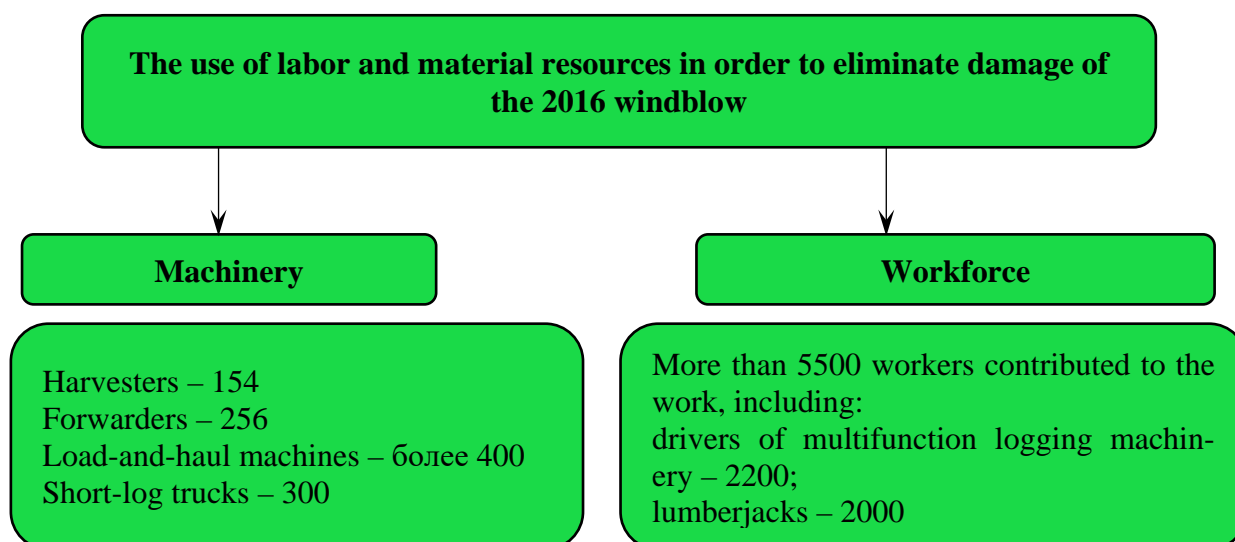


**Figure 3 – Sequence of recovery operations in the windblow affected areas**

*Source:* authors' development based on the data of the Ministry of Forestry of the Republic of Belarus

A lot of multifunction machinery and workforce carried out logging operations (Figure 4).

Forest regeneration was performed after the clear-up operations of the damaged cutting areas had been completed. It is worth mentioning that the forest nurseries of the Ministry of Forestry were able to provide enough planting material. The forest planting continued in 2017. The main recovery operations in the windblow affected areas had been completed by May 1, 2017.



**Figure 4 – The use of labor and material resources in order to eliminate damage of the 2016 windblow**

*Source:* authors' development based on the data of the Ministry of Forestry of the Republic of Belarus

The operational flexibility of the logging operations resulted in extra costs due to such factors as:

- 20-50% decreased production rates, higher labour costs and machinery maintenance costs;
- 10% increased fuel consumption;
- other extra costs (subsistence and other costs arising from relocation of people and machinery and workers' accommodation).

At the same time the 2016 windblow had only minor effect on the domestic timber market in the Republic of Belarus. When selling the windblow timber, it was a primary task to cover the domestic market needs on a first-priority basis. The timber that was not demanded in Belarus was exported. This was mainly represented by pulpwood bolts and technical rawwood used by pulp-and-paper industry and wood panel manufacturing. Total exports of timber amounted to 3.7 million m<sup>3</sup> in 2016, including 2.7 million m<sup>3</sup> of timber exported by the enterprises under the Ministry of Forestry of the Republic of Belarus. Table 2 gives information about the export sales of round timber and comparative price analysis.

Table 2 – Export sales of round timber in 2016

Indicator	Indicator value
Foreign currency earnings from the round timber export, million USD	83
Profit margin of exports of timber harvested from the windblow affected areas, %	24,9
including saw logs, %	60,1
The export price of pulpwood bolts, USD	25,3
The domestic market price of pulpwood bolts, USD	15,8
The export price of technical rawwood, USD	12,1
The domestic market price of technical rawwood, USD	9,3
The export price of saw logs, USD	52,7
The domestic market price of saw logs, USD	29,3

As can be seen from Table 2, under comparable conditions (without carriage charges) the average export price of pulpwood bolts was 1.6 times as high as the average domestic market price, that of technical rawwood was 1.3 times as high, that of saw logs was 1.8 times as high as the domestic market price.

On the whole the implementation of recovery operations after the 2016 windblow did not result in heavy losses of forestry enterprises due to two important resolutions taken by the government and the President, i.e., to decrease allowable final cuts and to authorize certain amount of round timber export.

The decrease in allowable final cuts prevented round timber prices from a dramatic drop both on the domestic and the CIS markets. The opportunity to export round timber and the resulting export profitability made it possible to compensate for the increased losses arising from more complicated technology of the recovery operations, reduced rates of production, increased fuel consumption rates, degraded assortment pattern of timber, enhanced volume of waste wood during and after harvest. Thus, the needs in additional public funding for the most affected forestry enterprises amounted to only 2 403 thousand BYN. Forestry enterprises received 3 000 thousand BYN of financial support coming from the public budget to compensate for the above costs and to recover from the windblow effects. The funds were allocated at the initiative of the Ministry of Forestry upon the approval of other governmental bodies. The remaining funds were allocated to forest regeneration.

To provide a more comprehensive assessment of windblow impacts on the forest sector, the review of economic consequences of the 2016 windblow was done by the example of two enterprises, i.e., state forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz”. Both enterprises belong to the forest sector and are under the jurisdiction of the Ministry of Forestry of the Republic of Belarus. The review involved data collection and the methodology applied to assess economic losses from forestry catastrophic events.

The analysis of direct losses from the 2016 windblow in the forestry enterprises under review has shown that major losses of timber sales can principally be explained by **lower grade of the timber harvested**. Under normal conditions final cuts can yield about 80% of merchantable wood and 20% of firewood under normal conditions. The cuts in the windblow areas resulted in 40% of merchantable wood and 60% of firewood. Moreover, the clear-up and restoration operations proved to be considerably labour-intensive and costly and had an unfavourable effect on the financial activities of the organizations involved.

As a result, round timber profitability of main stock items decreased in December 2016 as compared to the same values of June 2016 for state forestry enterprise “Cherven leskhoz”. The lowest profitability was registered for pine pulpwood to be sold on the domestic market. Thus, in December the costs were higher than the sales and profitability turned out to be negative (–2,74%). However, the prices of some stock items increased. For instance, the price of saw logs marketed in the Republic of Belarus went up by 7.8%. The most dramatic price rise was registered for exported timber.

Over the period from June to December 2016 the situation in state experimental forestry enterprise “Mozyr opytniy leskhoz” was different from that on state forestry enterprise “Cherven leskhoz”. The main stock items demonstrated improved profitability after the clear-up and restoration operations as compared that before the 2016 windblow. This fact proves high performance characteristics of the production processes. This was caused by a sharp and dramatic increase in wood harvest volumes by 105 thousand m<sup>3</sup> or 70%, which in its turn enabled lower conditional-constant costs and reduced costs of main stock items. State forestry enterprise “Cherven leskhoz” failed to demonstrate the same effect because timber harvest volumes had not gone up. Timber harvesting operations in the windblow areas were considerably supported by third parties.

In order to determine additional costs of the recovery operations after the 2016 windblow in the forestry enterprises, the costs of round timber harvest have been calculated. This was done for both normal conditions and for windblow areas. The calculation outcomes for state forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz” are given in Table 3.

Table 3 – Analysis of economic costs from 2016 windblow (the cases of state forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz”)

Index	State forestry enterprise “Cherven leskhoz”		State experimental forestry enterprise “Mozyr opytniy leskhoz”	
	Under normal conditions	Under windblow clear-up operations	Under normal conditions	Under windblow clear-up operations
Timber harvest volume, thousand m <sup>3</sup>	1 589,00	1 589,00	209,80	209,80
Labour costs of harvester operators, thousand BYN	2 189,94	2 576,40	289,14	340,17
Costs of harvester maintenance and operation, thousand BYN	8 515,72	10 593,33	1 124,35	1 373,37
Labour costs of tractor drivers, thousand BYN	995,43	1 171,09	131,43	154,62
Costs of tractor maintenance and operation, thousand BYN	2 033,79	3 013,84	268,53	389,17
Labour costs of forwarder operators, thousand BYN	1 082,30	1 273,30	142,90	168,12
Costs of forwarder maintenance and operation, thousand BYN	8 708,99	10 872,87	1 149,87	1 405,99
Total direct costs before delivery, thousand BYN	23 526,17	29 500,84	3 106,22	3 831,44
Delivery costs, thousand BYN	15 150,56	15 150,56	200,37	200,37
Other costs (subsistence allowance, travel expenses of workforce, delivery of machines), thousand BYN	0,00	5 238,98	0,00	691,72
Total costs incl. delivery, thousand BYN	38 676,73	49 890,39	5 106,59	6 523,53
Additional costs, thousand BYN	11213,65		1 416,93	

The analysis of data in Table 3 shows that the 15% increased fuel consumption rate and the 15% reduced productivity rate resulted in the additional losses of state forestry enterprise “Cherven leskhoz” to the amount of 11 213.65 thousand BYN. The 10% increased fuel consumption rate and the 15% reduced productivity rate led to the losses of state experimental forestry enterprise “Mozyr opytniy leskhoz” to the amount of 1416.93 thousand BYN. Thus, the costs of timber harvest and transportation during windblow clear-up operations increased by 20-25% as compared to normal conditions.

Infrastructure (roads, bridges, power lines, etc.) were badly damaged by the 2016 windblow. Forestry enterprises carried out repair and reconstruction of the forest roads that are used for the traffic of machinery involved in the recovery operations. The amount of financial support allocated from the public budget to repair and reconstruction of forest roads was 1.5 million BYN, including 1.0 million BYN allocated to the forest roads of state forestry enterprise “Cherven leskhoz” (Table 4).

Table 4 – Financial support allocated from the public budget to repair and reconstruction of forest roads

Forestry enterprise	Road length, km	Repair costs, BYN	Months					
			August		September		October	
			km	BYN	km	BYN	km	BYN
Borovlyany special forestry enterprise	26,8	200 000	15,0	110 800	11,8	89 200	–	–



Forestry enterprise	Road length, km	Repair costs, BYN	Months					
			August		September		October	
			km	BYN	km	BYN	km	BYN
State forestry enterprise "Smolevichi leskhoz"	41,7	300 000	17,0	120 000	17,0	120 000	7,7	60 000
State forestry enterprise "Cherven leskhoz"	150,1	1 000 000	50,0	298 300	50,0	350 800	50,1	350 900
Иторо	218,6	1 500 000	82,0	529 100	78,8	560 000	57,8	410 900

Apart from timber losses and increased costs of logging and forestry operations any adverse weather effects result in losses of forest ecosystem services.

Non-timber products include products of accessory forest utilization (mushrooms, berries, honey, sap, etc.) as well as products related to game, wildlife, nature and tourism. Calculations of non-timber losses from the past windblows have not been made by specialists of forestry enterprises and the Ministry of Forestry.

Calculations of indirect losses (soil and water impacts) from the past windblows have not been made by specialists of forestry enterprises and the Ministry of Forestry either.

International practices make us conclude that these losses can be important in the long term. To make reliable and accurate assessment it is advisable to develop methodologies for forest environment monitoring to obtain data necessary for assessment and calculations. For instance, it is required to have all data about damaged forest areas and harvest of non-timber products over the past periods in order to carry out comparative analysis and identification of losses.

In view of this fact, a review of the existing practices in Belarus and foreign countries has been made to develop a methodology for assessing economic losses and additional costs resulting from the recovery operations in forests.

The Republic of Belarus has no methodology for assessing damage from forestry catastrophic events. All calculations are made based on the existing Guidelines for Planning, Recording and Calculation of Prime Cost of Products (Works, Services) within the system of the Ministry of Forestry of the Republic of Belarus.

The Guidelines consider such costs as: raw materials; base and extra wages of workers; social security contributions; machinery maintenance and operation costs; general production expenses; general administrative expenses; other production expenses; sales costs.

Virtually, this methodology can only determine the prime cost of the harvested timber for further calculation of sales price.

The review of the existing European practices of assessing the consequences of forestry catastrophic events has shown that European countries do not have a uniform methodology for assessment of economic losses and damage done by natural disasters. As a rule, each country adopts its own methods that are best adapted to the economic, legislative, natural and industrial conditions. The review of the existing international methodologies for assessment of consequences of forestry catastrophic events has shown that the currently available methods of calculating and assessing of losses are either universal or specific depending on the character of the event.

Universal methodologies can be applied to all types of adverse weather effects. For instance, Poland and Croatia use such universal methods. Specific feature of this methodology is its universal character and recording of main cost items that affect the sum total of costs and losses. For instance, the methodology developed in Croatia is used for prompt assessment of damage and makes it possible to carry out a preliminary analysis of the range, intensity and cost of the damage done. Final assessment is made after the data on recovery operations and forest regeneration are available.

Specific methodologies for assessment of specific-type disaster aftereffects can be exemplified by the calculation methodology of forest fire damage in Italy, windblow damage in Ukraine.

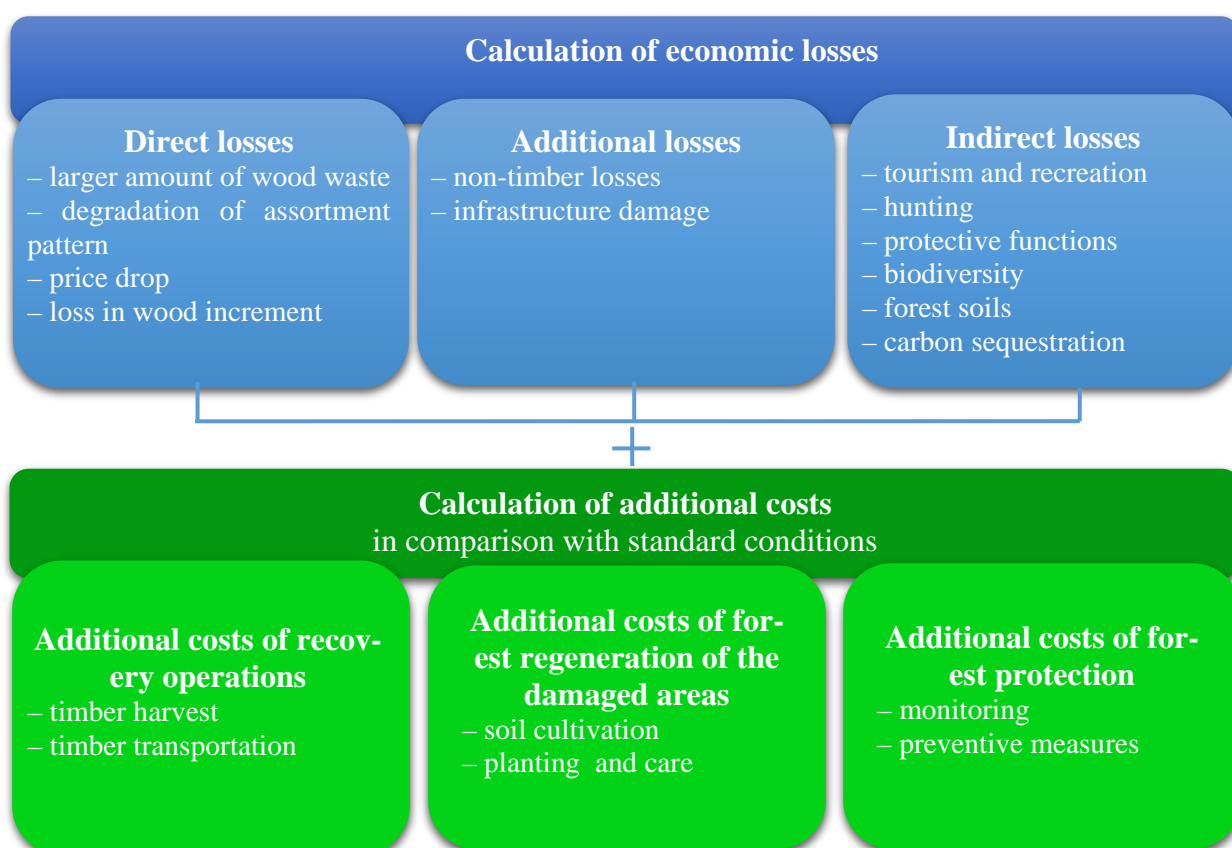
The review of European methodologies for assessing the consequences of forestry catastrophic events and their comparison to the Belarusian methodology has revealed their differences and highlighted some factors to be taken into account for more comprehensive and accurate assessment of damage.

For example, many European methodologies consider losses in the field of hunting, tourism, recreation, protective functions of forests, soil impacts, etc. In addition, they take into account losses in stand increment and time required to restore the forest stands. This results in increased forest protection costs that should also be taken into consideration.

Important points to be considered are labour safety costs, compensatory payments to people injured during recovery operations.

During discussion of methodology for economic assessment it was decided to develop a universal approach to assessing damage from various disasters in the Republic of Belarus. As has been shown by the comparative analysis, the lists of losses and basic costs for assessing damage from various disastrous events are virtually the same. Forest fires are the only exception here because of their specific character that requires assessment of additional costs of fire extinguishing operations, longer periods of restoration of the affected forest fund, etc.

**An improved methodology has been developed for the forest sector of the Republic of Belarus** based on the review of international and Belarusian best practices of rectification of consequences from forestry catastrophic events. The methodology enables comprehensive consideration of affecting factors and ensures more accurate assessment. The developed methodology is based on the approach that splits the economic damage from a catastrophic event into losses and costs (Figure 5).



**Figure 5 – Methodological scheme of economic assessment of losses and additional costs related to recovery operations after adverse weather effects**

*Source: authors' development*

Some indicators will be defined based on the existing Guidelines for Planning, Recording and Calculation of Prime Cost of Products (Works, Services) within the system of the Ministry of Forestry of the Republic of Belarus. These costs include timber harvesting and timber transportation costs. Some indicators are to be defined on actual basis, e.g., costs of reconstruction of buildings and facilities that belong to the enterprise.

The suggested methodology for economic assessment of losses and costs of several disasters makes both predictive and factual assessments possible. Calculation of main indicators after the recovery operations will provide more accurate data and detailed analysis of consequences of catastrophic weather events. Far more accurate data will be obtained at the level of individual forestry enterprises and forestry stations.

Thus, **total costs** of adverse weather effects can be calculated by the formula:

$$\sum CandL = L_{dir} + L_{add} + L_{indir} + C_{add} . \quad (1)$$

where  $\sum CandL$  – total costs and losses from adverse weather effects, BYN;

$L_{dir}$  – direct losses from a forestry catastrophic event, BYN;

$L_{add}$  – additional losses from a forestry catastrophic event, BYN;

$L_{indir}$  – indirect losses from a forestry catastrophic events, BYN;

$C_{add}$  – total additional costs of adverse weather effects, BYN.

Thus, **total direct losses** from a forestry catastrophic event can be determined by the formula:

$$L_{dir} = L_{ww} + L_{ass} + L_{pd} + L_{incr} , \quad (2)$$

where  $L_{ww}$  – losses associated with larger amount of wood waste, BYN;

$L_{ass}$  – losses from the degraded assortment pattern of the harvested timber, BYN;

$L_{pd}$  – losses from market price drops of timber, BYN;

$L_{incr}$  – losses from decline in annual increment in the damaged areas, BYN.

Thus, **total additional losses** from a forestry catastrophic event can be determined by the formula:

$$L_{add} = L_{nt} + L_{fr} \quad (3)$$

where  $L_{nt}$  – non-timber losses in the damaged forest stands, BYN;

$L_{fr}$  – losses from forest road damage, BYN.

Thus, **total indirect losses** from a forestry catastrophic event can be calculated by the formula:

$$L_{indir} = L_{t/r} + L_{hunt} + L_{prot} + L_{bio} + L_{f.s.} + L_{cs} . \quad (4)$$

where  $L_{t/r}$  – losses in tourism and recreation, BYN;

$L_{hunt}$  – losses in hunting sector, BYN;

$L_{prot}$  – losses from degraded protective functions of forest, BYN;

$L_{bio}$  – losses from degraded biodiversity, BYN;

$L_{f.s.}$  – losses from forest soil damage, BYN;

$L_{sc}$  – losses from reduced carbon sequestration, BYN.

**Total additional costs** of adverse weather effects can be calculated by the formula:

$$C_{add} = \Delta C_{harv} + \Delta C_{for} + C_{prot} , \quad (5)$$

where  $\Delta C_{harv}$  – additional costs of damaged trees harvest and clear-up operations on affected, BYN;

$\Delta C_{for}$  – additional costs of forest regeneration after adverse weather effects, BYN;

$C_{prot}$  – costs of forest protection, BYN.

The report contains calculation methods for any constituent factor of the above formulas.

The suggested methodology served as a basis for assessing losses from the 2016 windblow. The calculations were made for the affected forest area (various damage degree, including small damage) of 110 thousand ha. The volume of timber loss was considered as 6 million m<sup>3</sup>. The obtained values were compared to the results of assessment by the existing methodology. The calculation results are given in Table 5.

Table 5 – Results of the assessment of the 2016 windblow effects by the existing and the suggested methodologies, BYN

Indicators	Methodology	
	existing	suggested
<b>Direct losses</b>		
- formation of additional volume of wood waste	–	1 140 000
- degraded assortment pattern of timber	–	44 175 840
- price drop of round timber	–	-14 143 200
- decreased wood increment in damaged stands	–	13 398 000
<b>Total</b>	–	<b>44 570 640</b>
<b>Additional losses</b>		
- non-timber losses	–	127 015
- damage to forest roads	1 500 000*	1 500 000*
<b>Total</b>	<b>1 500 000</b>	<b>1 627 015</b>
<b>Indirect losses</b>		
- tourism and recreation	–	93 625
- game management	–	58 427
- protective functions of forest	–	–
- biodiversity	–	–
- forest soils damage	–	–
<b>Total</b>	–	<b>152 052</b>
<b>Recovery operations costs</b>		
- timber harvesting	109 053 061	109 053 061
- timber transportation	57 207 857	57 207 857
- other costs (subsistence, relocation of people and machinery)	19 782 617	19 782 617
<b>Total</b>	<b>186 043 535</b>	<b>186 043 535</b>
including additional costs:		
- harvesting of damaged trees and clear-up of damaged areas	–	40 929 680
<b>Additional costs</b>		
- forest regeneration after natural disaster	–	1 914 000
- forest protection	–	–
<b>Total</b>	–	<b>1 914 000</b>
<b>Total costs and losses from natural disaster</b>	<b>187 543 535</b>	<b>234 307 242</b>

\* – Borovlyany spetsleskhoz, state forestry enterprise «Smolevichi leskhoz», state forestry enterprise «Cherven leskhoz»

Analysis of the calculations shows that salvage/clear-up operation costs after the 2016 windblow amounted to 186 044 thousand BYN, road reconstruction costs to 1 500 thousand BYN, which is 187 543 thousand BYN in total. These costs were determined by the existing methodology used by forestry enterprises.

The suggested methodology makes it possible to assess direct, additional and indirect losses as well as additional costs of recovery operations after adverse weather effects. Thus, the salvage/clear-up operation costs (186 044 thousand BYN) include additional costs arising from the severe conditions of machinery operation (reduced rates of performance, increased fuel consumption rates and maintenance costs of machinery, increased costs of relocation of machines, workforce and expert personnel, subsistence expenses) totaling 40 930 thousand BYN (22%).

Besides the suggested methodology makes it possible to assess other indirect losses and additional costs that amounted to nearly 46 764 thousand BYN or 25% of the total costs of recovery operations after the catastrophic event. The most considerable losses are from degraded assortment pattern of timber (44 176 thousand BYN), decreased wood increment in damaged stands (13 398 thousand BYN), additional amount of wood waste (1 140 thousand BYN), additional costs of forest regeneration (1 914 thousand BYN). Nevertheless, it should be noted that prices of timber increased for main stock items (including exported timber) that resulted in the reduction of direct losses by 14 143 thousand BYN.

Thus the calculations made by the suggested methodology allow us to conclude that total losses and costs of the 2016 windblow amounted to 234 307 thousand BYN. As compared to normal conditions of timber harvest and forest regeneration, additional costs and losses amounted to 89 193 thousand BYN. The existing methodology records only 40 930 thousand BYN thereof. So, about 48 263 thousand BYN was not recorded. This sum can be attributed to either direct losses from aggravated commodity structure of timber or additional costs of forest regeneration or future lost income from non-timber products, tourism and recreation, game management, etc.

It is worth mentioning that it is still not possible to assess losses from reduced forest protective functions, biodiversity, forest soil damage, etc. that occur as a result of natural disasters. These losses can be a focus of further studies.

The results of the study make **the following conclusions** possible:

1. Extensive damage of forest stands by forestry catastrophic events can:

- alter forest ecosystems, natural habitats and forest stand structure;
- disturb forest management goals;
- aggravate economic situation of forest owners and woodworking enterprises and have a negative effect on timber markets.

As a rule, these consequences have long-term effect. Restoration of the forest fund can take about 30 years on average.

2. Planning and implementation of recovery operations is crucial in order to mitigate negative aftereffects of natural disasters. Proper measures must be taken on an immediate basis because any delay can cause more serious and longtime consequences.

3. European countries use the following action plan in response to adverse weather effects which is very similar to that in the Republic of Belarus:

- prompt assessment of damaged areas;
- measurement, marking and harvesting of timber on the affected areas;
- partial revision of forest management plans;
- reconstruction of damaged infrastructure or construction of new infrastructure facilities;
- prompt restoration of damaged stands by sanitary cuts and subsequent forest regeneration.

4. The required measures and actions of rectification of natural disaster aftereffects are laid down in relevant regulatory documents and guidelines. The European countries have drafted about a dozen of such documents. Currently the most comprehensive effective guideline is the Forest Crises Management Advisory Guide which can be accessed at [waldwissen.net](http://waldwissen.net) and [riskplatform.org](http://riskplatform.org). The document highlights the importance of preparatory operations prior to wood harvest in order to prevent secondary forest damage by subsequent pest outbreaks.

The following order of the harvesting operations in damaged areas must be observed:

- create transport accessibility of the damaged areas;
- priority harvesting of commercially valuable timber;
- removal of individual damaged trees to prevent secondary damage by pests;
- clear-up of large windblow affected areas;
- long-term conservation of timber of resilient species;
- harvesting of low-grade and small-sized timber of broadleaved species is to be done in the last run.

5. Rectification of natural disasters aftereffects involves a big number of operations to be done within a short period of time. This fact results in increasing costs of the work done which negatively affects the prime cost of the harvested timber and harvesting revenues. Besides, costs of forest growing and regeneration become higher as well, the increment of stands goes down.

Another negative factor affecting the business of forestry enterprises is the market price drop for timber which happens for several reasons:

- larger volumes of timber are supplied onto the market;
- the quality of timber harvested from the damaged areas is lower;
- the assortment pattern of the marketed timber is changed

International studies show that timber price drops may widely range, i.e., from 10 to 90%. Therefore, the revenues from timber sales go down considerably because of the dramatic timber price drops. The harvesting costs demonstrate slight rise thus leading to revenue shortfalls of forestry enterprises by nearly 80%.

6. The review of the existing methodologies for economic assessment of disaster consequences has shown that there is a variety of tools and procedures applied in European countries. However, in many cases the methodologies are not immediately available or applicable or written in a national language or accessible to experts only. The methodologies cannot be used in another country/region, however, they may contain certain relevant aspects or serve as a benchmark for developing similar methodologies in other countries/regions. Thus, the review of domestic practices of assessing the consequences of natural disasters as well as the review of international practices have made it possible to develop a methodology which differs from the currently existing one. The suggested methodology assesses a wider range of losses (associated with reduced wood increment; harvest and sales of mushrooms, berries, honey; infrastructure and facilities; hunting, tourism and recreation) and additional costs of salvage-clear-up operations on the windblow affected areas, subsequent forest regeneration, forest care and forest protection against secondary and tertiary damage by diseases, pests and invasive species.

The study can serve as the basis for **the following recommendations** for assessment and recovery operations after natural disasters under the conditions of the forest sector in the Republic of Belarus:

1. The required measures and actions of rectification of natural disaster aftereffects must be laid down in relevant regulatory documents and guidelines. The experience gained by the organizations of the Ministry of Forestry of the Republic of Belarus during the recovery operations after the windblow of July 2016 must be incorporated and taken advantage as the review shows that all the arrangements and planning were performed at a high level. International practices should be used in such fields as prediction of risks and damage to forest stands affected by adverse weather effects; development of recovery action plans; development and use of various insurance packages; long-term conservation of the harvested timber; decision-making approaches to restoration of forest stands; communication with stakeholders; monitoring and control of future forest damage, etc.

2. The documents must contain the points related to planning, organization, coordination and control of the proper operations:

- creation of command centres for logging operations in the most affected forestry enterprises/daily briefings of command centres;
- planning of harvesting operations;
- creation of temporary checkpoints of forest guards;
- creation of maintenance and repair stations for machinery;
- ongoing monitoring of damaged and neighboring areas, determination of logging deadlines;
- involvement of forest workers from other forestry enterprises in logging operations in windblow affected cutting areas;
- overtime work of forest workers of the most affected forestry enterprises;
- necessity for additional funding due to more complicated technology of the operations, reduced productivity rates, increased fuel consumption rates, degraded assortment pattern of timber. Additional costs (subsistence and other costs arising from relocation of people and machinery and workers' accommodation) must also be accounted for.

3. Practices of restricting timber harvest volumes during final fellings must be taken into consideration. This will prevent timber price drops due to suddenly bringing large volumes of timber onto the market.

4. In spite of the existing round timber export ban, it is advisable to allow exports of round timber coming from the windblow affected areas. It is the export sales of round timber from the

2016 windblow that made it possible to compensate for the increased expenditures and minimize the amount of public funding.

5. It can be effective to establish a special compensation fund for disaster damage under each state production forestry association. The funds will provide prompt assistance to forestry enterprises affected by forestry catastrophic events and minimize their financial losses.

6. Crisis management should be seen as a cyclic process. Larger efforts and costs at one stage can save time and money over the remaining parts of the cycle. Namely, more profound analysis of the past catastrophic events, proper training of personnel and implementation of preventive measures will ensure lower damage, costs and shorter time required to recover from the natural disasters.

7. It is recommended to use the universal methodology developed in the course of the study. Losses and additional costs arising from various natural disasters are very similar, demonstrate their effects during long periods of time and can considerably affect forestry, timber harvesting and timber sawing operations. At the same time, the methodology is not time-consuming because it uses the data collected and available at forestry enterprises to make calculations.

It is necessary to do further studies into more accurate assessment of damage such as weakened protective functions of forests, degraded biodiversity, soil impacts, etc. that are incurred by forestry catastrophic events and are of great importance.

## Introduction

This report has been drawn up within the study “Assessing the current losses and improving the economic analysis of the costs of the on-going climate related catastrophic forestry events based on international experience” funded by The Global Facility for Disaster Reduction and Recovery (GFDRR). This report was largely encouraged by the need to support the forest sector of Belarus to recover from the forestry catastrophic event of 2016 and to increase the resilience of Belarusian forests to future catastrophic windblows and other adverse weather effects.

The goal of the study is to improve the economic analysis of the impact of catastrophic weather events on Belarusian forests based on analysis of available research from the countries that have considerably advanced in this area as well as to develop recommendations on improvement of economic assessment with regard to the practices existing in the Republic of Belarus.

Global climate change has numerous negative impacts for the world community as a whole and for the Republic of Belarus in particular. The forest sector is challenged by the growing number and intensity of catastrophic weather events and the associated damage of thousands of hectares of forests. In 2011–2015 adverse weather events, forest fires and pests destroyed totally 50 thousand ha of Belarusian forests. Major damage to Belarusian forests was incurred by the 2016 windblows that proved to be the most intensive over the past 15 years. The damage was estimated at 22.5 thousand ha of the forest fund or 6 million m<sup>3</sup> of timber.

Assessment of current losses is required to mitigate economic losses, to plan recovery actions for forests and infrastructure, to enhance forest resilience to future adverse weather conditions. The review of the existing best European practices serves as a basis for making recommendations on improvement of economic analysis of costs related to forest damage by natural disasters.

The international practices were reviewed in close collaboration with expert Dr. Ch. Hartebrodt. The agenda of his visit to Belarus included working meetings with experts of the Ministry of Forestry of the Republic of Belarus and staff members of Belarusian State Technological University involved in the study.

A study visit of Belarusian experts of the forest sector including the head of this project, A.V. Lednitskiy was organized by the World Bank. The study visit was supported by The Global Facility for Disaster Reduction and Recovery (GFDRR) and the European Fund for Disaster Risk Management in the Forest Sector. It was aimed at studying the best international practices in the field of enhancing forest resilience and recovery of forests from natural disasters. The experts visited Baden-Württemberg (Germany) and Nouvelle-Aquitaine (France). The agenda of the study visit covered two areas: 1. Study of storm impacts and emergency actions under the conditions of Baden-Württemberg (Germany); 2. Exchange of best practices with experts of windblow risk management in Nouvelle-Aquitaine (France).

The study was done in close collaboration with authorities and experts of the Ministry of Forestry of the Republic of Belarus, state forestry production associations, local authorities, public and private companies that are subcontracted for timber harvesting, etc. State forestry enterprises “Cherven leskhoz”, “Starodorozhskiy leskhoz” and “Mozyr opytnyi leskhoz” contributed greatly to data collection.

A workshop prepared and held in order to exchange the findings and the recommendations of the study as well as to present the developed methodology for assessing economic losses from natural disasters in the forest sector. The conclusions made during the workshop incorporated in the final report.

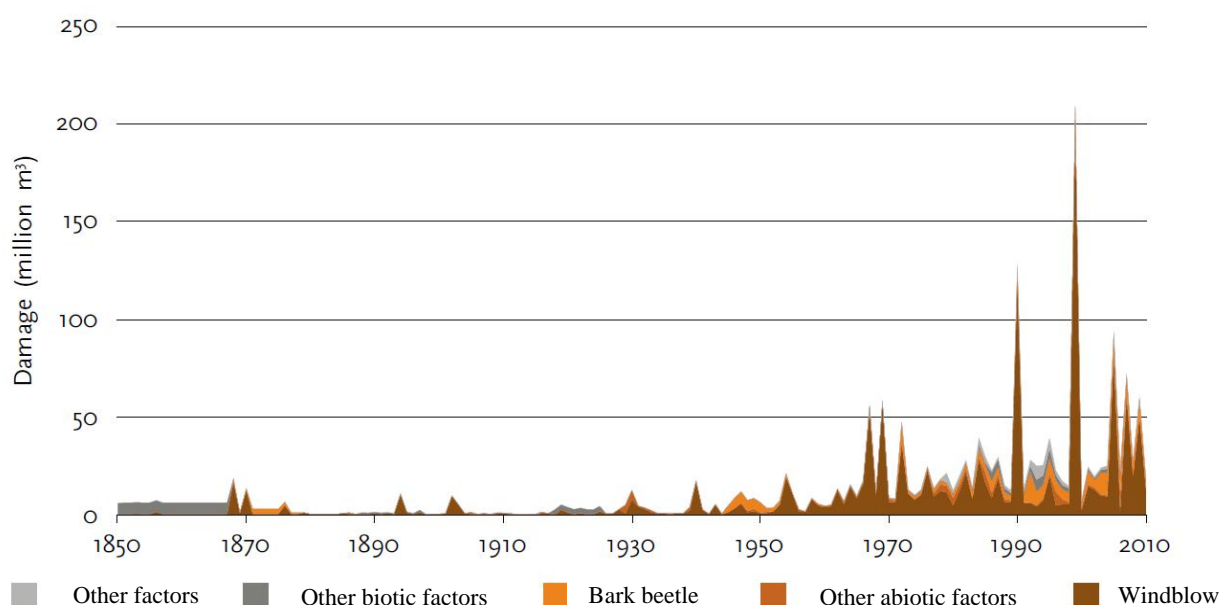


# 1 Analysis of windblow impacts on the forest sector, ways of rectification of windblow aftereffects and methods of economic assessment

## 1.1 Best practices of European countries in the field of assessment of losses and rectification of windblow consequences in the forest sector

### 1.1.1 Statistics of windblow damage in Europe

One of the key factors contributing to the forest stands damage in Europe is storms that develop into windblows. Figure 6 shows the dominating impact of storms on European forests as compared to other natural disasters. It should also be noted that the scope of forest damage by storms and windblows has considerably grown over the past decades as well as their frequency [1].



**Figure 6 – Total damage done to European forests (million m<sup>3</sup>) by various natural disasters (the category of “other factors” includes anthropogenic damage, unidentified factors and mixed factors)**

Source: EFI Report. Living with Storm Damage to Forests

The larger half of the wood harvest in Europe comes from the rectification of consequences of natural disasters. In the last years the number and the scope of the forest damage have increased. Large-scale windblows alter the landscape, natural habitats and forest stands structure. These events can prevent the European countries from achieving the objectives set in the field of sustainable forest management. They can also have an adverse effect on economic situation of private forest owners and woodworking enterprises as well as on the timber prices on the European markets.

Table 6 analyzes 11 most large-scale storms that occurred in Europe over the period from 1950 to 2010. The review of the Table makes it possible to reveal certain trends of suddenly bringing large volumes of timber onto the market. The storm damage causes sharp, unplanned rise in timber supply and affects timber prices and financial productivity of both the buyer and the seller. For instance, after the 2005 storm Gudrun the average prices of pine and spruce sawn timber in southern and central Sweden made only 63% and 83% of those in the preceding year respectively. The drastic price drop had serious negative impacts on forest owners and local residents. The timber price drop was less dramatic in other parts of Sweden outlying the storm area [2].

Table 6 – Characteristic of the forestry impacts from large-scale storms in European countries [1]

Countries	Storm name	Year	Loss, million m <sup>3</sup>	Market impacts	Direct losses, EUR billion
Scotland, Great Britain, the Netherlands	Storm	1953	1,8	–	–
Central Europe (mostly Germany)	A series of storms	1967	> 17,53	Roundwood prices dropped 1.6 times in Germany, timber prices fell by 10%	0,6
Sweden, Norway, Denmark	Storm	1969	Sweden – 42,2	–	–
The Netherlands, Great Britain, France, Belgium, Germany, Denmark, Poland	Storm	1972	25–28	Prices in the Netherlands dropped from 35-40 Dutch guilders per 1 m <sup>3</sup> to 1 Dutch guilder per 1 m <sup>3</sup>	–
England, France	Storm	1987	80	Initially the sawn timber prices dropped by 38% in England. For 7 consecutive years deciduous timber prices and sales volumes decreased by 25%. Sales were limited, extra costs associated with timber storage occurred.	–
Western Europe	Storms: «Daria», «Herta», «Judith», «Nana», «Ottilie» and «Polly», «Vivian», «Wiebke»	1990	Europe – 100, Germany – 72,5	Timber prices dropped dramatically due to lower quality and large volumes of timber on the market	Europe – 12,5
Western Europe	«Lothar», «Martin»	1999	France – 50–170	The market prices of timber went down by 50% in France. In 2000 the sales of timber increased by 49% as compared to 1999, however, their cost efficiency was by 7% lower	France – 6, Germany – 0,154
Slovakia	Storm in the Tatras	2004	5,3	Delayed woof harvest resulted in lower quality and timber price drop by 50%.	–
Sweden, Great Britain, Denmark, Latvia, Norway, Germany, Finland	«Gudrun» or «Erwin»	2005	Sweden – 75, Denmark – 2, Latvia – 5	–	Sweden – 1,2
Western, Central and Northern Europe	«Per» «Kyrill»	2007	Sweden – 12, Europe – 54	Timber price drop by 15% in Europe	Germany – 4,7
Western Europe	«Klaus»	2009	France – 43,1 Spain – 1,1	Before the storm the price of pine timber was ranging from 1 to 45 EUR per 1 m <sup>3</sup> . In 2009 the prices dropped to the level of 1-10 EUR per 1 m <sup>3</sup>	All Europe – 3

It should be noted that windblow impacts on forest ecosystems are usually felt for a long

period of time. Thus, the storms can be followed by secondary forest damage by pests, forest diseases and forest fires. These factors produce additional economic burden in the forest sector due to reduced sustainability and lower quality of the remaining standing forests and damaged trees.

### 1.1.2 Planning and implementation of rectification of the consequences of windblows and forest restoration methods

**Long-term effect of natural disasters in the forest sector.** Forests have positive impact on climate, oxygen generation, air purification, groundwater level control, erosion and landslide prevention, health of people and biosphere. Therefore, forest cuts or their full destruction by natural disasters has very serious implications. For these reasons, European experts and scientists focus not only on natural disasters alone, but on the time of their action on forest ecosystems, biodiversity and economy (Box 1).

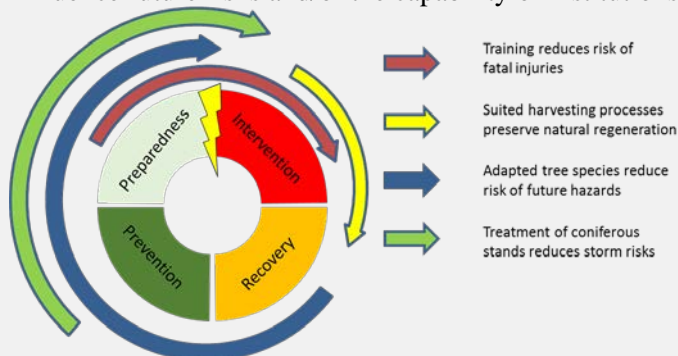
Adverse weather effects on forests (both individual trees and whole forest stands) alter their resistance, structure, quality and value to various extents. This calls for emergency measures and completely new approaches to actions on mitigation of long-term effects of natural disasters.

#### Box 1: Risk and Crisis Management in the Context of Climate Change

There is a wide consensus amongst scientists and (inter alia) actors in the field of civil protection, that the significance of natural hazards will increase in the nearer or further future as a consequence of climate change. Besides the continuing need to improve the capacities in overcoming hazardous events the risk and crisis management community focuses more and more on prevention and preparedness.

Whereas crisis management activities in the forestry sector focuses on the recovery phase, a future challenge is to adopt a perception of crisis management as a cyclic process.

The depicted figure XX gives a small selection of examples of how activities in individual phases will influence future risks and/or the capability of institutions to cope with them.



Crisis Management Cycle and interdependencies between phases

Increased efforts and expenses in one phase might result in reduced needs for time and money along the rest of the cycle. Thus, any kind of evaluation must basically focus on the whole cycle. Unfortunately, the long-term nature of forestry makes such a long-term holistic evaluation difficult and uncertain to some extent. However, it is important to keep the long-term nature of forestry always in mind and at least conduct a qualitative documentation and monitoring on expectable long-term effects, which can serve as explanation for unexpected outcomes in respect of single aspects or periods in the whole life of a stand or even a forest enterprise.

At the same time, failure to take short-term immediate actions on rectification of consequences and forest restoration will lead to serious long-term effects. However, even though the

necessary actions are taken within several months after a natural disaster, the damage and related consequences will appear for a long period of time. Usually the restoration of a damaged forested area takes about 30 years. This being the fact, the long recovery periods of forest stands and non-timber resources must be taken into account when assessing the negative impacts of forest damage by natural disasters [3].

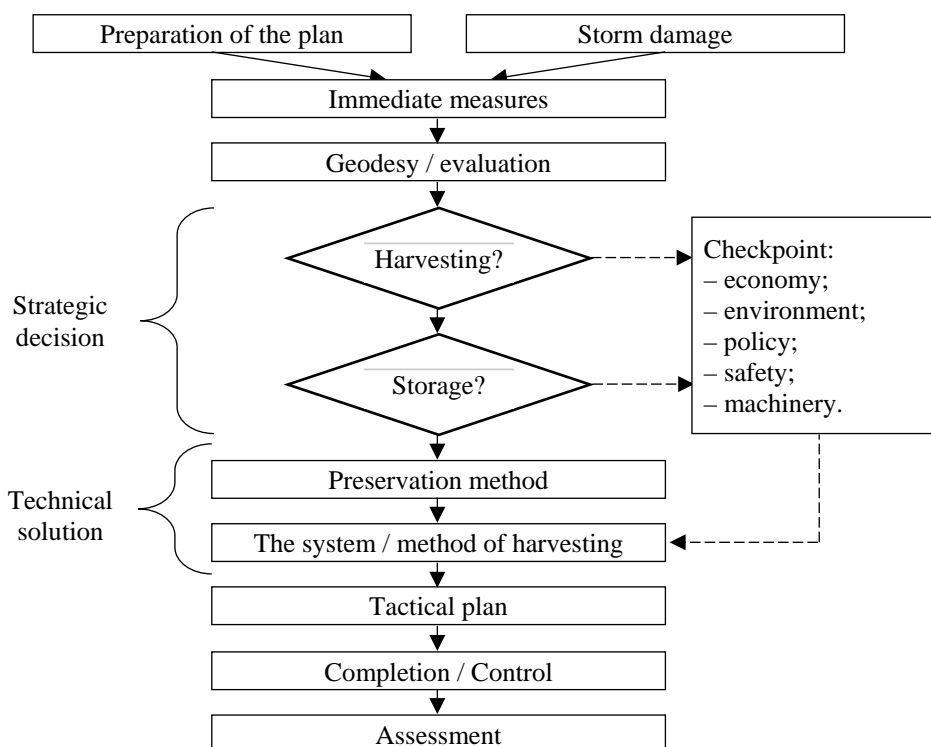
**Planning of harvesting operations in windblow affected areas.** Since the late 1990s the number and the intensity of natural disasters have considerably increased in Europe. This required a special regulatory document that would prescribe the procedures for damage assessment, establish the order and give recommendations on rectification of natural disasters consequences, clear-up operations, forest regeneration, timber storage, timber sales, etc. In the recent years several regulatory and guidance documents have been drafted in European countries for these purposes [4–11].

All the guidance documents contain relevant information on various aspects. However, the Forest Crises Management Advisory Guide which can be accessed at [waldwissen.net](http://waldwissen.net) can be regarded to be the most comprehensive guiding document. Most similar documents focus largely on technical aspects and give some information on natural disasters strategic management [4, 7].

The document [4] highlights the importance of preparatory operations prior to wood harvest and outlines the following points:

- optimal crisis management;
- workforce and machinery management;
- selection of appropriate technology and methods;
- logistics;
- assessment of financial costs.

For management purposes the guide gives a model of planning and implementation of harvesting operations (see Figure 7).

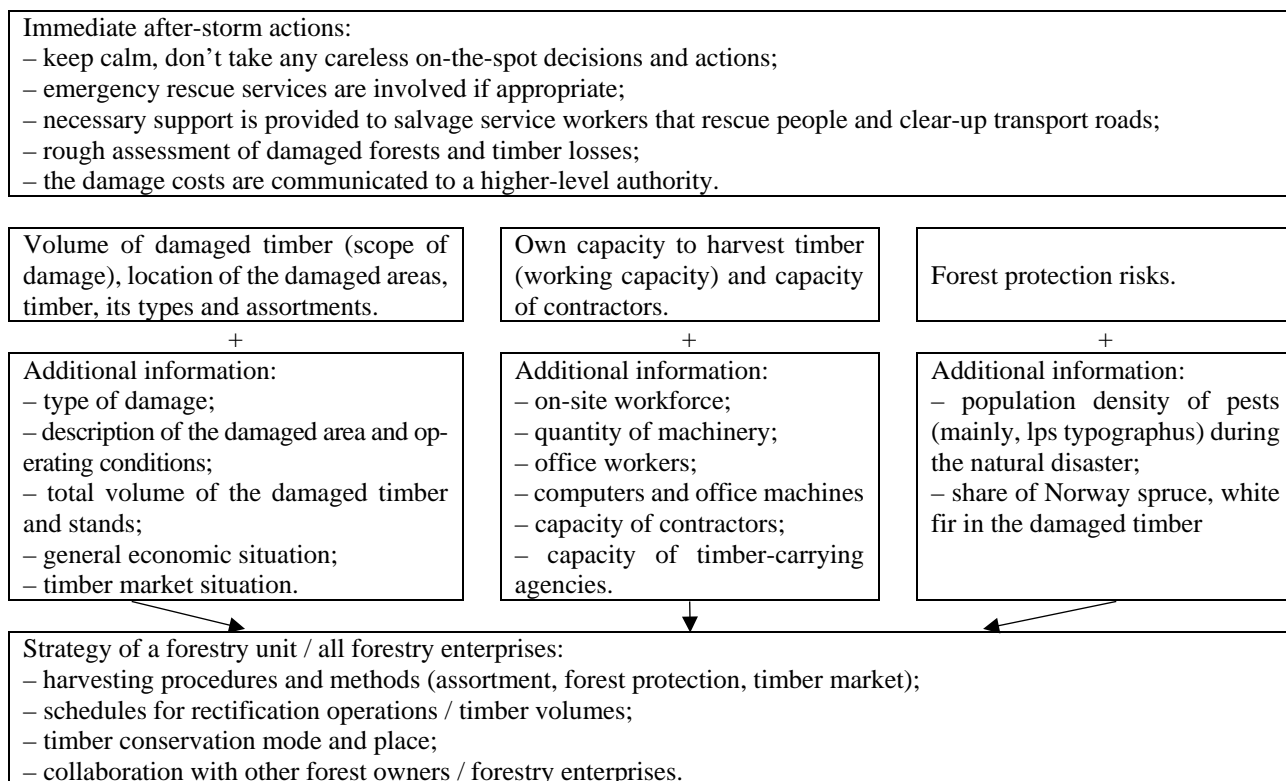


**Figure 7 – Decision-making chart for harvesting and conservation of storm damaged timber**

Source: Technical Guide on Harvesting and Conservation of Storm Damaged Timber. Stodafor Report

It can be seen from the figure 7 that an important aspect is planning of the operations before the natural disaster and immediately after it has occurred. The planning requires a strategic approach towards efficient and safe working conditions in the damaged areas.

The document [7] gives a more generalized chart that can be applied to develop strategies for rectification of natural disasters consequences and clear-up/recovery operations in damaged forests (Figure 8).



**Figure 8 – Development of strategies for rectification of storm consequences**

Source: Handreichung Sturmschadensbeteiligung. Hrsg. Landesforstverwaltung Baden-Wurtemberg und Landesforsten Rheinland-Pfalz

**Actions after natural disasters.** All actions to be taken after natural disasters include timber measurement, marking and harvesting; partial revision of forest management plans; reconstruction of the damaged forest roads and construction of the new ones. Besides, the actions include operations on immediate restoration of the damaged stands by means of sanitary cuts and forest regeneration.

Practices of recovery operations in European forests make it possible to draw some conclusions for more efficient decision-making during disaster clean-up operations in the future (Box 2).

**Box 2: European experience in eliminating the consequences of natural disasters**

It was evident, that the forest sector was only partially prepared for such type of natural hazards. In the first month, a lot of decisions were made which proved later as being imperfect and weakly informed. There are several studies, which provided evidence that in the first month the number of fatal injuries was extremely high, whereas it normalized after four months.

Based on the experience, there are main lessons learned:

- Due to the low frequency of these events, it is unlikely that practical and appropriate experiences are in place. The preparedness of the forest enterprises and the managers was poor.

- The awareness or even the willingness to use external help and advice when developing a management strategy for the respective event was lacking.
- Additionally it has to be mentioned, that availability and accessibility of experts was low. There is a high need for information, advice and support provided from the central management units, albeit the operative strategies for overcoming the situation should be better developed on the local level.
- Due to shortages of transportation capacity frequently an imbalance between harvesting and shipping occurred, which caused logistical problems and an increase of degradation of timber with negative financial outcome.
- In many cases, the primary objective was to overcome the intervention period after the hazardous event as soon as possible, which is technically possible as a result of modern and highly efficient harvesting technology. This led in many cases to imperfect outcomes in various aspects. Especially the high number of fatal injuries in the first month after the event was a sad and basically unacceptable outcome.

In order to take immediate recovery actions through forest cutting and forest regeneration, the experts make an on-site assessment of the damaged forest stands. In order to assess how severe the disaster consequences are, we calculate the damage as the percentage of the total affected area or timber volume or the relation between annual regular cuts and after-disaster cuts (Box 3).

**Box 3: Assessment of the severity of the consequences of natural disasters**

There is a wide consensus that the degree of damage as a percentage of the growing stock (in terms of hectares or volume) is an appropriate way to characterize the overall dimension of the disaster. Another frequently applied method to define the severity of a storm event is the ratio between the regular amount of fellings per year and the amount of fellings due to the hazardous event. From empirical evidence the following differentiation into degrees of severity seems to be appropriate:

Ratio: Unplanned fellings [m <sup>3</sup> /year] / Normal fellings [m <sup>3</sup> /year]	Severity of hazardous event
< 1.0	moderate
1.0–3.0	relevant
> 3.0	severe

Nevertheless, with regard to the assessment of damages it has to be concluded that the possibilities of interpretation and comparison across Europe are limited by the lack of a standardized system of damage reporting. Therefore, significant uncertainties remain in the evaluation and comparison of individual events.

After timber harvesting and clear-up operations in the quarter area, the other damaged areas are cleared up and restored by using the revised standard marking of trees.

It has to be mentioned that damaged stands call for immediate restoration in order to protect forest soils and to prevent erosion on steep slopes and nutrient-poor soils areas that can be washed by abundant precipitation. Tree marking and measurement as well as recording of all damaged trees must be done depending on the extent damage to the forest stands. The trees that are able to self-recover must be left in the forest, while those that are marked during taxation are to be cut.

New forest roads and tracks must be designed and constructed if necessary. These roads must ensure transportation of all timber harvest from the affected areas with minimum damage done to the future forest stands.

Upon the harvesting operations the assessment of undergrowth and young stands left for further growing. Afterwards forest planting operations are to be done. Part of the damaged forested

areas must be planted with deciduous trees (8000 pcs/ha) and coniferous seedlings (1000 pcs/ha) to create mixed forest stands that will be more resistant to storm winds [3].

In the light of modern studies, practical experience and operating conditions, a sequence of clear-up/recovery operations in the storm damaged forest areas has been suggested in central Europe:

1. It is necessary to ensure access to damaged areas and conditions for the transportation of the harvested timber.

2. Commercially valuable timber must be harvested first – minimum quality class B and size L 3b (medium diameter > 35cm) (3a > 30 cm). Cutting operations are first done on large areas (within 4 month after the storm), then individual lying trees are taken out (within 8 months after the storm). Maximum economy must be ensured when harvesting and processing of small-sized and low-grade deciduous timber because of its high harvesting costs per unit.

3. In order to minimize secondary damage by pests, it is necessary to take out individual lying trees and clear up small “split-nests”, in particular in spruce and pine stands. Handling of “split-nests” is done by hand-held power tools.

4. Clear-up of large windblow areas in Norway spruce and pine stands is to be carried out within 15 months after the natural disaster. Private organizations and contractors are involved when required. In case there is no market demand for timber or no possibility of wet conservation of timber, the clear-up operations in such areas can be postponed for a more extended period. This measure is particularly appropriate for large damaged areas with a less than 20% share

5. The clear-up operations can also be postponed for damaged fir stands if appropriate. The experience of the 1990 storm showed that bark beetles attacked fir stands in a less aggressive manner, so long-term timber conservation (24 months) was made possible.

6. Harvesting of valuable timbers of oak must be done only on demand. Both types of timber can be stored on damaged areas for 12–24 months without harvest.

7. Harvesting of small-sized coniferous trees (breast height diameter < 20 cm) and commercial deciduous species is of secondary importance.

By the 1990 experience it can be concluded that risks of pest outbreaks can be controlled if the above recommendations are observed. Minimum risks of pest attacks were registered in broadleaved forests.

### **1.1.3 Analysis of suddenly bringing large volumes of timber onto the market**

**Changes in prices for timber.** Along with the aggravation of the general conditions of forest stands the natural disasters considerably affect the economy of forest owners and forest users in the region. This can be explained by dramatic drop of timber prices due to suddenly bringing large volumes of timber onto the market. Besides the timber coming onto the market in the future cannot be sold at the expected price for rather long onward period. The price drop is caused not only by the large market supply of timber but also by the low quality of the timber marketed. Moreover, the range of timber that is traditional for the market is also disturbed because of the lower price and quality. All these factors negatively affect the profit of harvesting companies.

As many operations are to be done within a short period of time, their costs are likely to increase. So, the sales income is bound to go down. In addition, the costs of forest growing and regeneration will go up in the long term. After several years the increment of forest stands will decrease due to higher risks of secondary damage by pests and diseases as well as by changing environmental conditions.

One of the key factors of the economic impact of natural disasters is the factor of timber price drop, in particular in case of large-scale adverse weather effects. The price drop may have a large range (Table 7).

Table 7 – Minimum and maximum timber price drops

Indicator	Maximum	Minimum
Coniferous logs (standing sale)	> -70%	> -40%
Coniferous logs (upper yard sale)	< -50%	approx.-15%
Broadleaved (standing sale)	> -75%	approx.25%
Broadleaved (upper yard sale)	approx. -50%	approx.-10%

The reference source [12] gives information about the price drop of green wood after large-scale damage. Figure 9 shows the firewood price dynamics in Germany (diameter  $d = 30-35$  cm).



Figure 9 – Firewood prices after the Lothar storm in German state forests

Source: Hanewinkel and Peyron (2013)

The reference source [13] gives similar data on assortments of various diameters (quality grade B). However, the data do not provide valuable insight into all relevant effects on the timber market (Figure 10).

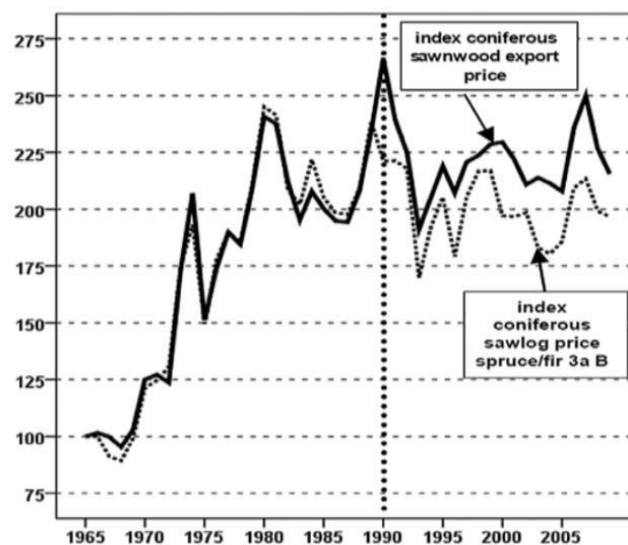
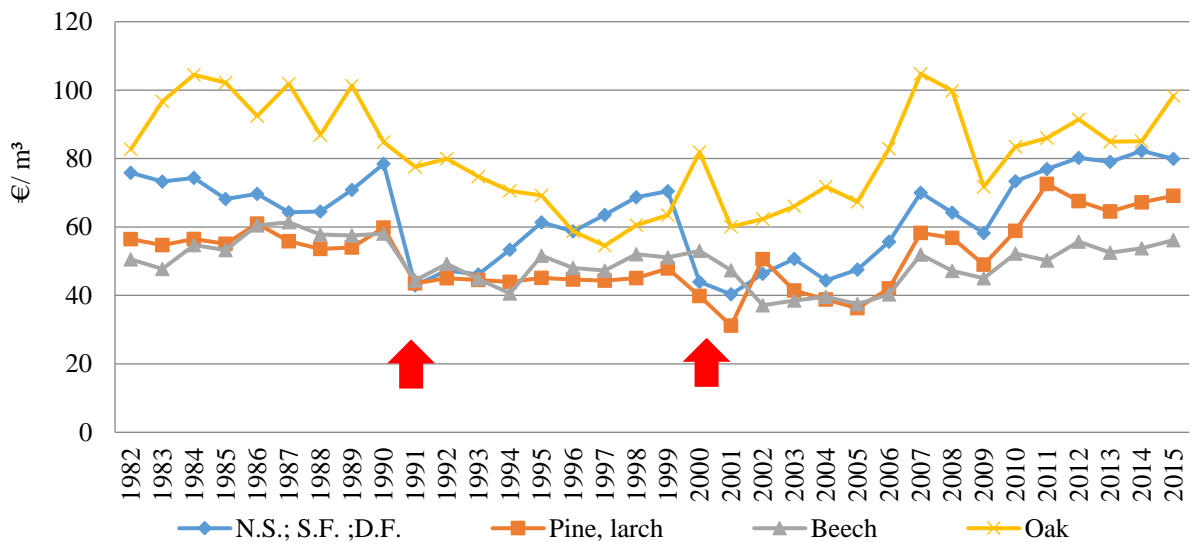


Figure 10 – Price dynamics of assortments and timber after the 2005 storm in Sweden

Source: Schwarzbauer and Rauch (2013)



Almost all studies compare prices before and after adverse weather effects across years. On the one hand, this information makes the heavy impact on the timber market evident. On the other hand, we must take into account that it does not give insight into the implications of such impact. Another important parameter is the rate of timber market recovery. Figure 11 shows the price dynamics and price differences across tree species in the light of the past storm event. After the 1990 storm it took 10 years for the timber market prices to recover. Among other things the price dynamics of various tree species was different. For instance, timber of Norway spruce and beech experienced more dramatic price drop and subsequent growth, whereas oak timber prices were not heavily affected by the past natural disaster.

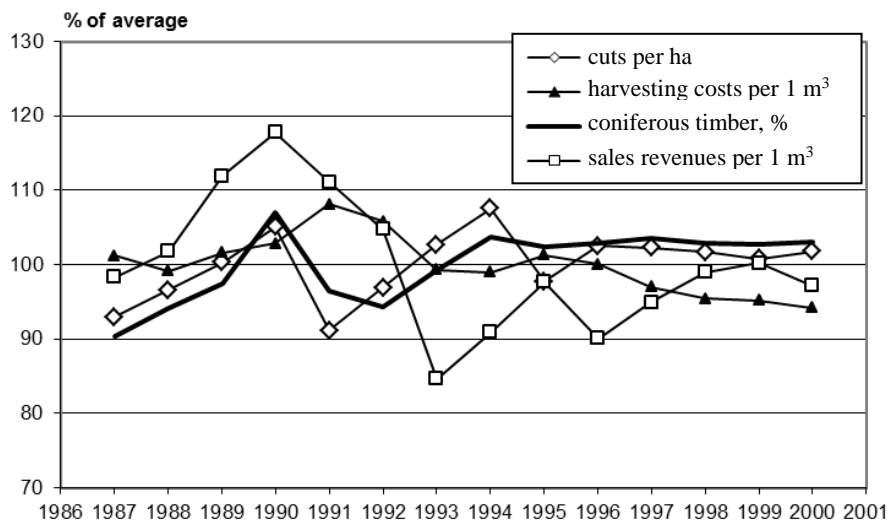


**Figure 11 – Timber prices in State forests BW in 1982-2015**

Source: TBN BMEL, own data

**Holistic assessment of profit loss due to market disturbances.** Since the total income results from sales of various grades and assortments of timber, the financial effects can only be estimated by the total price for a certain timber type. This being the case, this parameter shows the difference between the assortment type and its quality.

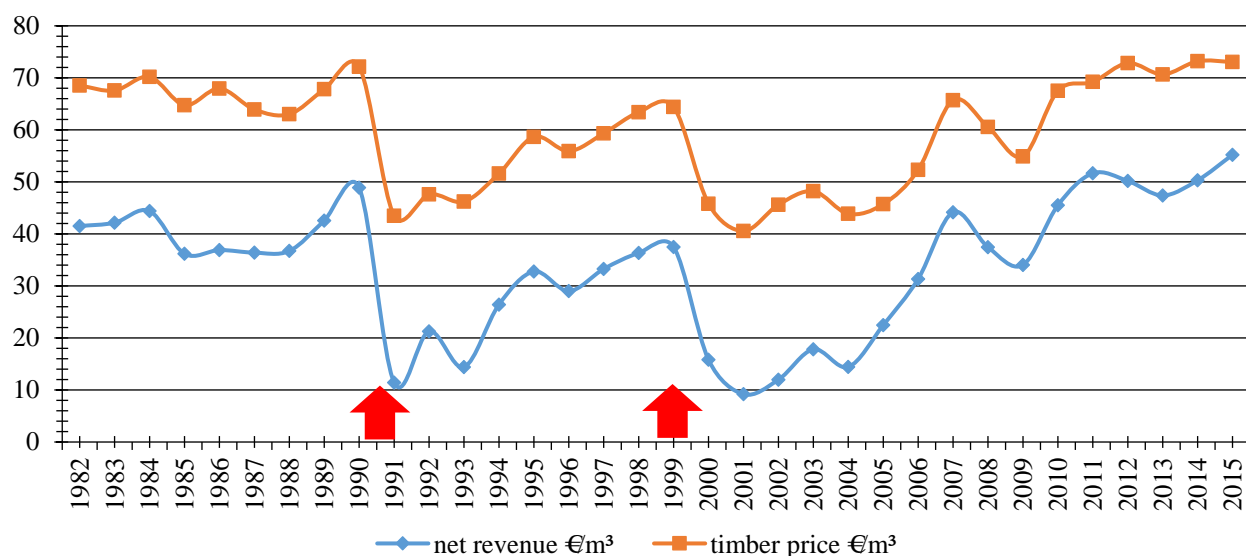
The reference source [14] illustrates that this parameter went down after the 1990 and 1994 storms (Figure 12).



**Figure 12 – Sales revenues (and other parameters) and storm events**

Source: Sekot (2002)

Similar information is given by the State Forestry Enterprise of Baden-Württemberg. Besides it can be mentioned that net revenues considerably decrease (%) as the timber prices drop. As a result the costs of timber harvest are affected only slightly (Figure 13). For instance, after the 1991 storm the 80% net profit drop was registered (Table 8).



**Figure 13 – Timber prices and net profit per 1 m<sup>3</sup> in the State forestry enterprises of BW**  
*Source: BMEL, own data*

**Table 8 – Minimum and maximum movements of timber prices and net profit**

Indicator	Maximum	Minimum
Timber price, €/ m <sup>3</sup>	Approx. –40%	Approx. –25%
Net profit, €/ m <sup>3</sup>	Approx. –80%	Approx. –60%

#### 1.1.4 Review of international methodology for assessment of losses from windblows

Forestry catastrophic events usually result in more intensive forestry operations and simultaneous cost increase and decline in profits from timber sales. However the economic consequences of the adverse weather effects cannot be predicted in their entirety and their level and economic costs cannot be assessed due to the diversity of accidental events, their intensity, spatial distribution, duration as well as other factors related to the national forest economy. At the same time natural disasters are an integral part of forest management and their economic analysis must be done on a large scale in order to minimize negative effects from future catastrophic events [15].

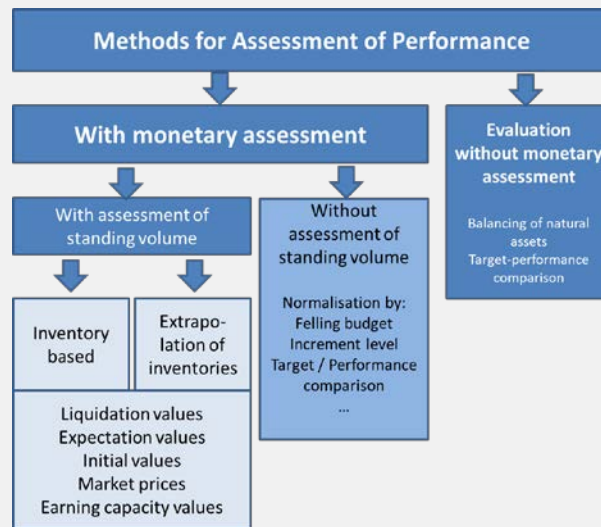
European countries do not have a uniform methodology for assessment of economic losses and damage done by natural disasters. As a rule, each country adopts its own methods that are best adapted to the economic, legislative, natural and industrial conditions (Box 4).

The review of the existing international methodologies for assessment of consequences of forestry catastrophic events has shown that the currently available methods of calculating and assessing of losses are either universal, i.e., they can be applied to all types of adverse weather effects, or assess the consequences of a given natural disaster. For instance, Poland and Croatia use such universal methods [3, 15]. Specific feature of this methodology is its universal character and recording of main cost items that affect the sum total of costs and losses in the economic assessment of consequences from various natural disasters.

At the same time specific methodologies for assessment of windblow aftereffects have been developed and are being applied. Similar methodology has been developed and is being applied in Ukraine [16]. The methodology of ecological-and-economic windblow assessment involves calculation of two constituent losses from windblows, i.e., ecological and economic. The calculation of economic losses is made as follows.

#### Box 4: Methodology for the Assessment of Large Scale Disasters

Taking into account the storm events that took place in the past, it is proposed to use the following approaches in the assessment of natural disasters.



Overview on assessment methods of overall performance

The performed analysis of the studies showed, that most authors focused on monetary assessments, using one of these methodological ways. The choice of the method and contents of the studies are frequently depending on the availability of data. Thus, various results were provided which in many cases cannot be compared directly in terms of total costs or consequences, due to the diversity of methods and data used for calculation.

The monetary assessment is mostly much more concrete than the assessment of social and ecological values. However, they underline that this type of analysis would be especially suited to provide a deeper understanding of the mode of “functioning” of natural hazards and that this knowledge is needed for the development of appropriate procedures for prevention and overcoming of natural hazards.

Two reasons can be seen as key explanatory factors for this imbalance between monetary assessment and non-monetary evaluation:

- The assessment of social and ecological consequences is much more complex from a methodological point of view and there is frequently no way to make a summarizing balance of consequences.

- In contrast to the economic data, which were recorded permanently (e.g. related to needs for taxation purposes) frequently no reference values of the situation before (or without) the existence of the natural hazard are available, and consequently a proper assessment is impossible due to missing data.

**Economic assessment of losses from lower quality of assortments and economic value of commercial timber** is made by comparing the assortment structure of harvested timber and material and monetary assessment of the standing wood stock before and after the windblow. The assortment structure of the undamaged stand is defined by the data of the most recent forest inventory. The assortment structure of the windblow damaged stand is based upon the material and monetary assessment which is done when the stand is allocated for cutting. The difference between the monetary value of the two structures is fixed as losses arising from the degraded quality of windblow timber. The difference can be calculated by the formula:

$$L_{as} = V_{bw} - V_{aw}, \quad (6)$$

where  $L_{as}$  – timber losses due to the altered timber assortment structure;

$V_{bw}$  – value of timber before the windblow;

$V_{aw}$  – value of timber after the windblow.

**Losses from timber undersupply** are calculated by establishing the difference between the timber stock that a stand is supposed to have for final felling ( $A_f$ ) and the actual timber stock of the windblow area ( $A_w$ ):

$$L_{tu} = (A_f - A_w) \cdot a, \quad (7)$$

where  $a$  – average price of 1 m<sup>3</sup> of timber.

**Losses from increased costs of logging operations in the windblow area are defined by comparing the actual costs** of logging operations in the windblow area and the estimated costs according to the existing logging technology for clear cuts with appropriate technological map-making:

$$L_{hml} = C_{lw} - C_{lu}, \quad (8)$$

where  $L_{hml}$  – losses from high-maintenance logging operations in the windblow area;

$C_{lw}$  – costs of logging operations in the windblow area;

$C_{lu}$  – costs of logging operations in the undamaged area by clear cut.

The calculations mentioned below are intended for assessment of ecological losses from windblow.

**Costs that may arise from decreased windblow resistance of neighboring forest stands** are determined based on the study of the impact that the changed ecological situation from the complete forest destruction in a certain cutting area may have on decrease in windblow resistance of neighboring stands. From the reference source [16] it is known that for the zones wider than 100 m around the periphery of the clear cut area the index of windblow non-resistance of undamaged stands is 1.3 as compared to the windblow non-resistance index of the stands in the areas not allocated for clear cutting. Providing that both clear cuts and large-scale windblows have identical negative environmental impacts, these parameters are taken as designed ones. Thus, losses arising from the changed ecological situation will be considered as a certain part of total losses related to the area affected by large-scale windblow. This is equal to the product of the clear cut intensity along the periphery of the cutting area. The calculations made by the formula:

$$L_{pr} = 100 \cdot P \cdot (L_{as} + L_{hml}) \cdot 0.3, \quad (9)$$

where  $L_{pr}$  – possible losses due to decreased windblow resistance of neighboring stands;

$P$  – length of periphery of the windblow area.

**Negative effect from enhanced erosion** is determined by the amount of the soil washed out due to the impeded soil-protective qualities of the forest stands damaged by windblow.

The amount of soil is calculated by the data of experimental studies given in scientific papers. Enhanced erosion after clear cuts is associated by the wash-out of soil to the amount of 300-400 t/ha. Therefore it should be taken into account that each hectare affected by a large-scale windblow afflicts environmental damage to the forests. The scope of damage is assessed by the amount of soil washout.

However it should be kept in mind that the soil losses occur only after the clear cutting of the windblow areas. Without the clear cut, the amount of soil washout would be not that considerable (60–70 t/ha). This proves the fact that windblow damage and economic activity must be analyzed taken together, i.e., the soil losses result not from the windblow but after clear cutting of the windblow area.

**Methodology for calculation of costs that may arise from plant diseases emissions and entomological pests in neighboring forest lots** is based upon the study data with determination of windblow resistance index of forest stands under selective sanitary cuts. More intensive diseases and pest attacks requires selective sanitary cuts. The studies have revealed that the index of decreased windblow resistance of forest stands under selective sanitary cuts is 1.4 as compared to the forest lots not allocated to cutting. This parameter is considered as an appropriate probability level of large-scale windblow, and hence as an appropriate level of losses. Moreover, costs must

be taken into account that arise from selective sanitary cuts that would not take place in case of no windblow.

In terms of the foregoing, the economic losses from aggravated environmental situation are calculated by the formula:

$$L_{sc} = (I \cdot L \cdot 0,4) + C_c, \quad (10)$$

where  $L_{sc}$  – losses from aggravated sanitary conditions in neighboring stands;

$I$  – extent of the zone of aggravated sanitary conditions (taken as 100 m if no special studies have been conducted);

$L$  – length of the periphery of the forest lot affected by windblow; ;

$C_c$  – costs of selective sanitary cuts in the area that is equal to  $I \cdot L$ .

Methodology for ecological assessment of windblow impact on water-regulating and water-protection roles of forests and methodology for ecological assessment of negative windblow impact on the fauna have not been reviewed in this study [16].

Subject-related literary sources give the opinion that natural disasters lead to more intensive forest management operations and the associated increased costs [17, 18, 19]. Nevertheless the costs are affected by many factors that are related to forest management and are not easy to define. Foreign authors put forward similar arguments [20, 21, 22]. However, economic consequences of adverse weather effects as well as their long-term analysis are currently downplayed.

The study [15] cites 8 types of costs of main forest management operations in the forest district Węgierska Górka (Poland). The analysis embraces direct costs in the period of 2004–2010 [23]:

– **forest protection costs** (PLN / ha) – share of the total costs of forest protection in the forest district. All costs are shown in the accounting statement “Forest protection from damage-inducing factors”, including control of the amount of forest pests and fungi as well as protection against animal damage;

– **maintenance costs of forest infrastructure** (PLN / ha) – share of the total maintenance costs of forest infrastructure in the forest district area. The costs are shown in the accounting statement “Maintenance of forest roads” and cover mainly forest roads and drainage facilities;

– **costs of forest improvement** (PLN / ha) – share of the forest improvement in the total area under improvement in the reporting year. The costs are registered in the accounting statement “Silvicultural activities” and cover clear-up operations on logging sites and additional forest improvement operations;

– **costs of forest regeneration and afforestation and costs of forest stands restoration** (PLN / ha) – share of the total area under the mentioned operations in the reporting year. The costs are registered in the accounting statement “Silvicultural activities” and cover soil cultivation, costs of planting material and planting operations as well as the costs of restoration of stands affected by damage-inducing factors;

– **costs of additional planting operations** (PLN / ha) – share of the total costs of additional planting operations in the reporting year. The costs are shown in the accounting statement “Forest management activities” and cover costs of seedlings and planting operations in the areas of forest regeneration and afforestation in the prior years;

– **costs of plantations care** (PLN / ha) – share of the total costs of plantations care in the areas under “care” in the reporting year. The costs are registered in the accounting statement “Silvicultural activities” and cover, among other costs, soil cultivation and preliminary commercial thinning of stands;

– **costs of cutting and debucking** (PLN / m<sup>3</sup>) – ratio of the total costs of cutting and debucking of trees to the total wood harvest volume of the reporting year. The costs are included in the accounting statement “Wood harvest”;

– **timber transportation costs** (PLN / m<sup>3</sup>) – ratio of the total costs of timber transportation to the wood harvest volume of the reporting year. The costs are included in the accounting statement “Wood harvest”.

The below conclusions were drawn based on the review of the past windblows in European countries, study of their impact on timber markets, review of the methods of rectification of the consequences and their economic assessment:

- natural disasters cause losses across only a few prime cost items irrespective of the scope of the actions taken, i.e., cutting and debucking of trees, forest improvement, forest protection, forest infrastructure maintenance and plantations care;

- natural disasters do not result in increased per unit costs of wood harvest, forest regeneration, stands restoration (calculated together) and additional planting;

- natural disasters cause economic losses in the forest industry that can be seen from higher per unit costs of forestry activities;

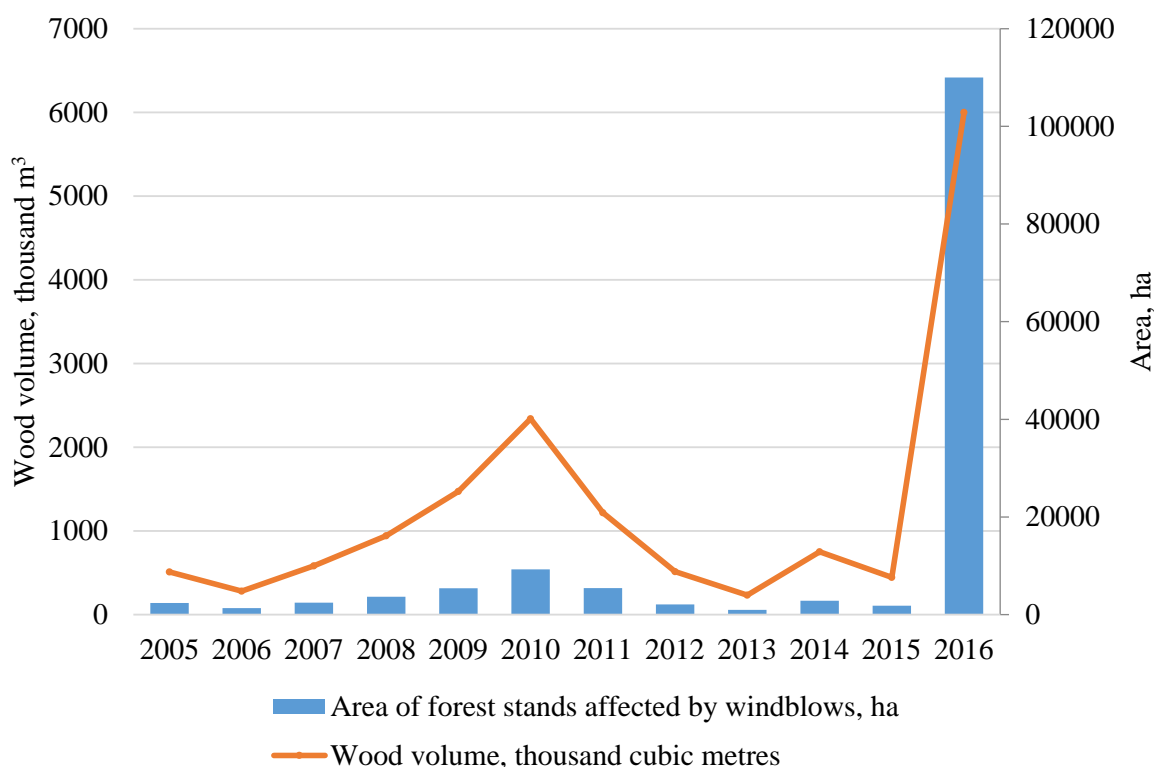
- comprehensive analysis of economic consequences of forestry catastrophic events must embrace longer time periods and take account of tendencies and periodic fluctuations because a major part of costs of restoration operations will become visible only during subsequent time periods [15].

## 1.2 Best practices of the Republic of Belarus in the field of assessment of losses and rectification of windblow consequences in the forest sector

### 1.2.1 Review of the past windblows in the forest sector of the Republic of Belarus over the recent years

The forest fund of the Republic of Belarus annually experiences several adverse weather effects, i.e. fires, draughts, pests, etc. However, windblows and heavy storms cause the most substantial damage to the forest.

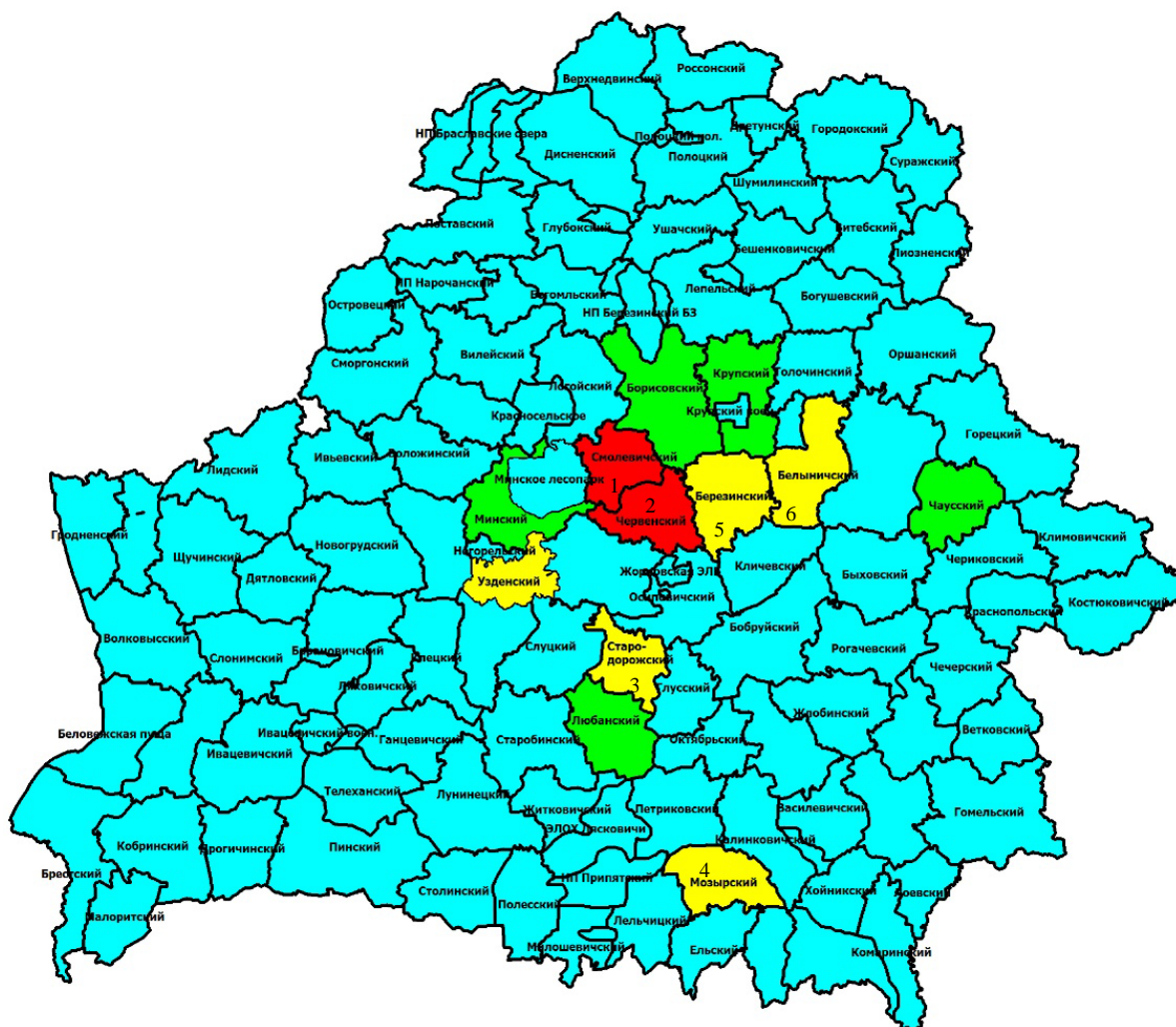
Figure 14 shows total statistics of the windblow damage to the forested areas over the period from 2005 to 2016.



**Figure 14 – Dynamics of forest damage by heavy windblows**

*Source:* data of the Ministry of Forestry of the Republic of Belarus

As can be seen from Figure 14, the forest sector of the Republic of Belarus suffered greatly from the windblow that happened on June 17, June 21 and July 12-13, 2016. As a result of the severe weather more than 22.5 thousand ha of forested lands were badly damaged with the wood losses of approx. 6 million m<sup>3</sup>. The forested areas of state forestry enterprise “Smolevichi leskhoz”, state forestry enterprise “Cherven leskhoz”, state experimental forestry enterprise “Starodorozhskiy opytniy leskhoz”, state experimental forestry enterprise “Mozyr opytniy leskhoz”, state forestry enterprise “Berezinskiy leskhoz”, state forestry enterprise “Belynichi leskhoz”. State experimental forestry enterprise “Borisov opytniy leskhoz”, state forestry enterprises “Minsk leskhoz”, “Krupki leskhoz”, “Luban’ leskhoz” and “Chaussy leskhoz” suffered from the above adverse weather effects to a lesser extent with damaged wood volumes ranging from 50 to 100 thousand m<sup>3</sup>. All the other forestry enterprises of the country had only minor damage of less than 50 thousand m<sup>3</sup>. Figure 15 illustrates the extent of damage incurred to the forestry enterprises of the Republic of Belarus by the 2016 forestry catastrophic events.



- forestry enterprises with damaged wood volume less than 50 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume from 50 to 100 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume from 100 to 300 thousand m<sup>3</sup>;
- forestry enterprises with damaged wood volume over 300 thousand m<sup>3</sup>.

**Figure 15 – Map of forest fund damage incurred to the organizations under the Ministry of Forestry of the Republic of Belarus:**

1 – state forestry enterprise “Smolevichi leskhoz”, damaged wood volume – 1.589 million m<sup>3</sup>, damaged area – 8796 ha or 21,4 % of the total forested area;

2 – state forestry enterprise “Cherven leskhoz”, damaged wood volume – 1.720 million m<sup>3</sup>, damaged area – 11955 ha or 16,3 % of the total forested area;

3 – state experimental forestry enterprise “Starodorozhskiy opytniy leskhoz”, damaged wood volume 0.220 million m<sup>3</sup>, damaged area – 6601 ha or 10.2 % of the total forested area;

4 – state experimental forestry enterprise “Mozyr opytniy leskhoz”, damaged wood volume 0.231 million m<sup>3</sup>, damaged area – 3133 ha or 3.6 % of the total forested area;

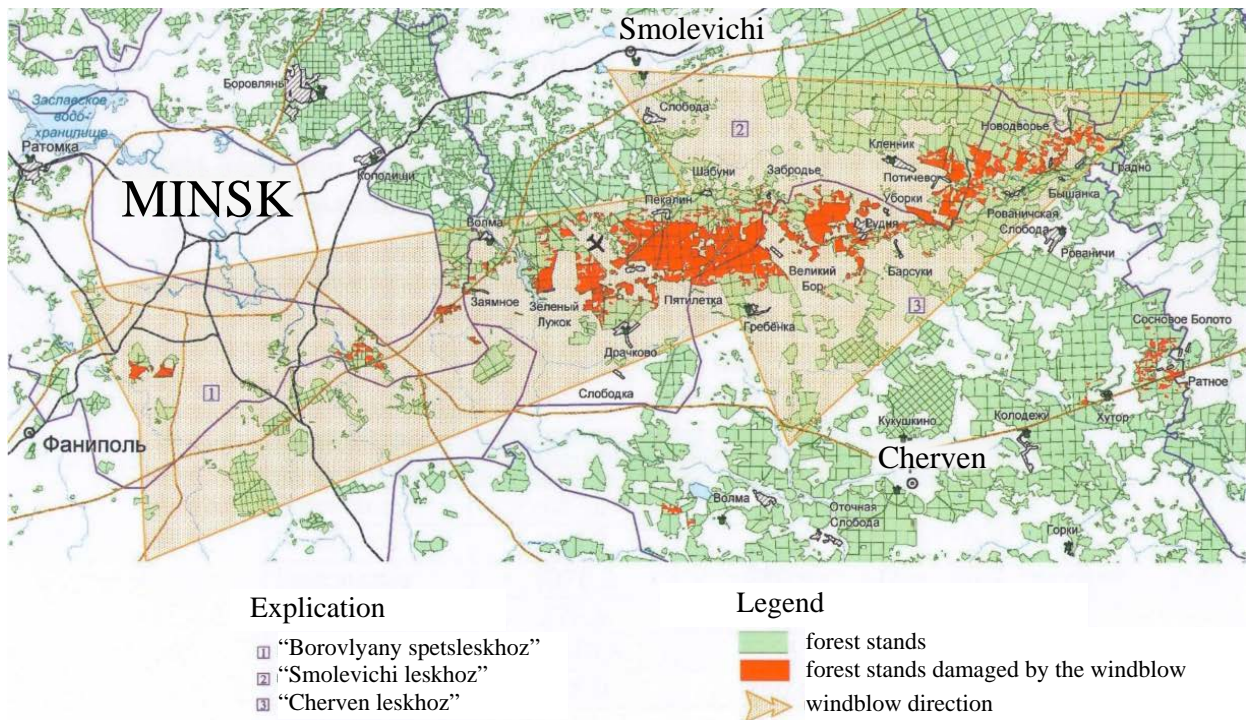
5 – state forestry enterprise “Berezinskiy leskhoz”, damaged wood volume 0.134 million m<sup>3</sup>, damaged area – 2680 ha or 2.8 % of the total forested area;

6 – state forestry enterprise “Belynichi leskhoz”, damaged wood volume 0,104 million m<sup>3</sup>, damaged area – 1713 ha or 1.8 % of the total forested area.

*Source:* authors’ development based on the data of the Ministry of Forestry of the Republic of Belarus

The heaviest wind storm was registered on July 13, 2016 and affected mainly the forested areas eastwards of Minsk (Figure 16). The storm was centered in the forested areas of state forestry enterprises “Smolevichi leskhoz” and “Cherven leskhoz”.





**Figure 16 – Map of forest stands most heavily damaged by the windblow of July 13, 2016**

*Source: data of the Ministry of Forestry of the Republic of Belarus*

The damaged areas were mostly middle-aged stands of 40–60 years with a special pattern of the spatial structure, significant “holes” in the forest canopy, open tree-fallen areas alternating with forest covered areas with topless broken trees. The windblow-affected areas contained taproot system trees with broken trunks (pine) and lying lateral-root-system trees with pulled-out roots (spruce). General picture of the windblow-affected forest stands is shown in Figure 17.



**Figure 17 – Typical damage to the forest stands in state forestry enterprise “Smolevichi leskhoz” after the windblow of July 13, 2016**

*Source: data of the Ministry of Forestry of the Republic of Belarus*

### 1.2.2 Planning and implementation of clear-up and recovery operations in the affected forested areas

Planning and implementation of clear-up and recovery operations in the forested areas of the Republic of Belarus after the windblows of June-July 2016 were done by the organizations of the Ministry of Forestry.

The windblows greatly affected over 110 thousand ha of forest stands with the wood losses of approx. 6 million m<sup>3</sup>. Major damage was done on June 17, June 21 and July 12–13, 2016 in the

forest fund areas of state forestry enterprise “Smolevichi leskhoz”, state forestry enterprise “Cherven leskhoz”, state experimental forestry enterprise “Starodorozhskiy opytniy leskhoz”, state experimental forestry enterprise “Mozyr opytniy leskhoz”, state forestry enterprise “Berezinskiy leskhoz”, state forestry enterprise “Belynichi leskhoz”.

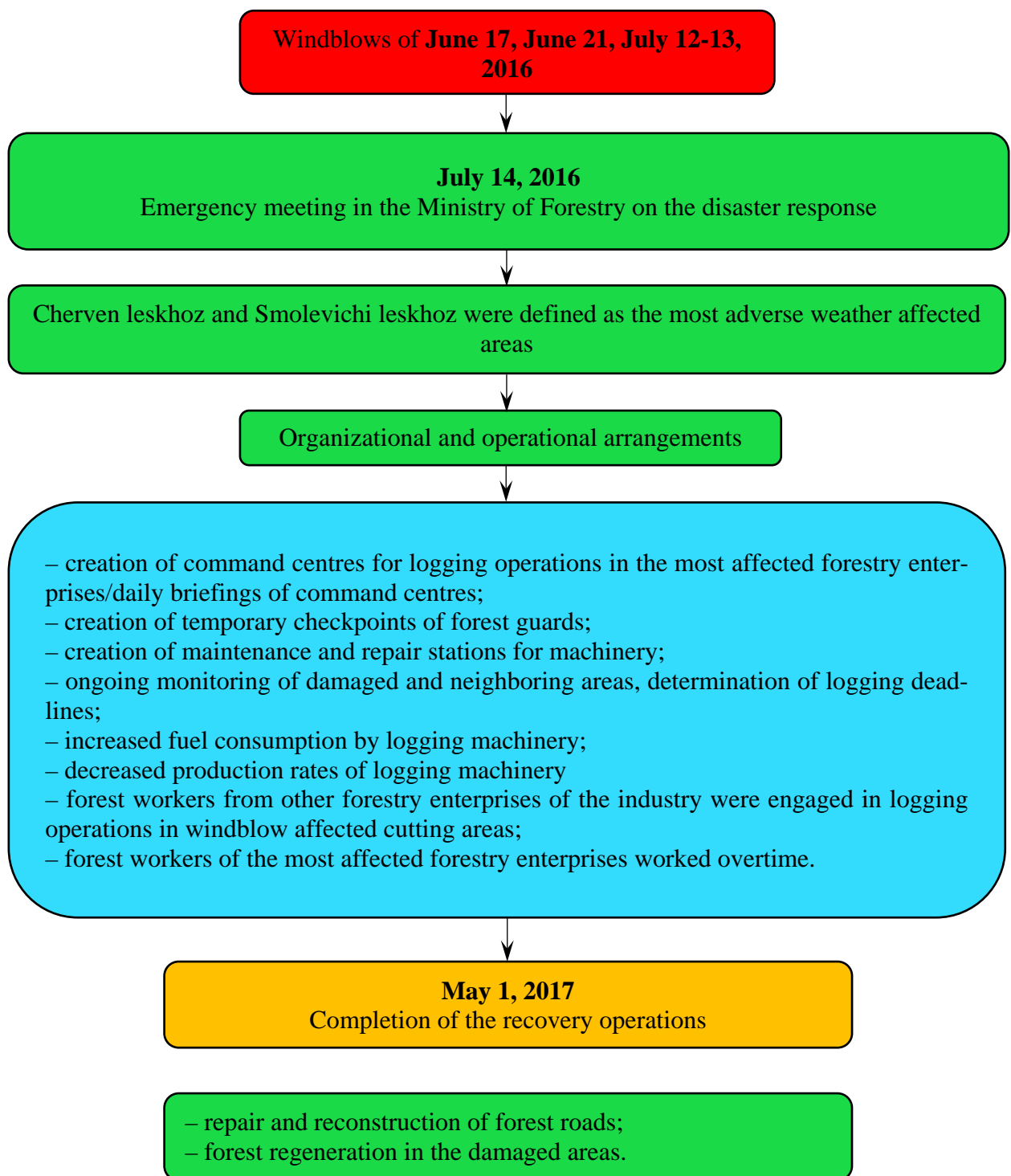
The heaviest wind storm was registered on July 13, 2016. The emergency meeting of July 14, 2016 in the Ministry of Forestry came to a decision to mobilize all the forestry enterprises in order to eliminate the windblow damage. In addition, it was decided to involve multifunction machinery to ensure maximum labour safety during the recovery operations. Since the first days after the windblow more than 500 workers were involved in the inspection of damaged forest stands in the forestry enterprises of the Minsk region. Scaled-up estimation of the scope of damaged forested areas was done by aerial survey and air drones. Final update was done during allocation of sites for cutting operations by forestry enterprises specialists. As a result of this work two forestry enterprises were defined as the most affected ones: Cherven leskhoz and Smolevichi leskhoz.

To ensure timely rectification of consequences from the adverse weather effects of July 2016 and to prevent degraded quality of timber the Ministry of Forestry mobilized all its own resources and engaged other agencies of all ownership forms.

Logging operations were carried out by multifunction machinery to include 154 harvesters, 256 forwarders, more than load-and-haul machines, 300 short-log trucks and other machinery. The multifunction machinery made it possible to reduce the time required for the logging operations. Besides higher labour safety was ensured in that way. More than 5500 workers contributed to the work, including 2200 drivers of multifunction logging machinery and 2000 lumberjacks.

Figure 18 illustrates the actions taken to ensure smooth work and timely rectification of the windblow consequences.

Command centres for logging operations of the windblow affected cutting areas were created in the most damaged forestry enterprises. Their main task was to coordinate the wood harvesting operations through engagement of workers from different forestry enterprises. Daily briefings of the command centres covered such issues as selection and approval of logging technology for windblow areas, analysis of immediate work outcomes and living on-site conditions of workers.



**Figure 18 – Sequence of recovery operations in the windblow affected areas**

*Source:* authors' development based on the data of the Ministry of Forestry of the Republic of Belarus

To ensure favourable working conditions and labour safety, new workwear, supplementary felling equipment (felling wedges, breaking bars, etc.). Off-schedule and targeted safety instructions were regularly given to the workers. Engineering personnel had regular on-site meetings with multifunction machinery drivers and crew workers to explain and instruct them in productive and safe working practices (Figure 19).



**Figure 19 – Logging operations in the windblow areas: a – by multifunction machinery, b – by gas-powered saws**

*Source: Ministry of Forestry of the Republic of Belarus*

A special order of the Ministry of Forestry allowed 30% reduced production rates and 10% increased fuel consumption rates. The rates were established individually for each forestry enterprise by local orders.

Foresters were engaged in order to mobilize extra workforce for clear-up operations in the damaged stands. By the legislation in law, foresters may do cutting operations only within the boundaries of their assigned forestry districts; they are not allowed to perform any forestry-related operations in other forestry enterprises. So, the decision was taken to temporarily transfer them to do worker’s job, but only if they agreed to do so.

New process flow diagrams (PFD) were drafted and approved by state forestry enterprise “Cherven leskhoz” in order to improve the performance quality and achieve planned targets. The PFDs included PFD 00995017.007-2016 “Classification of timber products by their origin characteristics” and PFD 00995017.008-2016 “Marking of products with a forest certification mark”.

24/7 checkpoints of state forest guards were established in order to monitor timber transportation (Figure 20).



**Figure 20 – Checkpoints of timber transportation**

*Source: Ministry of Forestry of the Republic of Belarus*

Temporary accommodation campuses for workers and service technicians were established in the forestry enterprises most affected by the windblow (Figure 21). The campuses had all conditions for year-round accommodation.



**Figure 21 – Temporary accommodation campuses for workers and service technicians**

*Source:* Ministry of Forestry of the Republic of Belarus

Main logging operations in the windblow cutting areas were completed by May 1, 2017.

It should be noted that relocation of extensive technical, material and human resources for the logging operations resulted in extra costs. In addition, the costs increased due to such factors as:

- 20-50% decreased production rates, higher labour costs and machinery maintenance costs;
- 10% increased fuel consumption;
- other extra cost (subsistence and other costs arising from relocation of people and machinery and workers' accommodation).

Forestry enterprises received BYN 3 million of financial support coming from the public budget for rectification of windblow consequence and subsequent forest regeneration. The funds were allocated at the initiative of the Ministry of Forestry upon the approval of other governmental bodies, i.e., Ministry of Emergencies, Ministry of Law, Ministry of economy, Ministry of Finance, Council of Ministers.

Forest regeneration was jointly performed by forestry workers, university and college students, volunteers and employees of different organizations. Forest regeneration was done in all windblow affected areas. It is worth mentioning that the nurseries under the Ministry of Forestry were able to provide enough planting material. Forest regeneration operations are described by Table 9.

**Table 9 – Forest regeneration operations**

Indicators	2011	2012	2013	2014	2015	2016	2017
Forest regeneration and afforestation, total, thousand ha	27,3	27,9	27,1	29,5	30,9	34,0	37,9
incl. forest plantations created by seed and planting material, thousand ha	7,8	8,5	8,8	9,6	10,4	11,7	15,2

Enhanced scope of forest regeneration in 2016–2017 was required after the cutting operations in the areas of dead coniferous stands and windblow affected sites.

Thus, in 2017 forest regeneration of on damaged (windblow) affected forested areas was performed on 7641 ha in 57 forestry enterprises, including Brest State Production Forestry Association (SPFA) – 4 forestry enterprises, Vitebsk SPFA – 10, Gomel SPFA – 8; Grodno SPFA – 11, Minsk SPFA – 12 and Mogilev SPFA – 12. The largest forest plantations on windblow affected areas were created in Smolevichi forestry enterprise (3397 ha), Cherven forestry enterprise (1757 ha), Borovlyany special forestry enterprise (317 ha), Berezinskiy forestry enterprise (241 ha), Minsk forestry enterprise (167 ha) and Belynichi forestry enterprise (156 ha).

### 1.2.3 Consequences of bringing increased timber volumes onto the market of Belarus

Timber sales on the domestic market are effected through the commodity exchange JSC Belarusian Integrated Commodity Exchange. Since 2015 the standing wood has not been traded with the exception of softleaved merchantable wood on the cutting areas of hard access.

The organizations under the Ministry of Forestry harvest timber and put the harvested timber out to tender. Primary task of the forestry enterprises is to ensure sufficient timber supply to legal persons and individuals on the domestic market. The amount of timber that has not been demanded by the domestic market is put to export sales. In the period of 2010–2017 the domestic market experienced boost of round timber sales in the domestic market (Table 10).

Table 10 – Round timber sales in the domestic market, thousand m<sup>3</sup>

Indicator	2010	2011	2012	2013	2014	2015	2016	2017
Round timber in the domestic market	6088,5	6475,2	6353,6	6624	7963,4	8730	9337	12384
incl. commercial timber	2601,2	2770,8	2844,1	3045	4342,3	5167	5955	8020

As can be seen from Table 6, the round timber sales in the domestic market have doubles over the period of 2010-2017 and amounted to 12.3 million m<sup>3</sup>.

Core buyers of commercial timber in Belarus are legal bodies of no departmental affiliation that cover 65–70% of the total sales volume. Other major buyers are enterprises of Bellesbumprom concern, including those taken over by JSC “Development Bank of the Republic of Belarus”. The individuals buy 4–55 of the total volume of commercial timber.

All domestic consumers were completely supplied by timber as prescribed by the governmental policy for domestic round timber processing and export sales of high added value products. The export sales of timber are effected by the enterprises under the Ministry of Forestry residually, i.e., small-sized commercial timber (pulpwood, technical rawwood) for pulp-and-paper and wood panel production are put to external markets if there is no domestic demand.

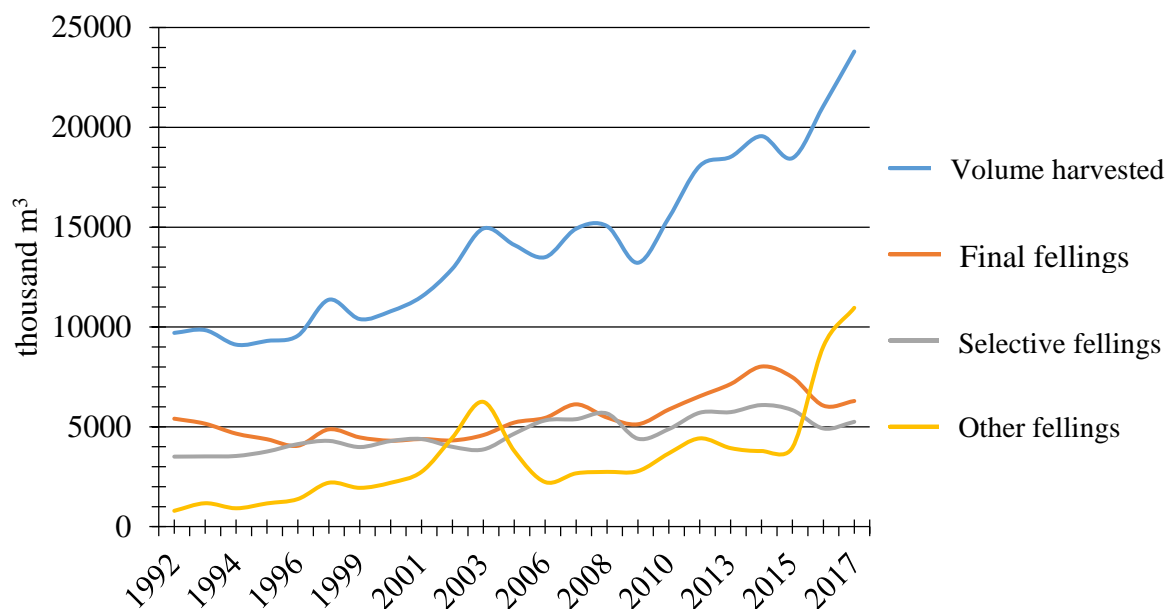
Since 2010 the export sales of timber have increased both by value and by volume. The 2016 exports of round timber amounted to 2.6 million m<sup>3</sup> (up 146.8% on the 2010 sales). Maximum export supply by value was registered in 2017 and amounted to 147 million USD that is by 40% higher than in 2010 (Table 11).

Table 11 – Export sales of timber by value and by volume

Year	Export sales of timber	
	By volume, thousand m <sup>3</sup>	By value, million USD
2010	1771	105,9
2011	1835	133,8
2012	1914	111,6
2013	2226	144,8
2014	2090	164,3
2015	2218	124,0
2016	2600	140,0
2017	1737	147,0

It should be mentioned that timber was exported to 30 countries (Russia, Kazakhstan, Ukraine, Moldova, Azerbaijan, Uzbekistan, Austria, the UK, Belgium, Hungary, Vietnam, Germany, the Czech Republic, Denmark, Italy, Latvia, Lithuania, the Netherlands, Poland, Romania, Slovakia, Finland, France, Sweden, Estonia, Turkey, China, UAE, Cyprus, Kuwait). Poland (38.2% of value) is ranked first among the main export destinations of timber followed by Lithuania (16.6%), Latvia (10.6%), Germany (10.2%), Romania (8.1%) and the Netherlands (2.8%).

After the 2016–2017 windblows that badly affected the national forest fund, the top management authorities of the Ministry of Forestry have taken a centralized decision on interruption of scheduled final cuts in order to immediately respond to the natural disaster consequences. The decision taken made it possible to prevent sudden increase in timber volumes on the domestic market, and hence dramatic price drops did not happen (Figure 22). Therefore the calculated allowable final cuts were done only by 60% in 2016.



**Figure 22 – Timber harvest dynamics across types of cuts in the Republic of Belarus**

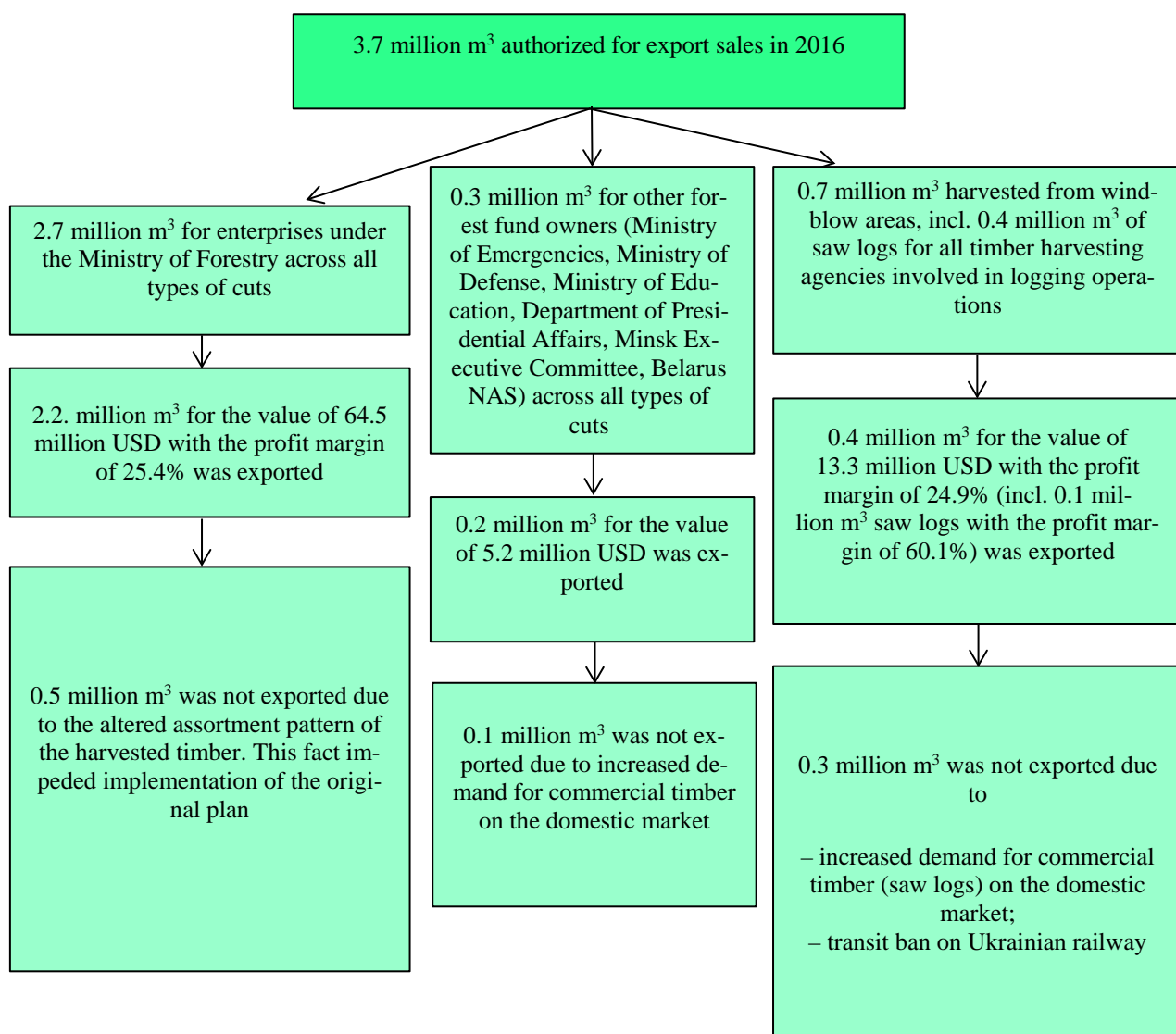
Source: Ministry of Forestry of the Republic of Belarus

The forestry catastrophic events of 2016–2017 have considerably aggravated the assortment pattern of timber. Under normal conditions the commercial timber output amounts to 80%, that of firewood is 20%. The assortment structure of timber after the windblows looked as follows: commercial timber – 40%, firewood – 60%.

Clause 29 of the Rules of Timber sales in the Domestic Market of the Republic of Belarus approved by Presidential decree No. 214 dated 07.05.2007 stipulates that exports of pulpwood, technical rawwood, plywood and saw logs is not allowed if unless otherwise provided by the President of the Republic of Belarus.

However, 6.0 million m<sup>3</sup> of commercial timber (115% of the 2015 exports) was exported in 2016 in order to sell the timber that was not demanded by the domestic market and to compensate for the losses incurred by the logging operations in the windblow affected areas. By a Presidential permit 3.7 million m<sup>3</sup> of round timber was exported (Figure 23). Potential supply markets were explored in order to identify timber buyers abroad. Export sales were effected at double price of the domestic level thus making it possible to compensate for the losses incurred by damaged wood harvesting and to avoid direct losses.

Foreign currency earnings from the 2016 round timber export amounted to 83 million USD with profit margin of 25.4%. In comparable conditions (excluding carriage charges) the average sales price of exported pulpwood was 25.3 USD or 1.6 times the average price of pulpwood sales on the domestic market. The export price of technical rawwood was 12.1 USD (1.3 times the domestic market price), that of saw logs was 52.7 USD (1.8 times the domestic market price). *Background information: as of 07.12.2016 the export sales price of coniferous saw logs of grade 1 that was harvested from windblow affected areas amounted to 87 EUR or 170 BYN under free-on-rail station terms (71 BYN higher than the domestic market price for the non-windblow timber).* Taken as a whole, the profit margin of exports of timber harvested from the windblow affected areas amounted to 24.9%, incl. 60.1% for saw logs.



**Figure 23 – Export sales of round timber in 2016**

*Source:* Ministry of Forestry of the Republic of Belarus

In 2017 the authorized exports of round timber amounted to 1.77 million m<sup>3</sup>, including 1.19 million m<sup>3</sup> of pulpwood, 0.54 million m<sup>3</sup> of technical rawwood, 0.038 million m<sup>3</sup> of saw logs. The timber was sold with the profit margin of 41%. Thus, the opportunity to export round timber at higher prices made it possible to avoid direct losses from harvesting operations in the windblow affected areas.

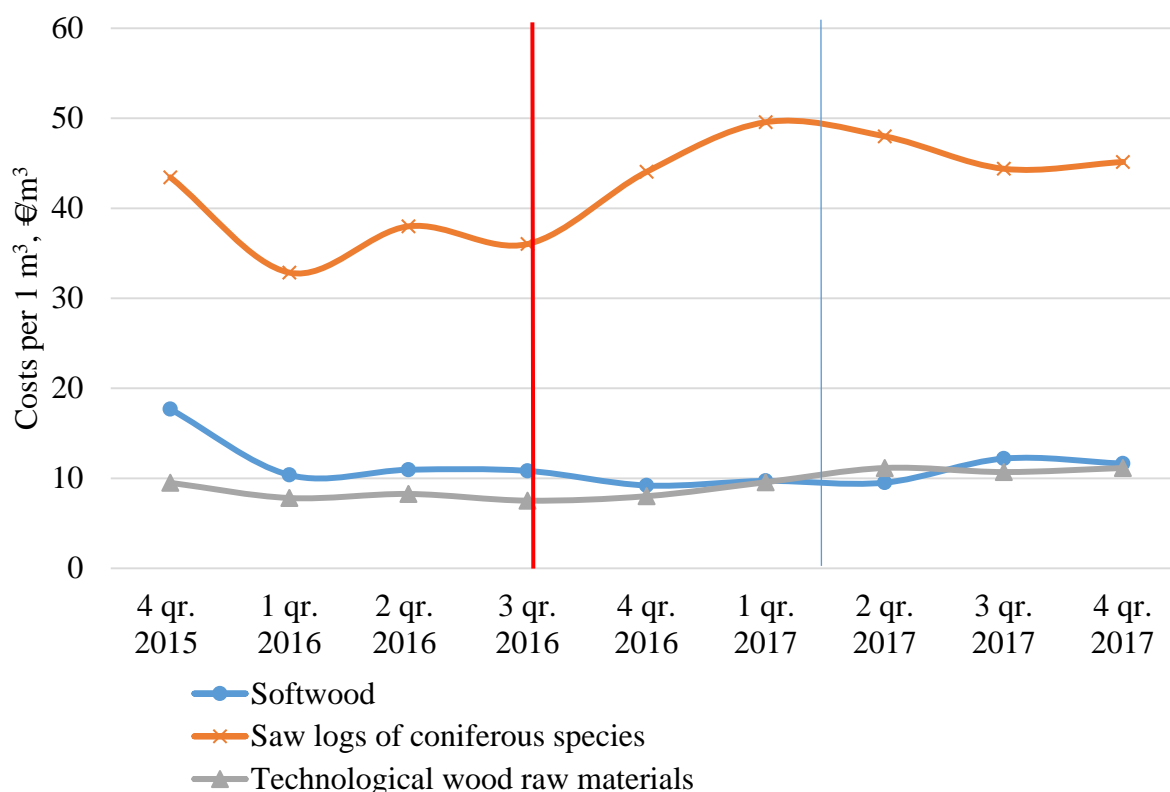
**Market prices at the Belarusian Integrated Commodity Exchange.** Clause 38 of the Rules of Timber sales in the Domestic Market of the Republic of Belarus approved by Presidential decree No. 214 dated 07.05.2007 “Initial price of commercial timber to be sold at the Belarusian Integrated Commodity Exchange” stipulates that the price is formed by legal bodies, individual proprietors. They are entitled by the law to negotiate commercial timber sales whereas the price must be compliant with quarter exchange quotations over the three months (a quarter) prior to the start of the next quarter. If no exchange quotations are available for certain assortments, the initial price is formed by the seller under the laws of price formation. The sales price is determined by the results of commodity exchange based on the exchange deal/contract.

In view of the above, it is worth mentioning that there was no pricing policy for timber harvested from windblow areas. Therefore it was traded at the prices that were established for timber coming from final cut areas. The prices could be different for lower quality timber (lower grade).



Varying natural and production conditions, applied technology and machinery systems, transport accessibility and other factors contributed to constantly changing losses from logging operations in the windblow areas. Fluctuations of supply and demand resulted in fluctuating commodity exchange prices for timber.

Figure 24 shows fluctuations of exchange quotations of coniferous pulpwood prices (pine, diameter – 6-13 cm, grades 2 and 3), coniferous saw logs prices (pine, diameter – 26 cm and larger, grade 1), technical rawwood (all tree species) under delivery conditions of franco-intermediate yard.



**Figure 24 – Timber price dynamics in 2015–2017**

Note: red vertical line – windblow; blue vertical line – completion of logging operations of windblow areas

Source: authors' development

Figure 24 makes us conclude that timber prices were fluctuating only slightly mainly due to market fluctuations. After the 2016 windblow (red vertical line in the diagram) the following price changing trends can be identified:

- saw logs prices went up dramatically in the following year (30% up);
- coniferous pulpwood price drops were registered during logging operations due to excessive market supply.

Table 12 gives the calculation of costs and financial receipts resulting from the recovery operations in the forestry enterprises that were most affected by the 2016 windblow.

Table 12 – Calculation of receipts and costs of recovery operations after the 2016 windblow

Indicators	Costs
<b>COSTS BY OPERATIONS</b>	
<b>1. Wood harvest, thousand m<sup>3</sup></b>	<b>4 500,00</b>
Costs per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	1,20
Payroll budget per wood harvest volume, thousand BYN	5 445,00
NSSF contribution, thousand BYN	1 851,00

Indicators	Costs
<b>1.1 Payroll total and harvesting charges, thousand BYN</b>	<b>7 296,00</b>
Number of machine-shifts (at the rate of 51 m <sup>3</sup> per shift), thousand machine-shifts	88,00
Operational costs per 1 machine-shift of harvester, BYN	340,00
<b>1.2 Total costs of harvesters maintenance, thousand BYN</b>	<b>29 920,00</b>
<b>1.3 Total costs of timber harvest operations, thousand BYN</b>	<b>37 216,00</b>
<b>2. Timber transportation, thousand m<sup>3</sup></b>	<b>4 500,00</b>
Costs per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	0,60
Payroll budget per wood harvest volume, thousand BYN	2 475,00
NSSF contribution, thousand BYN	842,00
<b>2.1 Payroll total and transportation charges, thousand BYN</b>	<b>3 317,00</b>
Number of machine-shifts (at the rate of 15.2 m <sup>3</sup> per shift), thousand machine-shifts	296,00
Operational costs per 1 machine-shift of tractor, BYN	35,00
<b>2.2 Total costs of tractors maintenance, thousand BYN</b>	<b>10 360,00</b>
<b>2.3 Total costs of timber transportation, thousand BYN</b>	<b>13 677,00</b>
<b>3. Timber delivery to intermediate yard</b>	<b>2 925,00</b>
Costs per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	0,90
Payroll budget per wood harvest volume, thousand BYN	2 691,00
NSSF contribution, thousand BYN	915,00
<b>3.1 Payroll total and delivery charges, thousand BYN</b>	<b>3 606,00</b>
Number of machine-shifts (at the rate of 24 m <sup>3</sup> per shift), thousand machine-shifts	122,00
Operational costs per 1 machine-shift of forwarder, BYN	223,70
<b>3.2 Total costs of forwarders maintenance, thousand BYN</b>	<b>27 291,00</b>
<b>3.3 Total costs of timber delivery to intermediate yard, thousand BYN</b>	<b>30 897,00</b>
<b>Total direct costs before delivery, thousand BYN</b>	<b>81 790,00</b>
<b>Transportation and delivery costs, thousand BYN</b>	<b>42 906,00</b>
<b>Other costs (subsistence allowance, travel expenses of workforce, delivery of machines), thousand BYN</b>	<b>14 837,00</b>
<b>Total costs incl. Delivery, thousand BYN</b>	<b>139 533,00</b>
<b>SOURCES OF FUNDING</b>	
<b>Receipts from timber sales incl. exports, thousand BYN:</b>	<b>137 130,00</b>
– commercial timber	81 510,00
– firewood	55 620,00
<b>Financial needs, thousand BYN</b>	<b>2 403,00</b>
<b>Public funds allocation, thousand BYN</b>	<b>3 000,00</b>

As can be seen from the Table 12, the implementation of recovery operations after the 2016 windblow did not result in heavy losses of forestry enterprises due to two important resolutions taken by the government and the President, i.e., to decrease allowable final cuts and to authorize certain amount of round timber export. The decrease in allowable final cuts prevented round timber prices from dramatic fall both on the domestic and the CIS markets. The opportunity to export round timber and the resulting export profitability made it possible to compensate for the increased losses arising from more complicated technology of the recovery operations, reduced rates of production, increased fuel consumption rates, degraded assortment pattern of timber, enhanced volume of waste wood during and after harvest. Thus, the needs in additional public funding for the most affected forestry enterprises amounted to only 2 402 thousand BYN.

## 1.2.4 Analysis of economic costs from 2016 windblow (the cases of state forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz”)

### 1.2.4.1 General description of state forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz”

State forestry enterprise “Cherven leskhoz” and state experimental forestry enterprise “Mozyr opytniy leskhoz” belong to the forest sector and are under the jurisdiction of the Ministry of Forestry of the Republic of Belarus. Both enterprises are state-owned.

Main activities of the forestry enterprises include:

– forestry activities aimed at efficient use of forest resources, forest protection and regeneration; conservation and development of highly-productive, biologically sustained forests and forest fauna. These measures are supported by public funds and earnings originating from the forestry activities;

– commercial activities aimed at forest cuts, woodworking production, timber transportation from the forest to industrial warehouses or other consumers’ yards in order to cater for the needs of domestic and external markets. They also include accessory forest use and harvesting of secondary forest resources. Main type of the economic activity is timber harvest.

The production facilities of state forestry enterprise “Cherven leskhoz” embrace 9 forestry sections, production and logging camp “Zagorye”, a logging station.

The total area of state forestry enterprise “Cherven leskhoz” occupies 71093 ha, including 65289 ha of forest covered lands. The standing wood volume is 14279 thousand m<sup>3</sup>. The wood volume of mature and overmature wood is 1360.7 thousand m<sup>3</sup> or 9.5% of the total wood volume. Main performance indicators of the forestry enterprise are given in Table 13.

Table 13 – Main performance indicators of state forestry enterprise “Cherven leskhoz” in 2014–2016

Main indicators	Period			Growth rate, %	
	2014	2015	2016	2015/2014	2016/2015
1. Forest regeneration of national forests, thousand ha	490,00	376,00	1878,00	76,73	499,47
including forest sowing and planting, thousand ha	426,00	312,00	1874,00	73,24	600,64
2. Improvement fellings in young forests, thousand ha	563,00	570,00	573,00	101,24	100,53
3. Intermediate fellings (merchantable wood), thousand m <sup>3</sup>	65,20	67,40	35,30	103,37	52,37
4. Other fellings (merchantable wood), thousand m <sup>3</sup>	75,90	86,90	127,10	114,49	146,26
5. Total volume of merchantable wood, thousand m <sup>3</sup>	141,10	154,30	162,40	109,36	105,25
6. Exploitation of allowable final cuts, thousand m <sup>3</sup>	85,70	63,60	57,20	74,21	89,94
7. Production volume in current prices, thousand BYN	2251,00	2423,00	5275,00	107,64	217,71
8. Timber transportation, thousand m <sup>3</sup>	137,90	145,70	106,80	105,66	73,30
9. Sawn timber production, thousand m <sup>3</sup>	2,50	2,50	6,80	100,00	272,00
10. Export supplies, thousand USD	860,30	647,60	1175,00	75,28	181,44
11. Cost efficiency of the goods, works and services sold, %	12,00	15,60	30,00	130,00	192,31

The industrial sector maintained the tendency of growing timber transportation volumes in order to increase the production volume and product sales. Export supplies in 2014–2016 were fluctuating, i.e., they decreased considerably in 2015 due to dramatic drop in contractual prices of the supplied timber; in 2016 they increased due to the growing delivery of paper wood and technical rawwood. The production output in 2014–2016 demonstrated a steady growth not only because of the increased actual volumes but also due to the higher cost of timber and forest products. The considerable growth of prices on the domestic market and export prices ensured higher cost effectiveness of sold products in 2016 as compared to the prices of 2014–2015.

The production facilities of state experimental forestry enterprise “Mozyr opytniy leskhoz” comprise 11 forestry sections, a woodworking shop and a logging unit. The total area of forests belonging to state experimental forestry enterprise “Mozyr opytniy leskhoz” occupies 96 800 ha, including 87 900 ha of forest covered lands. The standing wood volumes amount to 19 800 thousand m<sup>3</sup>. The volume of mature and overmature wood is 3 500 thousand m<sup>3</sup> or 17.8% of the total wood volume.

Main performance indicators of state experimental forestry enterprise “Mozyr opytniy leskhoz” are given in Table 14.

Table 14 – Main performance indicators of state experimental forestry enterprise “Mozyr opytniy leskhoz” in 2014–2016

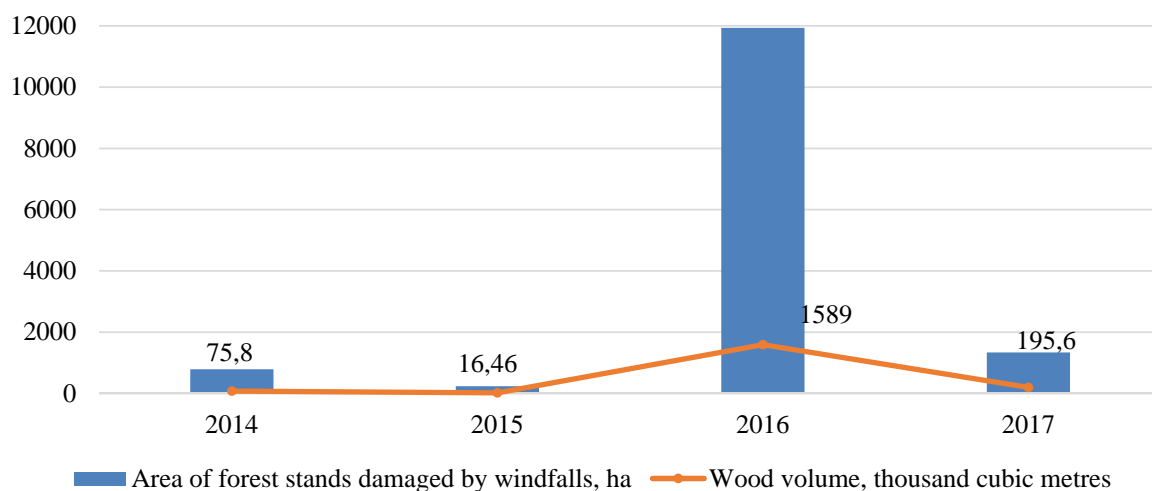
Main indicators	Period			Growth rate, %	
	2014	2015	2016	2015/ 2014	2016/ 2015
1. Forest regeneration of national forests, thousand ha	331,00	455,00	564,00	137,46	123,96
2. Improvement fellings in young forests, thousand ha	0,80	0,78	0,84	97,50	107,69
3. Intermediate fellings (merchantable wood), thousand m <sup>3</sup>	68,20	87,60	93,50	128,45	106,74
4. Other fellings (merchantable wood), thousand m <sup>3</sup>	7,10	17,50	63,00	246,48	360,00
5. Total volume of merchantable wood, thousand m <sup>3</sup>	75,30	105,10	210,00	139,58	199,81
6. Wood harvest	126,30	150,50	255,10	119,16	169,50
7. including wood harvest of felling value	43,70	43,50	94,00	99,54	216,09
6. Exploitation of allowable final cuts, thousand m <sup>3</sup>	103,50	94,00	85,00	90,82	90,43
7. Production volume in current prices, thousand BYN	3836,00	5623,00	13144,00	146,58	233,75
10. Revenues from sales of products, works, services	5200,00	5932,00	13390,00	114,08	225,72
8. Timber transportation, thousand m <sup>3</sup>	86,50	120,00	157,60	138,73	131,33
9. Sawn timber production, thousand m <sup>3</sup>	1,72	4,16	7,60	241,86	182,69
10. Export supplies, thousand USD	1082,50	1421,00	3798,99	131,27	267,35
11. Cost efficiency of the goods, works and services sold, %	10,60	10,50	27,10	99,06	258,10

The analysis of data in Table 14 shows that harvest of merchantable wood increased annually over the three years. In 2016 the allowable cut areas were not completely reclaimed due to the wood harvest after the 2016 windfall. The industrial sector maintained the tendency of growing timber transportation volumes in order to increase the production volume and product sales. Export supplies in 2014–2016 increased due to the growing delivery of paper wood and technical rawwood. The production output in 2014–2016 demonstrated a steady growth not only because of the in-

creased actual volumes but also due to the higher cost of timber and forest products. The considerable growth of prices on the domestic market and export prices ensured higher cost effectiveness of sold products in 2016 as compared to the prices of 2014–2015.

#### 1.2.4.2 Analysis of direct losses

Figure 25 shows the dynamics of the windblow damage incurred to forests stands in state forestry enterprise “Cherven leskhoz” over the period from 2014 to 2017.

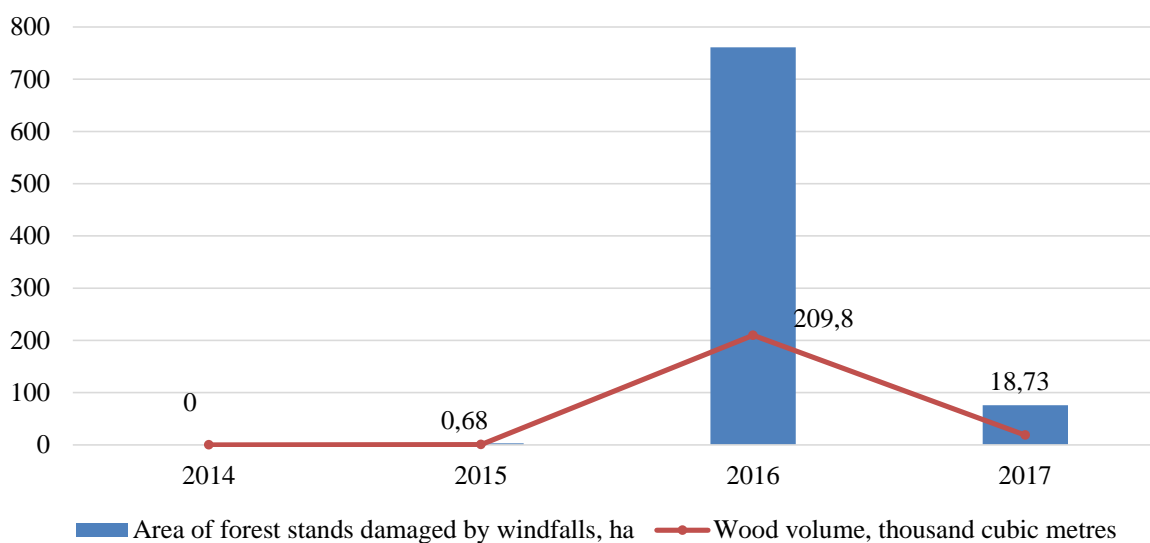


**Figure 25 – Dynamics of the windfall damage incurred to forests stands in state forestry enterprise “Cherven leskhoz”**

*Source: data of state forestry enterprise “Cherven leskhoz”*

The data in Figure 25 shows that over 2014-2017 the total wood harvest in the windblow areas amounted to 1876.86 thousand m<sup>3</sup>. The largest proportion of wood harvest was registered in 2016, i.e., 84.66% of the total harvest volume. The damaged area and the wood harvest volumes increased in 51 and 97 times respectively as compared to 2015.

Figure 26 shows the dynamics of the windblow damage incurred to forests stands in state experimental forestry enterprise “Mozyr opytnyi leskhoz” over the period from 2014 to 2017.

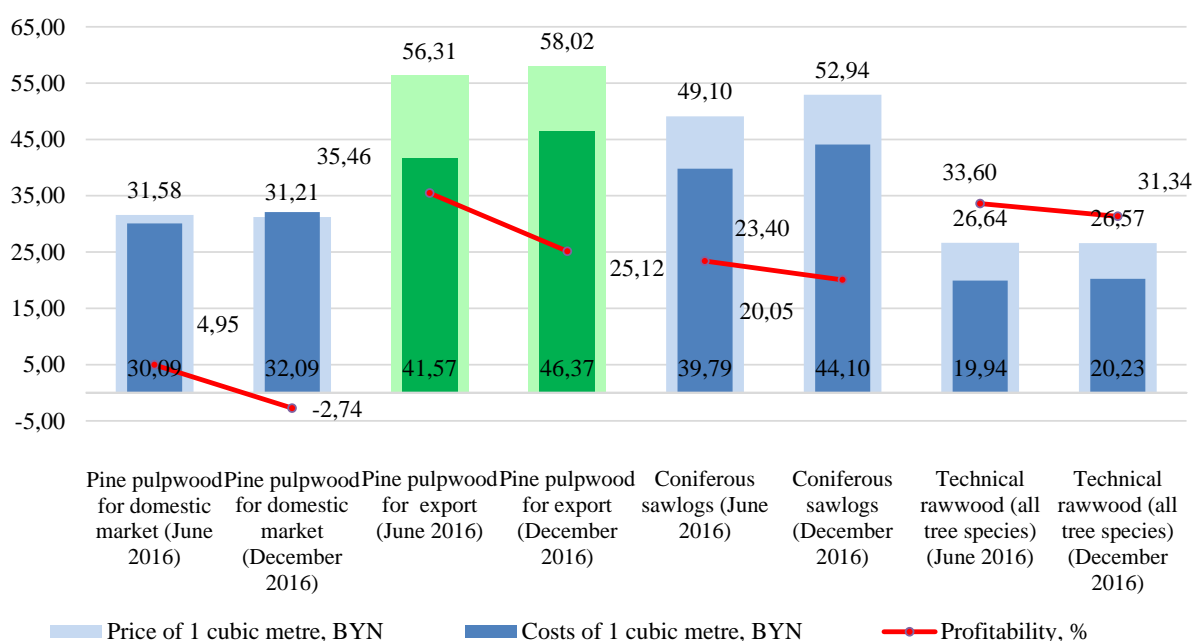


**Figure 26 – Dynamics of the windblow damage incurred to forests stands in state experimental forestry enterprise “Mozyr opytnyi leskhoz”**

*Source: data of state experimental forestry enterprise “Mozyr opytnyi leskhoz”*

As can be seen from Figure 26, the total volume of wood harvested in the windblow areas of state experimental forestry enterprise “Mozyr opytniy leskhoz” amounted to 229.21 thousand m<sup>3</sup> in 2014–2017. The 2016 windblow areas of state experimental forestry enterprise “Mozyr opytniy leskhoz” was by 11175.9 ha smaller than that of state forestry enterprise “Cherven leskhoz”.

Economic losses during timber sales after the 2016 windblow in the Republic of Belarus can principally be explained by lower grade of the timber harvested in pine stands (this type of stands suffered most from the 2016 windblow). Thus, final cuts can yield about 80% of merchantable wood and 20% of firewood under normal conditions. The cuts in the windblow areas resulted in 40% of merchantable wood and 60% of firewood. Moreover, the clear-up and restoration operations proved to be considerably labour-intensive and costly and had an unfavourable effect on the financial activities of the organizations involved. Figure 27 illustrates the dynamics of prices, costs and profitability of the harvested timber in state forestry enterprise “Cherven leskhoz” before and after the 2016 windblow.

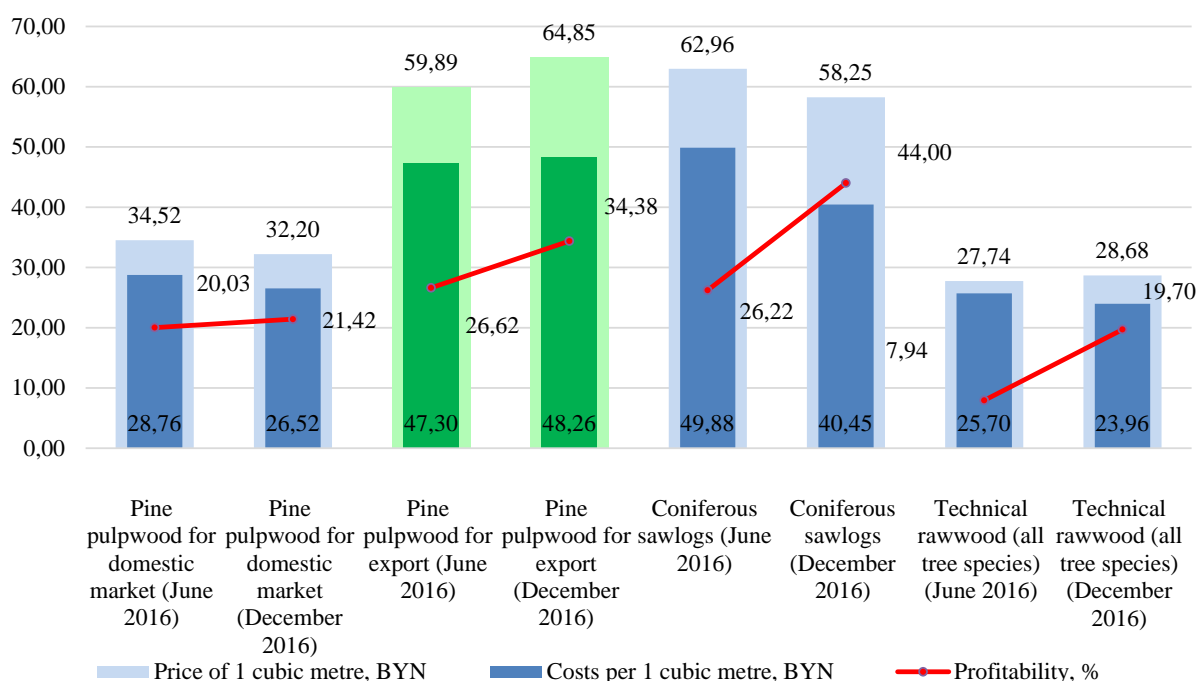


**Figure 27 – Dynamics of prices, costs and profitability of timber after windblows in state forestry enterprise “Cherven leskhoz”**

*Source: data of state forestry enterprise “Cherven leskhoz”*

The analysis of data in Figure 27 shows that round timber profitability of main stock items decreased in December 2016 as compared to the same values of June 2016. This fact can be explained by more rapid growth of harvesting costs against the growth rate of selling prices. The lowest profitability was registered for pine pulpwood to be sold on the domestic market. Thus, in December the costs were higher than the sales and profitability turned out to be negative (-2.74%). In addition, it should be noted that prices of pine pulpwood and technical rawwood changed only slightly as compared with coniferous saw logs with prices going up by 7.8%.

Figure 28 illustrates the dynamics of prices, costs and profitability of the harvested timber in state experimental forestry enterprise “Mozyr opytniy leskhoz” before and after the 2016 windblow.



**Figure 28 – Dynamics of prices, costs and profitability of timber after windfalls in state experimental forestry enterprise “Mozyr opytniy leskhoz”**

*Source:* data of state experimental forestry enterprise “Mozyr opytniy leskhoz”

The analysis of data in Figure 28 shows that over the period from June to December 2016 the situation in state experimental forestry enterprise “Mozyr opytniy leskhoz” was different from that on state forestry enterprise “Cherven leskhoz”. The main stock items demonstrated improved profitability after the clear-up and restoration operations as compared that before the 2016 windblow. This fact proves high performance characteristics of the production processes. This was caused by a sharp and dramatic increase in wood harvest volumes by 105 thousand m<sup>3</sup> or 70% (see Table 2) which in its turn enabled lower conditional-constant costs and reduced costs of main stock items. State forestry enterprise “Cherven leskhoz” failed to demonstrate the same positive effect because wood harvest volumes had not gone up. Wood harvesting operations in the windblow areas were considerably supported by third parties.

### 1.2.4.3 Analysis of additional costs and indirect losses

**Costs of cutting operations in windblow affected areas (incidents, clear-up operations).** In order to determine additional economic costs from the 2016 windblow in state forestry enterprise “Cherven leskhoz”, the costs of round timber harvest have been calculated for normal conditions and for windblow areas. Table 15 gives the calculation of operational costs per 1 machine-shift of logging machinery. The calculation has been made based on the basic standard costs and tariffs provided by the specialists of the Ministry of Forestry.

Table 15 – Calculation of operational costs per one machine-shift

Cost item	Tractor		Harvester		Forwarder	
	normal conditions	windblow areas	normal conditions	windblow areas	normal conditions	windblow areas
Fuel, BYN:	15,38	17,68	123,00	141,45	92,25	106,09
– fuel consumption rate, l	15,00	15,00	120,00	120,00	90,00	90,00
–adjusting factor	1,00	1,15	1,00	1,15	1,00	1,15
– adjusted fuel consumption rate, l	15,00	17,25	120,00	138,00	90,00	103,50

Cost item	Tractor		Harvester		Forwarder	
	normal conditions	windblow areas	normal conditions	windblow areas	normal conditions	windblow areas
– price of 1 l of fuel, BYN	1,03	1,03	1,03	1,03	1,03	1,03
Spare parts, BYN	9,97	9,97	56,89	56,89	67,70	66,76
Salary of repair workers, BYN	1,00	1,00	4,80	4,80	25,30	25,30
Social security contributions to repair workers, BYN	0,34	0,34	1,63	1,63	8,60	8,60
Mandatory insurance, BYN	0,01	0,01	0,03	0,03	0,15	0,15
Depreciation, BYN	0,30	0,30	84,60	84,60	0,00	0,00
Repair and maintenance services, BYN	5,70	5,70	50,60	50,60	16,80	16,80
Total costs per one machine-shift, BYN	32,69	35,00	321,55	340,00	210,80	223,70

The 15% increase in fuel consumption rate has resulted in costs per one machine-shift for tractors from 32.69 BYN to 35.00 BYN, for harvesters from 321.55 BYN to 340.00 BYN, for forwarders from 210.80 BYN to 223.70 BYN.

Table 16 gives the analysis of timber harvesting costs in state forestry enterprise “Cherven leskhoz”.

Table 16 – Analysis of timber harvesting costs in state forestry enterprise “Cherven leskhoz”

Indicator	Normal conditions	Windblow area
<b>1 Timber harvesting, thousand m<sup>3</sup></b>	<b>1 589,00</b>	<b>1 589,00</b>
Tariff per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	1,03	1,21
Payroll budget for the timber harvest volume, thousand BYN	1 634,29	1 922,69
NSSF contribution, thousand BYN	555,66	653,71
<b>1.1 Total NSSF and harvesting charges, thousand BYN</b>	<b>2 189,94</b>	<b>2 576,40</b>
Productivity rate, m <sup>3</sup>	60,00	60,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	60,00	51,00
Total number of machine-shifts (at the rate of 51 m <sup>3</sup> per one shift), thousand machine-shifts	26,48	31,16
The number of machine-shifts in state forestry enterprise “Cherven leskhoz”, machine-shifts	534,65	534,65
Operational costs of 1 machine-shift of harvester, BYN	321,55	340,00
<b>1.2 Total maintenance costs of harvesters, thousand BYN</b>	<b>8 515,72</b>	<b>10 593,33</b>
<b>1.3 Total timber harvesting costs, thousand BYN</b>	<b>10 705,66</b>	<b>13 169,74</b>
<b>2. Timber transportation, thousand m<sup>3</sup></b>	<b>1 589,00</b>	<b>1 589,00</b>
Tariff per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	0,47	0,55
Payroll budget for the timber harvest volume, thousand BYN	742,86	873,95
NSSF contribution, thousand BYN	252,57	297,14
<b>2.2 Total NSSF and transportation charges, thousand BYN</b>	<b>995,43</b>	<b>1 171,09</b>
Productivity rate, m <sup>3</sup>	16,00	16,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	16,00	13,60
Total number of machine-shifts (at the rate of 13.6 m <sup>3</sup> per one shift), thousand machine-shifts	62,21	86,11
The number of machine-shifts in state forestry enterprise “Cherven leskhoz”, machine-shifts	4 205,36	4 205,36



Indicator	Normal conditions	Windblow area
Operational costs of 1 machine-shift of tractor, BYN	32,69	35,00
<b>2.2 Total maintenance costs of tractors, thousand BYN</b>	<b>2 033,79</b>	<b>3 013,84</b>
<b>2.3 Total timber transportation costs, thousand BYN</b>	<b>3 029,22</b>	<b>4 184,94</b>
<b>3. Timber delivery to intermediate yard</b>	<b>1 032,85</b>	<b>1 032,85</b>
Productivity rate, m <sup>3</sup>	0,78	0,92
Decreasing factor	807,69	950,22
Decreased productivity rate, m <sup>3</sup>	274,61	323,08
<b>3.1 Total NSSF and delivery charges, thousand BYN</b>	<b>1 082,30</b>	<b>1 273,30</b>
Productivity rate, m <sup>3</sup>	25,00	25,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	25,00	21,25
Total number of machine-shifts (at the rate of 21.25 m <sup>3</sup> per one shift), thousand machine-shifts	41,31	48,60
The number of machine-shifts in state forestry enterprise “Cherven leskhoz”, machine-shifts	861,73	861,73
Operational costs of 1 machine-shift of forwarder, BYN	210,80	223,70
<b>3.2 Total maintenance costs of forwarders, thousand BYN</b>	<b>8 708,99</b>	<b>10 872,87</b>
<b>3.3 Total costs of timber delivery to intermediate yard, thousand BYN</b>	<b>9 791,29</b>	<b>12 146,17</b>
<b>Total direct costs before delivery, thousand BYN</b>	<b>23 526,17</b>	<b>29 500,84</b>
<b>Delivery costs, thousand BYN</b>	<b>15 150,56</b>	<b>15 150,56</b>
<b>Other costs (subsistence allowance, travel expenses of workforce, delivery of machines), thousand BYN</b>	<b>0,00</b>	<b>5 238,98</b>
<b>Total costs incl. Delivery, thousand BYN</b>	<b>38 676,73</b>	<b>49 890,39</b>
<b>Additional costs, thousand BYN</b>	<b>11 213,65</b>	

The costs analysis for normal conditions and for windblow areas shows that additional costs of state forestry enterprises “Cherven leskhoz” amount to 11 213.65 thousand BYN. The higher costs result from the 15% increased fuel consumption rate and the 15% reduced productivity rate.

Table 17 describes the costs of 1 machine-shift for main logging machinery in state experimental forestry enterprise “Mozyr opytnyi leskhoz”.

Table 17 – Calculation of costs per one machine-shift

Cost item	Tractor		Harvester		Forwarder	
	normal conditions	windblow areas	normal conditions	windblow areas	normal conditions	windblow areas
Fuel, BYN:	15,38	16,91	123,00	135,30	92,25	101,48
– fuel consumption rate, l	15,00	15,00	120,00	120,00	90,00	90,00
–adjusting factor	1,00	1,10	1,00	1,10	1,00	1,10
– adjusted fuel consumption rate, l	15,00	16,50	120,00	132,00	90,00	99,00
– price of 1 l of fuel, BYN	1,03	1,03	1,03	1,03	1,03	1,03
Spare parts, BYN	9,97	9,97	56,89	56,89	67,70	66,76
Salary of repair workers, BYN	1,00	1,00	4,80	4,80	25,30	25,30
Social security contributions to repair workers, BYN	0,34	0,34	1,63	1,63	8,60	8,60
Mandatory insurance, BYN	0,01	0,01	0,03	0,03	0,15	0,15

Cost item	Tractor		Harvester		Forwarder	
	normal conditions	windblow areas	normal conditions	windblow areas	normal conditions	windblow areas
Depreciation, BYN	0,30	0,30	84,60	84,60	0,00	0,00
Repair and maintenance services, BYN	5,70	5,70	50,60	50,60	16,80	16,80
Total costs per one machine-shift, BYN	32,69	34,23	321,55	333,85	210,80	219,09

The 10% increase in fuel consumption rate has resulted in costs per one machine-shift for tractors from 32.69 BYN to 34.23 BYN, for harvesters from 321.55 BYN to 333.85 BYN, for forwarders from 210.80 BYN to 219.09 BYN.

Table 18 gives the analysis of timber harvesting costs in state experimental forestry enterprise “Mozyr opytniy leskhoz”.

Table 18 – Analysis of timber harvesting costs in state experimental forestry enterprise “Mozyr opytniy leskhoz”

Indicator	Normal conditions	Windblow area
<b>1 Timber harvesting, thousand m<sup>3</sup></b>	<b>209,80</b>	<b>209,80</b>
Tariff per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	1,03	1,21
Payroll budget for the timber harvest volume, thousand BYN	215,78	253,86
NSSF contribution, thousand BYN	73,36	86,31
<b>1.1 Total NSSF and harvesting charges, thousand BYN</b>	<b>289,14</b>	<b>340,17</b>
Productivity rate, m <sup>3</sup>	60,00	60,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	60,00	51,00
Total number of machine-shifts (at the rate of 51 m <sup>3</sup> per one shift), thousand machine-shifts	3,50	4,11
The number of machine-shifts in state experimental forestry enterprise “Mozyr opytniy leskhoz”, machine-shifts	321,55	333,85
<b>1.2 Total maintenance costs of harvesters, thousand BYN</b>	<b>1 124,35</b>	<b>1 373,37</b>
<b>1.3 Total timber harvesting costs, thousand BYN</b>	<b>1 413,50</b>	<b>1 713,54</b>
<b>2. Timber transportation, thousand m<sup>3</sup></b>	<b>209,80</b>	<b>209,80</b>
Tariff per 1 m <sup>3</sup> , BYN/m <sup>3</sup>	0,47	0,55
Payroll budget for the timber harvest volume, thousand BYN	98,08	115,39
NSSF contribution, thousand BYN	33,35	39,23
<b>2.2 Total NSSF and transportation charges, thousand BYN</b>	<b>131,43</b>	<b>154,62</b>
Productivity rate, m <sup>3</sup>	16,00	16,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	16,00	13,60
Total number of machine-shifts (at the rate of 13.6 m <sup>3</sup> per one shift), thousand machine-shifts	8,21	11,37
The number of machine-shifts in state experimental forestry enterprise “Mozyr opytniy leskhoz”, machine-shifts	32,69	34,23
<b>2.2 Total maintenance costs of tractors, thousand BYN</b>	<b>268,53</b>	<b>389,17</b>
<b>2.3 Total timber transportation costs, thousand BYN</b>	<b>399,96</b>	<b>543,79</b>
<b>3. Timber delivery to intermediate yard</b>	<b>136,37</b>	<b>136,37</b>
Productivity rate, m <sup>3</sup>	0,78	0,92
Decreasing factor	106,64	125,46
Decreased productivity rate, m <sup>3</sup>	36,26	42,66
<b>3.1 Total NSSF and delivery charges, thousand BYN</b>	<b>142,90</b>	<b>168,12</b>
Productivity rate, m <sup>3</sup>	25,00	25,00
Decreasing factor	1,00	0,85
Decreased productivity rate, m <sup>3</sup>	25,00	21,25

Indicator	Normal conditions	Windblow area
Total number of machine-shifts (at the rate of 21.25 m <sup>3</sup> per one shift), thousand machine-shifts	5,45	6,42
The number of machine-shifts in state experimental forestry enterprise “Mozyr opytный leskhoz”, machine-shifts	210,80	219,09
<b>3.2 Total maintenance costs of forwarders, thousand BYN</b>	<b>1 149,87</b>	<b>1 405,99</b>
<b>3.3 Total costs of timber delivery to intermediate yard, thousand BYN</b>	<b>1 292,77</b>	<b>1 574,11</b>
<b>Total direct costs before delivery, thousand BYN</b>	<b>3 106,22</b>	<b>3 831,44</b>
<b>Delivery costs, thousand BYN</b>	<b>2 00,37</b>	<b>2 00,37</b>
<b>Other costs (subsistence allowance, travel expenses of workforce, delivery of machines), thousand BYN</b>	<b>0,00</b>	<b>691,72</b>
<b>Total costs incl. delivery, thousand BYN</b>	<b>5 106,59</b>	<b>6 523,53</b>
<b>Additional costs, thousand BYN</b>		<b>1 416,93</b>

The costs analysis for normal conditions and for windblow areas shows that additional costs of state experimental forestry enterprise “Mozyr opytный leskhoz” amount to 1416.93 thousand BYN. The higher costs result from the 10% increased fuel consumption rate and the 15% reduced productivity rate.

**Losses from infrastructure damage (roads, bridges, power lines, etc.).** Table 19 illustrates the amount of financial support allocated from the public budget to repair and reconstruction of forest roads that were used by machinery for rectification of the windblow consequences in 2017 (Resolution of the council of ministers of the Republic of Belarus No. 496 dated 01.07.2017).

Table 19 – Financial support allocated from the public budget to repair and reconstruction of forest roads

Forestry enterprise	Road length, km	Repair costs, BYN	Months					
			August		September		October	
			km	BYN	km	BYN	km	BYN
Borovlyany special forestry enterprise	26,8	200 000	15,0	110 800	11,8	89 200	–	–
State forestry enterprise “Smolevichi leskhoz”	41,7	300 000	17,0	120 000	17,0	120 000	7,7	60 000
State forestry enterprise “Cherven leskhoz”	150,1	1 000 000	50,0	298 300	50,0	350 800	50,1	350 900
Итого	218,6	1 500 000	82,0	529 100	78,8	560 000	57,8	410 900

Thus, the amount of financial support allocated from the public budget to repair and reconstruction of forest roads that were damaged during the recovery operations in the windblow areas was 1.5 million BYN, including 1.0 million BYN allocated to the forest roads of state forestry enterprise “Cherven leskhoz”.

**Calculation of non-timber losses and indirect losses (impacts on soils and water).** Non-timber products include products of accessory forest utilization (mushrooms, berries, honey, sap, etc.) as well as products related to game, wildlife, nature and tourism. Calculations of non-timber losses from the past windblows have not been made by specialists of forestry enterprises and the Ministry of Forestry. However, forestry enterprise workers pointed out that they had not spotted any dead animals during the recovery operations in the windblow areas. It should also be added that the windblow affected areas were not popular tourism and hunting places.

International practices make us conclude that these losses can be important in the long term. To make reliable and accurate assessment it is advisable to develop methodologies for forest environment monitoring to obtain data necessary for assessment and calculations. For instance, it is required to have all data about damaged forest areas and harvest of non-timber products over the past periods in order to carry out comparative analysis and identification of losses.

Calculations of indirect losses (impacts on soils and water) from the past windblows have not been made by specialists of forestry enterprises and the Ministry of Forestry. However, Belarusian experts believe that assessment of these losses is not possible and further studies are required into this issue.

Additional costs and indirect losses calculated in West European and North European countries are given in Box 5.

**Box 5: Additional Losses and indirect losses in Forests and for Society caused by Storm Events – Experiences from Western and Northern Europe**

There is no common understanding of how to stratify other direct losses and which are the most relevant cost factors of large scale natural disturbances. However, it can be shown that there are some factors which are used in the majority of the published studies (table). An in-depth analysis shows that it is frequently not reported whether these cost have been calculated and analyzed.

Table – Direct losses included in various studies

	Hanewinkel and Peyron (2013)	Kont 2006	Odenthalt 2004	Gardiner et al 2013a	Karlson, 2016	TBN BMELV	TBN Austria	Manfred Handbook	Sikora, A.T. ; U-kalska, J. (2014):
Cost for intervention								x	
Assessment of damaged area		x	x						
Harvesting costs	x	x	x	x	x	x	x	x	x
Timber storage			x			x			
Restoration costs	x	x	x	x	x	x	x*	x	x
Silvicultural measures					x	x	x*	x	x
Costs for forest infrastructure		x	x	x	x	x	x	x	x
Forest projection			x			x	x*	x	x

It can be recommended to include all cost centers listed in table xx above in an analysis of cost, if reliable data is available.

The prior findings in Western and Northern Europe related to these cost centers can be holistically summarized as follows:

- Costs for intervention are, compared to the other cost centers, of minor importance.
- The costs for damage assessment play a role, albeit they vary widely depending on the intensity and methods applied.
- It is a wide consensus in the relevant studies, that the total amount of harvesting costs will increase notably due to the higher quantities of timber to be processed.

- On the other hand, data from long term time series makes it evident, in contrast to the opinion of most forest practitioners, that the costs per unit [m<sup>3</sup>] are frequently not higher during the narrower period of the salvage logging campaign.

- There are hints, that they tend to increase to some extent (+ 10 to +20%) in the following years when bark beetle management becomes important, which leads to scattered harvesting patterns.

- Evidence from economic databases and prior studies reveal, that the costs for regeneration activities increase, as there are more areas to be replanted.

- However there is also evidence, that the use of natural regeneration can reduce the amount of additional costs tremendously.

- Especially in the case of storm events secondary bark beetle outbreaks are unavoidable, but manageable to some extent by intense management (inspection) activities. Consequently, higher costs for forest protection occur, but can be seen as a contribution to a reduction of additional secondary damages. So a minimization of this type of costs is not necessarily positive.

- The change of costs for other silvicultural operations is frequently of minor importance.

## Conclusions on Part 1

1. The main source of forestry catastrophic events in Europe are storms and windblows. The larger half of timber harvest in Europe is caused by windblow events. From year to year there is a growing tendency towards the frequency and scope of adverse weather effects which cause increased amount of damage. European countries have more than half a century of experience in dealing with the effects of windfalls and windbreaks in forestry.

2. Research and comparison of long-term data of short-term and long-term consequences of floods in Europe have allowed to develop approaches and methods, to evaluate the impact of windfall / windbreak on forest ecosystems, biodiversity and the economy.

A plan for mitigation is being developed for each damaged region, which includes the following main stages:

- operative assessment of the damaged area and consequences;
- measurement, marking and logging operations in the damaged areas;
- timber export and storage organization;
- reconstruction of damaged or construction of new infrastructure facilities;
- restoration of damaged plantations.

Considering that one of the most difficult and important steps is logging on damaged areas, the following order of the harvesting operations must be observed:

- transport accessibility of the damaged areas;
- priority harvesting of commercially valuable timber;
- removal of individual damaged trees and small “spit-nests” to prevent secondary damage by pests;
- clear-up of large windblow affected areas;
- long-term conservation of timber of resilient species;
- harvesting of low-grade and small-sized timber of broadleaved species is to be done in the last run.

Performance of liquidation of consequences of windfalls in this sequence reduces the cost of these activities and increases the shelf life of the wood.

3. Significant attention in European countries is paid to the study of wood prices dynamics after the disaster. Due to the possibility of reducing the cost of wood raw materials in the market after the windfall to maximize financial benefit and prevent a strong fall in wood prices, the storage of large volumes of timber at specially organized sites can become a necessary measure for several years.

4. European experts and scientists focus not only on natural disasters alone, but on the time of their action on forest ecosystems, biodiversity and economy. Adverse weather effects on forests (both individual trees and whole forest stands) alter their resistance, structure, quality and value to various extents. This calls for emergency measures and completely new approaches to actions on mitigation of long-term effects of natural disasters.

5. European countries do not have a uniform methodology for assessment of economic losses and damage done by natural disasters. As a rule, each country adopts its own methods that are best adapted to its economic, legislative, natural and industrial conditions. The review of the existing European methodologies for assessment of consequences of forestry catastrophic events has shown that the currently existing methods of calculating and assessing of losses are either universal or specific depending on the type of natural disaster.

Universal methods are used to assess damage from various natural disasters. The peculiarity of these methods is their universality and consideration of the main items of costs that will affect the total amount of costs and losses. At the same time, there are specific methods for assessing the consequences of windfalls and windbreaks, for example, the method of comparative analysis of losses from hurricanes that occurred over a certain period of time, used in Poland.

An analysis of earlier studies suggests that methods for assessing windblow damage in Europe may include the definition of losses with monetary valuation and without monetary valuation. Most authors have relied on monetary valuation. In this case, the choice of method and

content of research often depends on the availability of data. Thus, the results of various studies in many cases can not be compared directly in terms of overall costs or consequences due to the variety of methods and data used for the calculation.

At the same time, some elements of various European methods can be used as a foundation or base for developing a methodology for the economic assessment of the consequences of natural disasters for the natural and production conditions of Belarus.

6. In the last decade, there has also been a clear tendency in the forestry of the Republic of Belarus to increase the frequency and intensity of natural disasters associated with strong winds. Unlike the practice of European countries, Belarus has taken a course towards accelerated development of damaged plantations with the parallel sale of harvested wood. Some of the timber received is sold in round form abroad to reduce the losses incurred due to the higher cost of wood on the external market.

7. The domestic practice of eliminating the consequences of natural disasters by the example of the windblow in 2016 made it possible to develop a positive experience of measures to eliminate them:

- workers stimulation;
- creation of headquarters, experience exchange, expert assistance;
- organization of checkpoints for forest guard;
- organization of technical service points in the immediate vicinity of damaged areas;
- permanent monitoring of damaged and adjacent territories;
- improving fuel consumption rates of forest machinery;
- logging equipment production norms reduction;
- the direction of employees of other forestry enterprises for the development of windfall-cutting areas impassable in affected forest enterprises;
- involvement of employees of affected forest enterprises in overtime work;
- directive limitation of the volume of logging in the main felling cuts to prevent a fall in prices in the round timber market.

8. Belarusian experience analysis in estimating losses and costs from windblow events in forestry made it possible to establish that at present only additional costs for windfall areas development and the harvesting of damaged timber are actually taken into account by reducing the production rates and increasing fuel consumption rates. At the same time, a number of additional losses and costs that have a significant impact on the efficiency of forestry organizations in the current or future period of time remain unaccounted for:

- losses from lower prices on harvested roundwood;
- losses from deterioration of the assortment structure of harvested wood;
- losses from additional volume of wood waste formation;
- losses from reduction of the future growth of wood;
- losses from income shortage of non-timber products, tourism and recreational activities, hunting management, etc .;
- losses from the impact on water and soil;
- additional costs for infrastructure restoration;
- additional costs for reforestation;
- additional costs for safety and labor protection and a number of other factors.

9. Based on the completed research analysis on the problems of windblow events in the forests of Europe and the Republic of Belarus and covering activities for their elimination, estimating methods of losses and costs, timber market development, and methods for storing harvested wood, data were obtained, which later were used as the basis for developing an improved methodology, allowing more fully assess the impact of natural disasters and modern sustainable forest management and forest management.

## **2 Impact analysis of various climate related catastrophic forestry events. Development of a methodology for assessing the economic costs and losses from the natural disasters**

### **2.1 Comparison of economic costs of wind blows and other climate change related impacts (e.g. fire, drought, snow and ice, etc.) and their calculation methodology from other European countries**

#### **2.1.1 Brief description of the past natural disasters in Europe**

Adverse weather events have become more frequent and widespread in Europe over the recent years. These catastrophic events have social and environmental impacts and cause increasing damage and economic losses [24, 25, 26].

Right now natural hazards (heat waves, heavy precipitation, wind storms, landslides, droughts, forest fires, etc.) are of regular and intensive character and cause substantial economic damage in Europe. European experts estimate climate change events to be observed in the period ahead. Therefore the impact of all natural catastrophic events, their duration and intensity are expected to enhance [24, 27, 28].

Main disastrous factors that affect the forest sector in Europe are storms, fires, pests, snowbreaks, droughts, forest diseases and herbivorous animals.

*Wind storms (windblows)* and snowbreaks have major negative impacts on the forest sector of Europe. They cause up to 50% of the total damage incurred by natural disasters. The average annual damage by windblows is estimated at 38 million m<sup>3</sup> of damaged wood, that by snowbreaks – at 4 million m<sup>3</sup>.

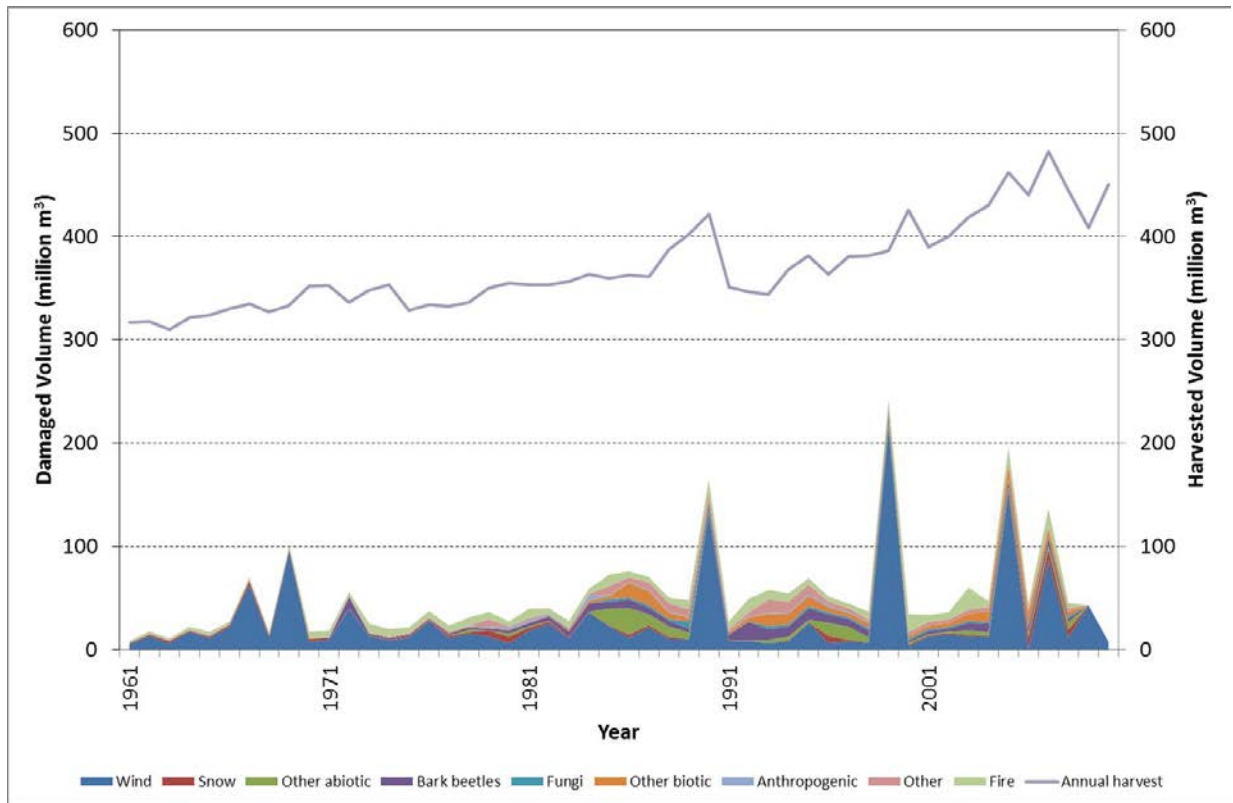
Over the last decade Europe has experienced two heavy storms. One of them, cyclone Klaus resulted in 43.1 million m<sup>3</sup> of damaged wood (14% of the total standing volume). Over 5 million m<sup>3</sup> was damaged by the successive wave of pests. 31 people died during rectification of the storm consequences (12 people in France, 15 people in Spain, 4 people in Italy).

South-west France experienced two heavy storms in 1999 and 2009 which caused approximately 75 million m<sup>3</sup> of damaged wood and 40 fatal cases. Direct costs of the forest sector amounted to nearly 1 billion EUR, the total economic loss was estimated at 3 billion EUR.

Since 1950 the relative share of damage to European forests has been proportional to the fixed volume of wood harvest or annual wood increment (Figure 29). Total damage an very considerably across countries. For instance, small countries (Denmark, the Netherlands and Switzerland) had a proportionally high level of damage. The damage incurred to large countries (Sweden, France, Germany) was highly expressed at the regional level and affected considerable share of wood volume and annual cuts. Heavy storms affecting the whole Europe (e.g., in 1999) led to the total damage that exceeded a half volume of the total wood harvest in Europe (excluding Russia). For several countries the losses were three times as high as the annual wood harvest.

In the last several years the movement pattern of storms affecting Europe has moved further southwards and eastwards. This leads to the fact that countries in South and Eastern Europe have been experiencing more frequent and more intensive storms that cause more considerable damage.

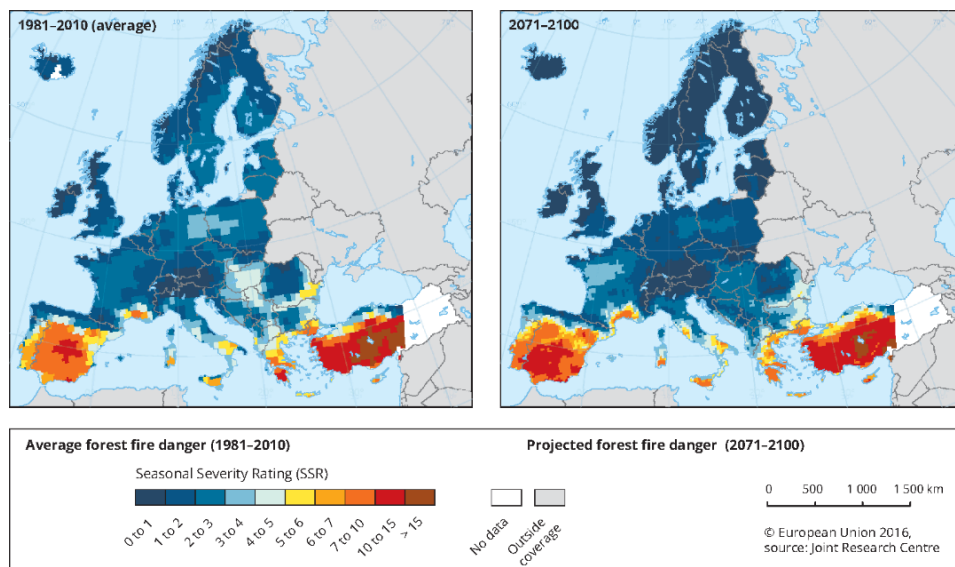




**Figure 29 – Damage volume by adverse weather effects in the European forests**  
 Source: Gardiner B. et.al., 2014 (data provided by Mart-Jan Schelhaas)

Forest damage by snowbreaks and ice is commonly observed in mountainous areas. For example, substantial damage was incurred to Slovenian forests in January-February 2014 with the damage volume of more than 9 million m<sup>3</sup> of wood.

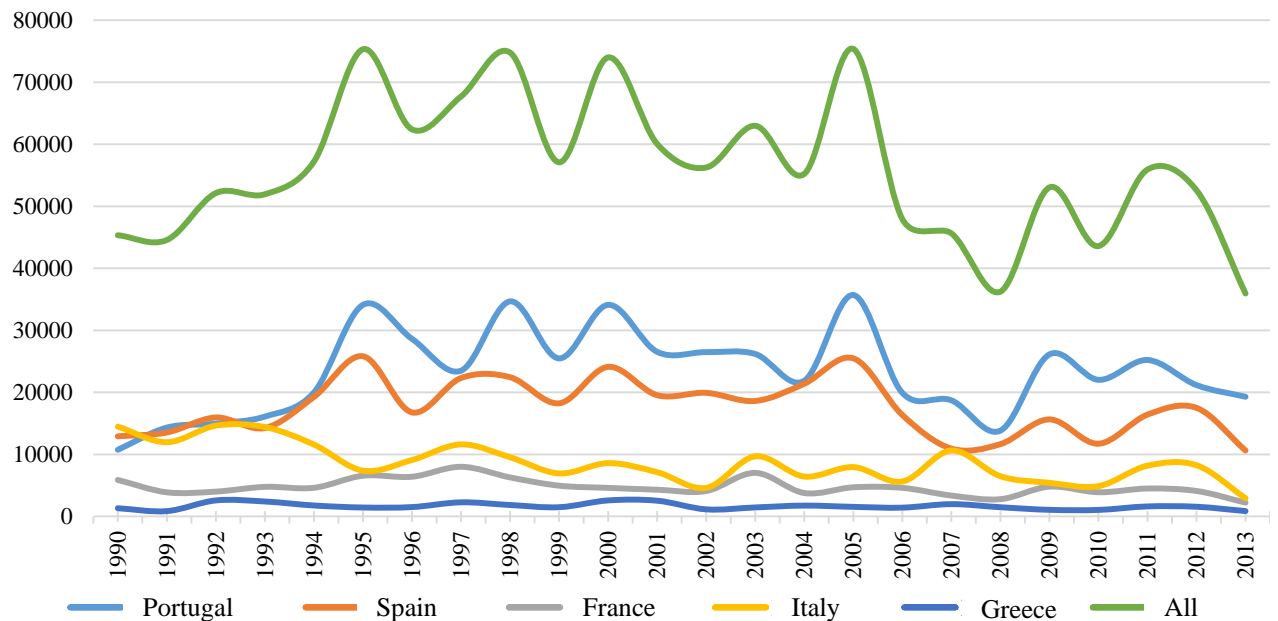
*Forest fires* are a serious challenge to most Mediterranean countries (Figure 30). In the last 20 years there has been a clear trend towards increasing cases of forest fires [29, 30].



**Figure 30 – Current and estimated condition and direction of fire hazards**  
 Source: Data of European Environment Agency

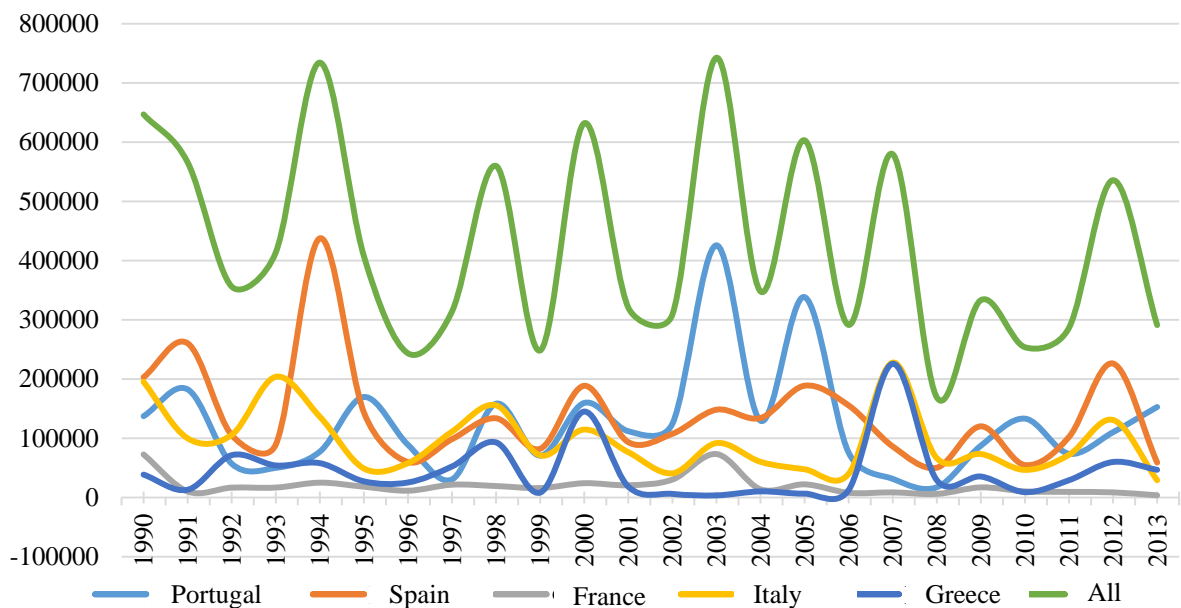
Annual average area affected by forest fires in Europe amounts to 500 000 ha, 95% of which is located in Mediterranean countries. They experience about 35 000 forest fires a year, i.e.,

about 100 fires a day [31]. Figures 31 and 32 illustrate the number of forest fires and burned-over areas in five countries that are characterized by the most frequent forest fire cases [29].



**Figure 31 – The number of forest fires in five South European countries**

Source: Data of European Environment Agency



**Figure 32 – Burned-over areas in five South European countries, ha**

Source: Data of European Environment Agency

Summarizing the above, it can be concluded that an unbiased assessment of economic costs of different forest-damaging factors is required in order to monitor the consequences of adverse weather impacts on forest ecosystems and to assess the damage in view of economic, ecological and social factors.

## 2.1.2 Comparison of economic losses from windblows and pests

### 2.1.2.1 Analysis of losses from windblows

**Increased amount of wood waste.** Most experts agree that the amount of wood waste increases after windblows. However, until now there have been no reliable estimates of total or relative amount of wood waste in any study. There are only some data [32] that allow us to make generalized assessment. Table 20 shows maximum and minimum amounts of wood waste after windblows.

Table 20 – Minimum and maximum amount of wood waste after windblows

Indicator	Maximum	Minimum
Increased amount of wood waste	+ 400%	+ 200%
Share of wood waste	20%	approx. 5%

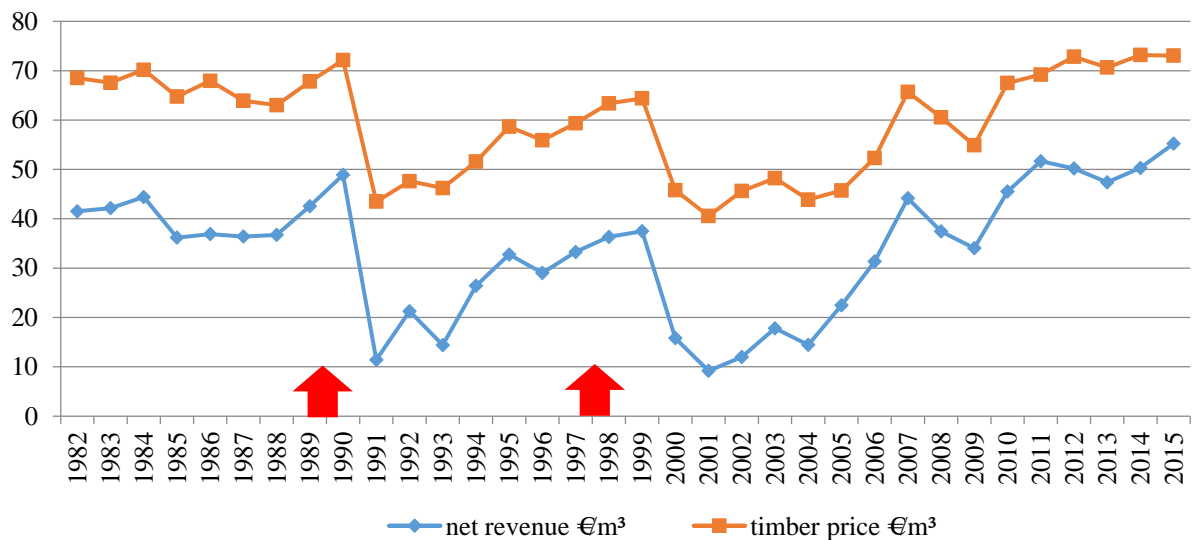
As can be seen from Table 20, wood waste amount increases 2-4 times after windblows which requires additional recording and disposal of the resulting wood waste.

**Wood market impacts.** Wood price drops are the main economic outcome of large-scale windblows in Europe. Various sources of data contain information about considerable price drops. Table 21 gives a selection of windblow impacts over different time periods in Europe as well as price dynamics for several timber types.

Table 21 – Price drops after large-scale windblows

Source	Country	Assortment, quality	Price drop
[33]	Estonia	–	1,42 €/m <sup>3</sup>
[34, 35]	–	–	6%
[36]	–	–	25%
[1, 37, 38]	Switzerland	Coniferous trees, class B/C	44%
		Coniferous trees, class D	40%
		Broadleaved trees, class B/C	34%
		Coniferous trees, class C/D	22%
[39]	–	Mature pine	44%
		Mature oak	23%
		Mature beech	75%
		Mature pine (roadside)	33%
		Mature oak (roadside)	10%
		Mature beech (roadside)	54%
[379]	Sweden, 2005	Spruce, pine	37%
		Spruce, pine	14%
	Germany, 1967	–	50
	Netherlands, 1972	–	>90 %
[40]	France, 2009	–	70
[40]	Switzerland	–	30%
[41]	Germany, 1990	Norway spruce, white fir, Douglas fir	45%
		Pine, larch	27%
		Beech	24%
		Oak	9%
	Germany 1999	Norway spruce, white fir, Douglas fir	38%
		Pine, larch	17%
		Beech	4%
		Oak	29%

Financial performance of forestry enterprises depend on the timber price dynamics. Data of the State forestry enterprise from Baden-Württemberg prove that net receipts from timber sales decline as timber prices go down but at a slower rate. This can be explained by changing costs of wood harvesting operations (Figure 33).



**Figure 33 – Timber prices and net profit per 1 m<sup>3</sup> (case of State forestry enterprise BW)**

*Source:* Bundesministerium für Ernährung und Landwirtschaft (BMEL), own data

Thus, natural disasters have a considerable impact on timber markets whereby market price fluctuations can hardly be predicted. Timber price drops resulting from adverse weather effects causes loss of profit and lower cost efficiency of forestry organizations (Box 6).

#### Box 6: Short and medium term losses of profitability

The profitability is basically driven by two factors, costs for and proceeds from forestry operations. Down to the present day the decrease of the net profits was mainly driven by the decrease of the proceeds from timber, which is still the main source of income for the majority of forest enterprises.

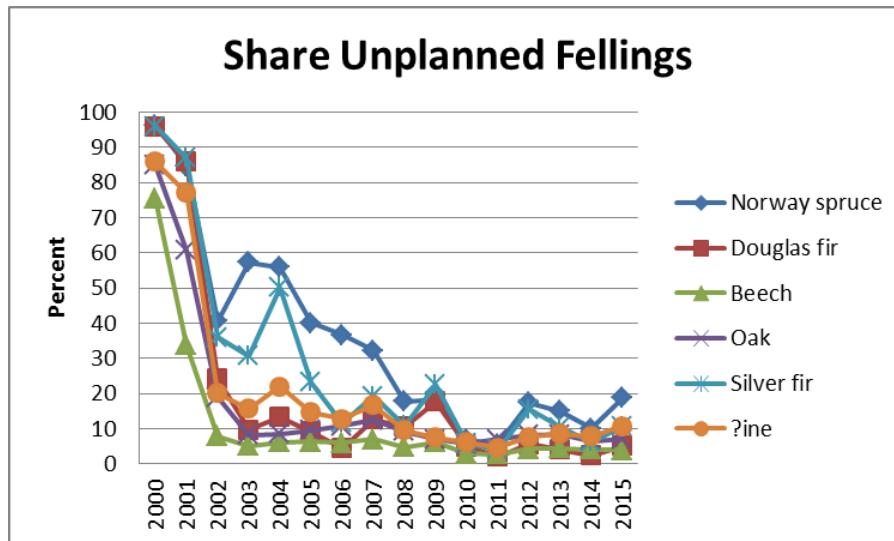
In almost all cases the decrease of timber prices after large scale disasters is the main explanatory factor for a short or medium term decrease of the profitability over a period of three to seven years. There are three main components that are influencing the overall net returns from timber:

- Share of wood waste is increasing
- Shift in shares of various assortments and grades to a higher proportion of lower grades
- Shift of timber prices for individual assortments and grades.

**Indirect losses of timber.** Windblows are usually followed by pest attacks in the damaged forest areas. The pests incur secondary damage to the forests. However, clear separation of the losses from windblows and those from pests is not possible as well as assessment of the associated economic damage because these events are usually overlapped. Secondary timber losses from pest attacks must also be taken into account as a factor that affects the timber market after windblows in the long term.

Information about unplanned fellings gives only approximate estimates about the duration of the timber market impacts and cannot be used to assess monetary effect. As cited in the reference source [42], the share of unplanned fellings increased since 2003 due to pest attacks which in its

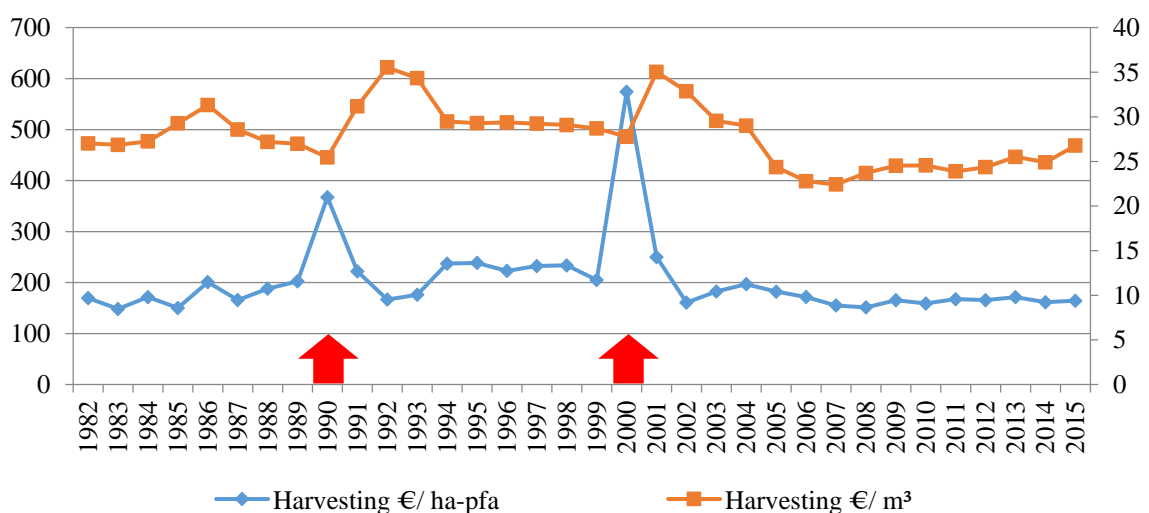
turn had a destabilizing effect on the market for subsequent 5–6 years (Figure 34).



**Figure 34 – Share of unplanned fellings for different tree species**  
*Source: own data*

**Assessment of damaged forested areas.** It is evident that forest damage by adverse weather effects will vary depending on natural conditions. There is no exact data available for this cost item. The reference source [33] gives information about the costs of 145 000 EUR for the windblow area with wood damage of about 1 million m<sup>3</sup>. It should be noted that the costs will vary for different regions.

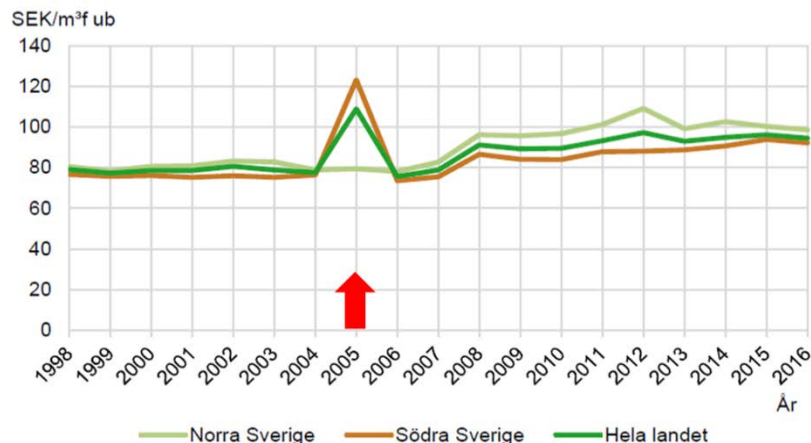
**Timber harvesting costs.** A major consequence of large-scale windblows is enhanced timber harvesting volumes. The results of State forestry enterprise BW where about 10 thousand ha of forest was damaged report considerably increased costs of felling operations on productive forested areas due to enhanced timber harvest. The per unit cost [€/m<sup>3</sup>] has slightly declined in the harvesting year, however, it increased 2–3 times after two years. Over four years additional costs increased by 10–15% (Figure 35).



**Figure 35 – Time sequence of harvesting costs in State forestry enterprise BW (TBN BMEL, own data)**  
*Source: (TBN BMEL, own data)*

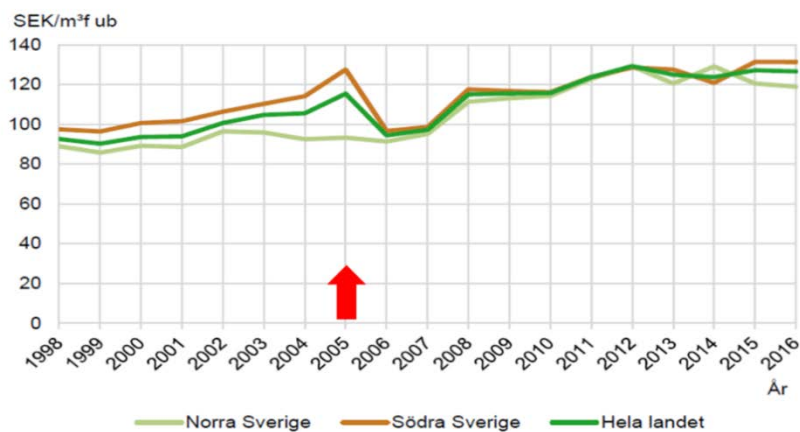
Similar studies from Sweden give a completely scenario [43]. Timber harvesting costs increased by approximately 25% (across the country) or by over 30% in the most damaged regions.

Considerable increase in costs was registered for the regions where forested areas were damaged (Figure 36). On the whole, additional costs went up by approximately 10% in 2005 and slightly dropped in the subsequent years, thus, the average increase was quite minor (Figure 37).



**Figure 36 – Timber harvesting costs, regeneration fellings**

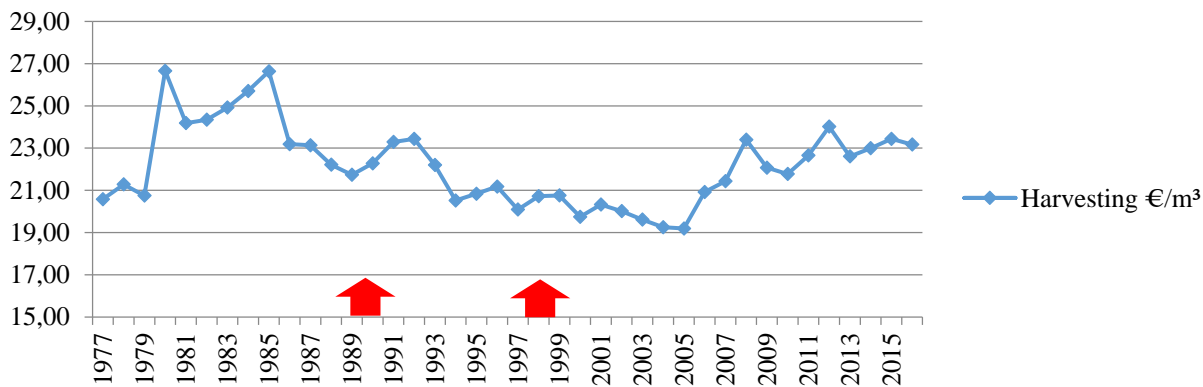
Source: Karlsson S., 2016



**Figure 37 – Timber harvesting costs, all felling types**

Source: Karlsson S., 2016

In Austria a slight increase (by less than 10%) was registered immediately after the storm events. However, afterwards the timber harvesting costs went down [44] (Figure 38).

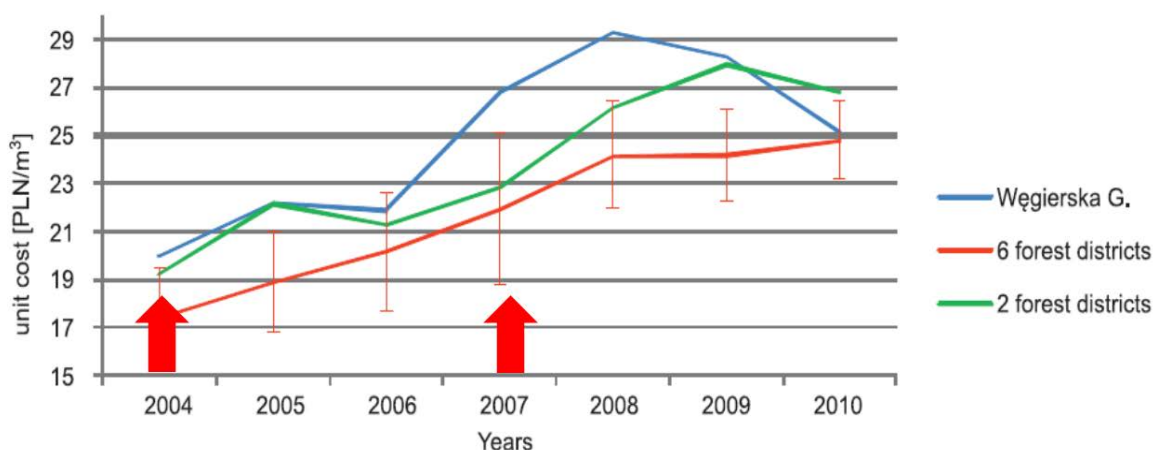


**Figure 38 – Timber harvesting costs in Austria**

Source: FADN data provided by Sekot, Boku Vienna

The reference source [45] gives a comparative study of recovery costs in heavily damaged and less damaged areas in Poland (Figure 39). Timber harvesting costs in heavily damaged areas

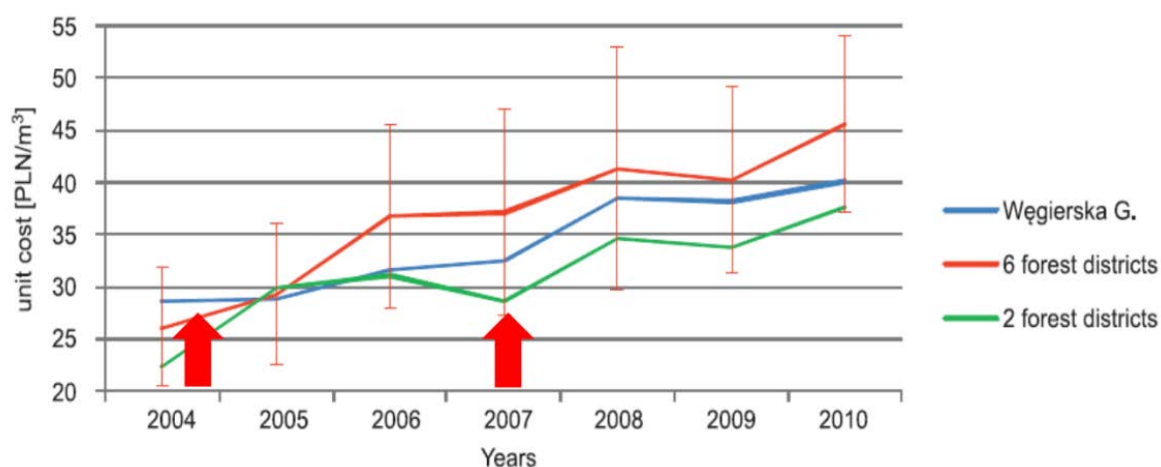
were about 10-15% higher than those in less damaged forest areas. However, the difference in cost values was greatly dependent on the time period when the studies were done and the areas selected.



**Figure 39 – Comparison of timber harvesting costs in Poland**

Source: Sikora A.T., Ukalska J., 2014

The same experts point out that timber transportation costs were lower as compared to most forest areas under study and increased only slightly as compared to two other areas (Figure 40).



**Figure 40 – Comparison of timber transportation costs in Poland**

Source: Sikora A.T., Ukalska J., 2014

The authors of [33] give data on increased harvesting costs by about 1 €/m³ in the Baltic countries. In Slovenia recovery operations after two windblows resulted in the increase of timber harvesting costs by 1 €/m³ and 7 €/m³ respectively. The reference source [35] informs about additional harvesting costs during recovery operations by approx. 4% as compared to normal conditions. Thus, it can be concluded that all the areas under study experienced increase in timber harvesting costs after windblows. The review has made it possible to establish a range of maximum and minimum costs of timber harvest (Table 22).

Table 22 – Minimum and maximum levels of increased timber harvesting costs

Indicator	Maximum	Minimum
Additional harvesting costs [€/ m³] in damaged areas	Up to 35%	–
Additional harvesting costs [€/ m³] with regard to larger areas and longer period	15%	Approx. 4%

**Timber storage costs.** The timber storage costs can vary substantially depending on the different storage conditions. The reference source [46] reports that the costs of wet storage of timber ranged from 5 to 50 Swiss francs. As a rule, the highest costs of timber storage are registered in the first year and amount to 15.00 €/m<sup>3</sup> whereas they decrease to 2.00–3.50 €/m<sup>3</sup> in the following years (Table 23) [47, 48].

Table 23 – Minimum and maximum levels of timber storage costs

Indicator	Maximum	Minimum
Costs of timber storage in the first year (including investment and transportation)	20.00 €/m <sup>3</sup>	6.00 €/m <sup>3</sup>
Costs of timber storage from the second year onward	3.50 €/m <sup>3</sup>	2.00 €/m <sup>3</sup>

**Forest regeneration costs.** More intensive forest planting activities and associated higher costs are registered within the first year after windblows due to large-scale damage and required forest regeneration on the damaged areas. However, the high costs result from the large areas where forest regeneration is required (Figure 41).

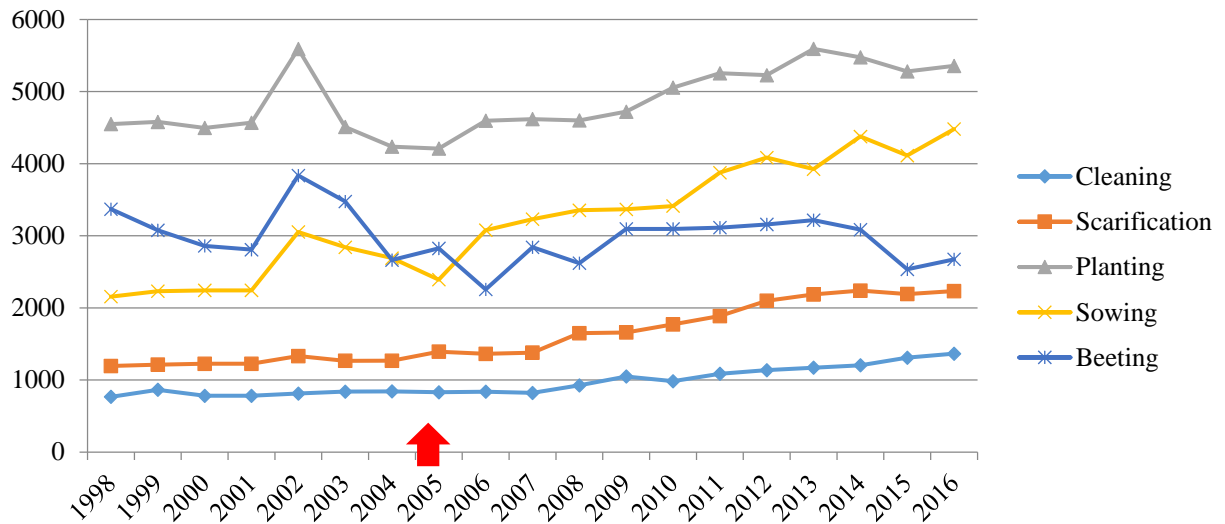


Figure 41 – Forest regeneration costs in Sweden [43]

Source: Karlsson S., 2016

The authors of the reference source [45] point out that forest regeneration costs in highly damaged forest areas can increase several times over a short period of time (Figure 42).

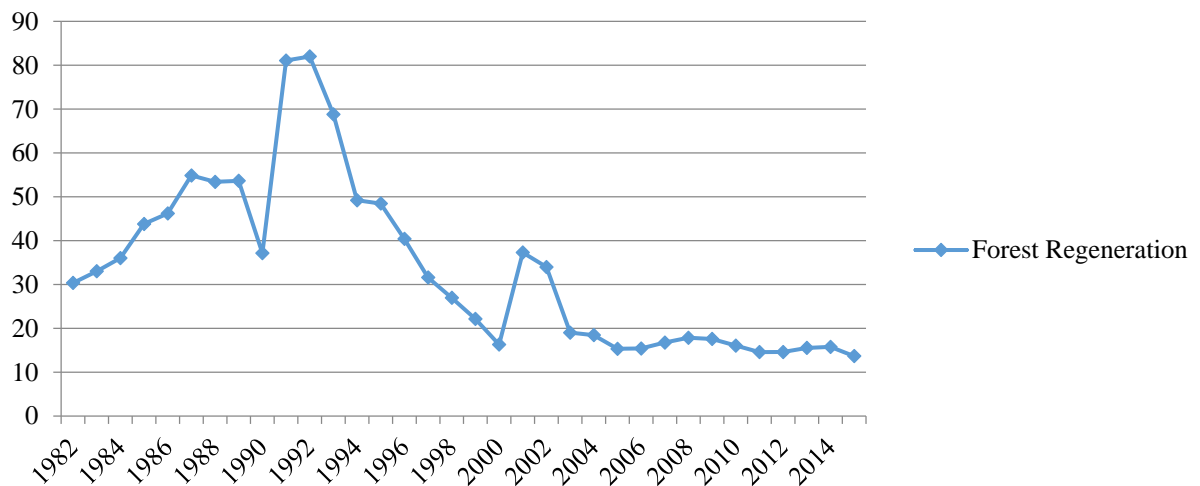


Figure 42 – Forest regeneration costs of a state forestry enterprise

Source: Sikora A.T., Ukalska J., 2014



The report [33] gives information about additional forest regeneration costs of about 500 € ha of cultivated area. The reference source [49] shows the relation between forest regeneration types and the associated costs when natural regeneration is applicable (Table 24). Table 25 provides a review of minimum and maximum forest regeneration costs.

Table 24 – Forest regeneration types and associated costs

Activity	Sequence – PRP 1 and 4		Sowing – PRP 3		Forest planting – PRP 2		Forest planting – PRP 5	
	€	%	€	%	€	%	€	%
Site preparation	1,006	100	1,006	79	1,006	19,5	1,006	16,5
Regeneration	0	0	270	21	2,209	43	2,900	48
Forest protection	0	0	0	0	1,938	37,5	2,158	35,5
Total	1,006	100	1,276	100	5,153	100	6,064	100

Table 25 – Minimum and maximum costs of forest regeneration

Indicator	Maximum	Minimum*
Forest regeneration costs €ha-pra**	+100%	+100% within two or three years ****
Forest regeneration costs €ra-ca**	6000 €ha-ca	500 €ha-ca

\* minimum in case of danger message

\*\* productive forest areas

\*\*\* cultivated areas

\*\*\*\* no additional costs have been registered in some areas

**Forest infrastructure costs.** In Sweden the costs of forest road infrastructure demonstrate a steady upward tendency. However, there was no direct connection to the storm Gudrun [43] (Figure 43).

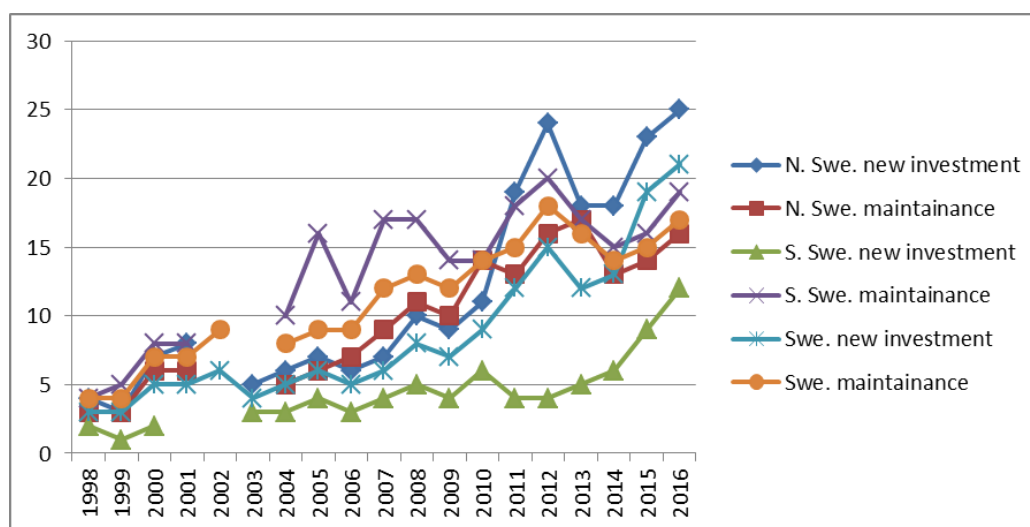


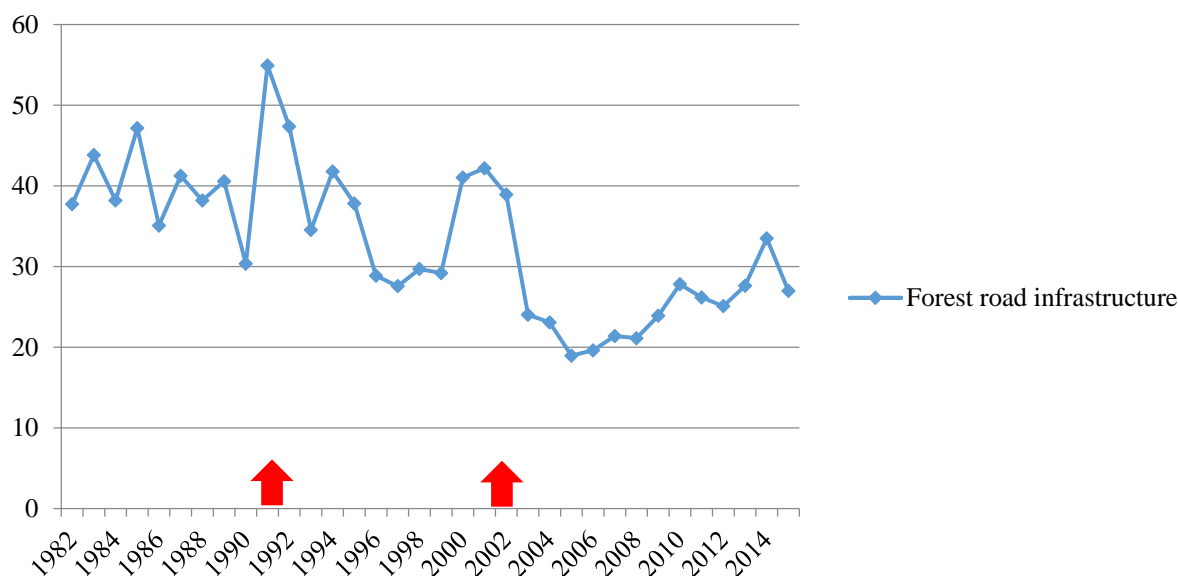
Figure 43 – Costs of forest road infrastructure in Sweden

Source: Karlsson S., 2016

On the contrary, the data of the state forestry enterprise Baden-Württemberg show a clear connection between the forest road infrastructure costs and adverse weather effects. Over two (1991-1992) or three (2000-2002) years the costs of forest road maintenance increased by approximately 25-30% (Figure 44). The findings of the study done in Poland also confirm the possible increase in costs [45] (Figure 45).

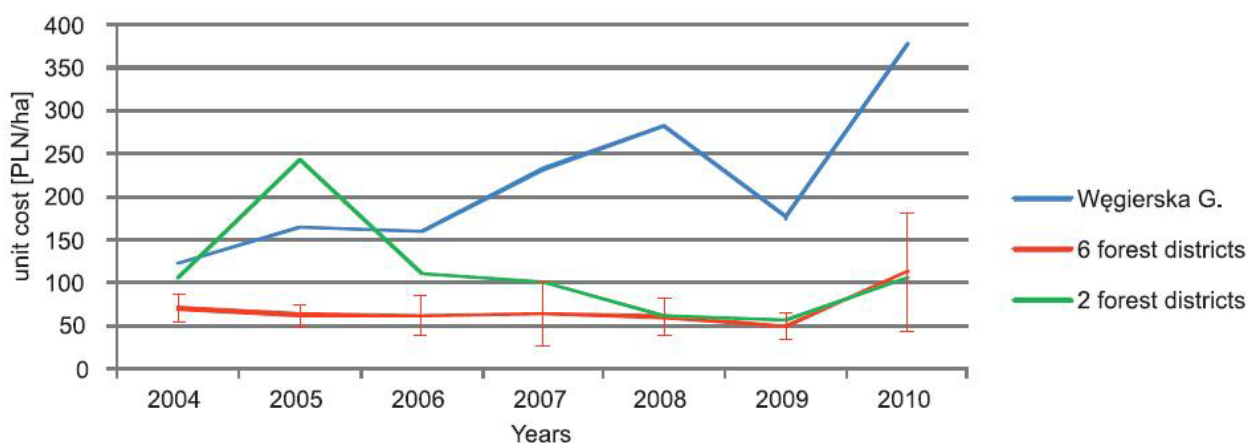
The report [43] gives data about additional costs that can be compared to those in Germany (the estimated area covers about 4 000 ha). The total costs amount to 1000 €/ha for small damaged areas and about 100 €/ha for large windblow damaged areas.

Table 26 provides a review of forest road infrastructure costs.



**Figure 44 – Forest road infrastructure costs of the State forestry enterprise BW**

Source: (TBN BMEL, own data)



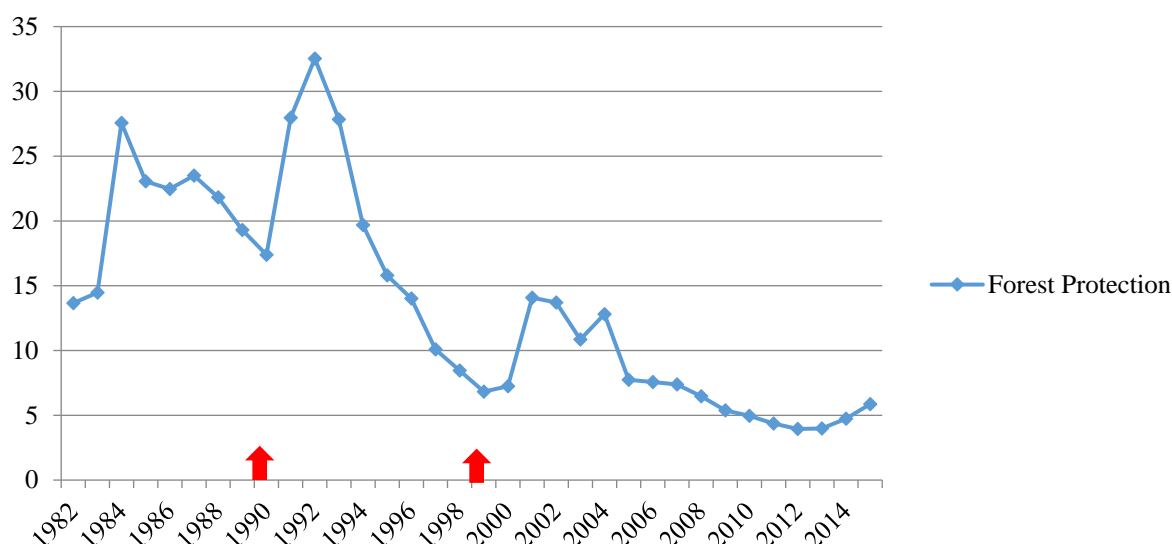
**Figure 45 – Comparative costs of forest road infrastructure in Poland**

Source: Sikora A.T., Ukalska J., 2014

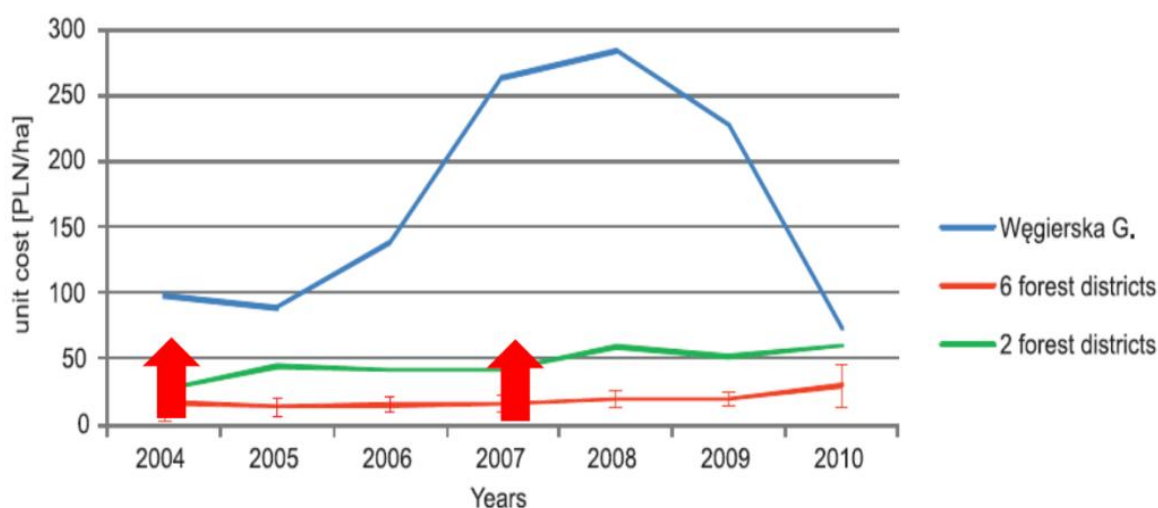
**Table 26 – Minimum and maximum levels of forest road infrastructure costs**

Indicator	Maximum	Minimum*
Total costs for damaged areas	100 €/ha of cultivated area	0
Increased costs due to larger scale of damage	Increase by 20–30% within 2–3 years	0

**Forest protection costs.** Most experts cite data about the increase in forest protection costs after storms and windblows. The case of state forestry enterprise Baden-Württemberg shows a double increase in the costs within 3-4 years (Figure 46). A Polish study gives information about the 500% increase in the forest protection costs as compared to reference values (Figure 47). In the Baltic countries the forest protection costs went up to 40 €/ha. However the studies do not clearly indicate whether the costs are related to damaged areas or the total productive area.



**Figure 46 – Forest protection costs**  
*Source: (TBN BMEL, own data)*



**Figure 47 – Comparison of forest protection costs in Poland**  
*Source: Sikora A.T., Ukalska J., 2014*

Table 27 shows the range of forest protection costs.

Table 27 – Minimum and maximum levels of forest protection costs

Indicator	Maximum	Minimum*
Forest protection costs (larger scale)	500% within two or three years	200% within two or three years

### 2.1.2.2 Analysis of losses from pests

**Increased amount of wood waste.** In case of pest damage of forest stands, the share of wood waste may remain stable due to the same felling operations as in normal conditions. It can be advisable to completely clear the felling sites from the wood waste by burning or processing into wood chips, thus preventing the pests from further spreading.

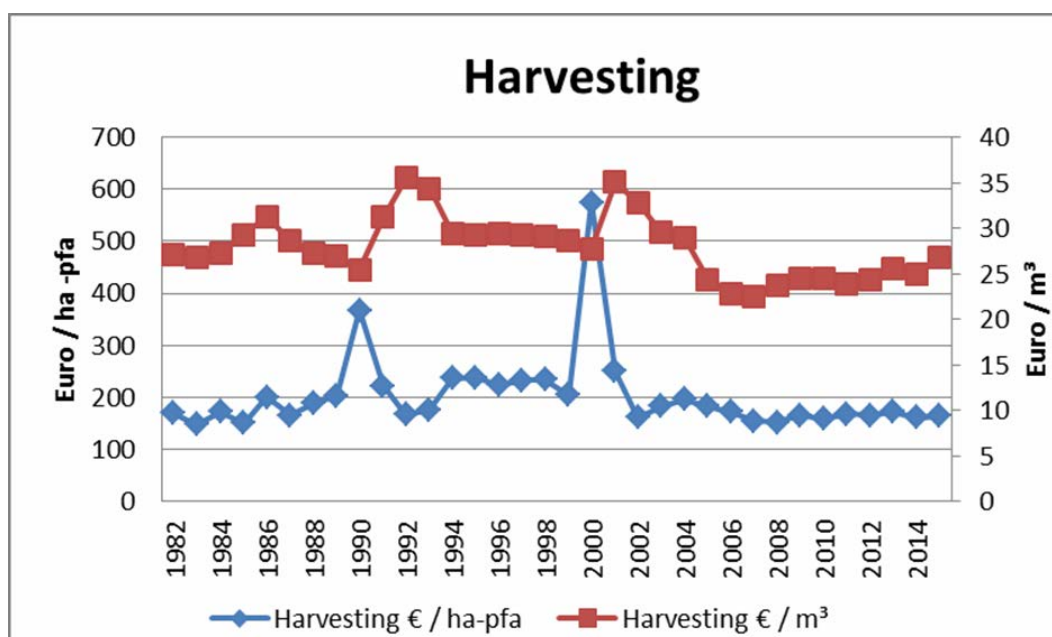
**Wood market impacts.** Pest attacks are expected to decrease the price of wood harvested from sanitary fellings. However, there are no data available about the percentage of rate of the price decline. Moreover, in Europe pest attacks are usually accompanied or caused by windblow

events. So clear differentiation between the price drops due to windblows and pests is hardly possible.

**Indirect losses of timber.** There are some evidences that pest attacks can cause certain typical secondary effects. In case there are remaining pest-attacked trees in the damaged areas, a risk of forest fires may arise. However, there are no accurate data available.

**Assessment of damage to the area.** In case of pest outbreaks no special measures are taken to assess the affected area. Usually the assessment is done during sanitary fellings in the area.

**Timber harvesting costs.** Timber harvesting costs in the areas under pest attacks are apparently the same as the costs of regular fellings. However, it is worth noting that the felling actions may (or must) be different. Recovery actions must be taken immediately after the first signs of pest invasion have become evident. In this case only small forest areas are cut out which leads to higher share of fixed and secondary costs, e.g., transportation of workforce and machinery to the cutting areas. Accounting data suggest that the costs are increase in the second-fourth years after windblow events (Figure 48). These years are characterized by more intensive cuts due to pest attacks.



**Figure 48 – Forest protection costs of state forestry enterprise BW**

*Source: TBN BMEL*

**Timber storage costs.** The storage costs of timber harvested from pest damaged areas are basically the same as those of timber harvested from windblow areas. Still, there is a widespread belief that the medium quality of timber from sanitary cuts is generally lower. Therefore we can hardly expect that future higher sales prices of timber will compensate for the costs incurred. Long-term storage of pest damaged timber is advisable if there is no opportunity of direct sale.

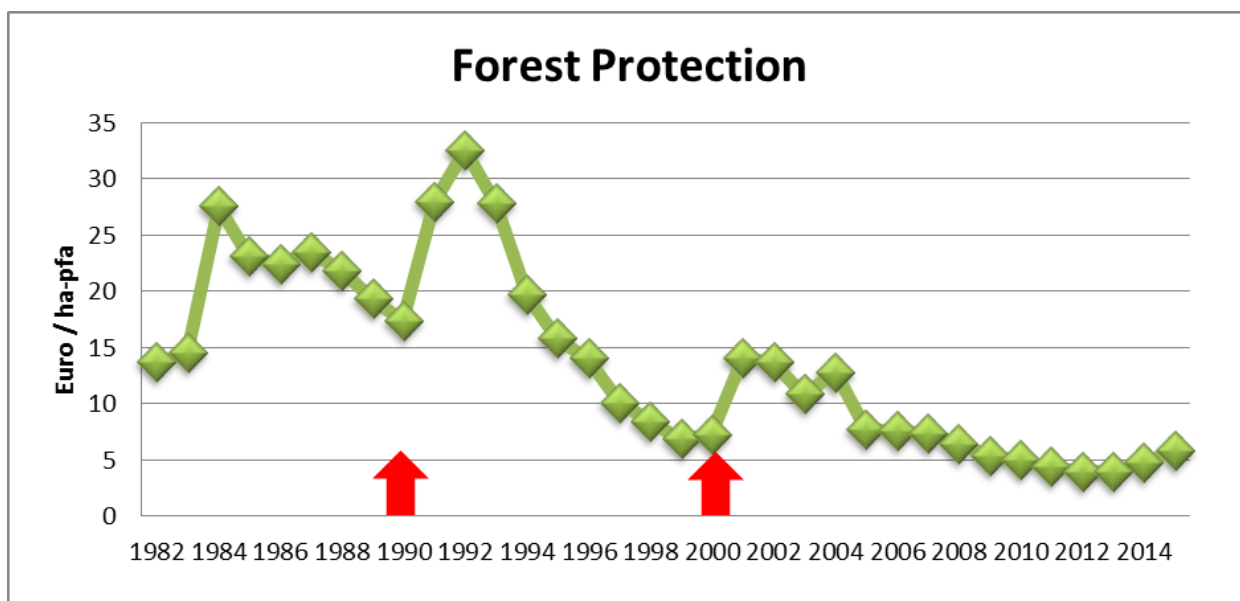
**Forest regeneration costs.** Commonly it is difficult to differentiate between certain risk factors in case of secondary pest damage. The costs of 1 ha cultivated area should generally be comparable to the costs of regular forest regeneration. Anyway the damaged areas must be recovered which can result in extra costs.

Besides, natural forest regeneration is unlikely to take place in the areas attacked by bark beetle. This being the case, extra costs may arise from the difference in costs of natural and artificial forest regeneration.

**Forest infrastructure costs.** During the cutting operations in the pest damaged areas the additional costs of forest infrastructure are usually attributed to higher timber volumes to be transported.

**Forest protection costs.** Contrary to windblow events, direct pest control actions are not only possible but highly important to considerably mitigate the negative consequences. Studies prove the importance of active pest control, but do not give any information about the related costs. Modified costs of forest protection registered in accounting systems or networks may be used a source of pest control costs (Figure 49). Though, it should be kept in mind that the accounting systems often do not illustrate administrative costs that are of critical importance.

Intensive pest control in the buffer zone of national parks is carried out to prevent pest outbreaks (towards managed forests). The annual costs can amount to about 100 €per 1 ha (total costs) [50]. Thus, it should be noted that the costs may vary depending on the intensity of pest control actions.



**Figure 49 – Forest protection costs in state forestry enterprise BW**

*Source:* (TBN BMEL, own data)

Therefore it can be concluded that different natural disasters (windblows, snowbreaks, drying-out, fires, pests, etc.) lead to substantial losses in the forested areas and costs of recovery operations. Main losses and costs have been identified as follows: increased amount of wood waste; timber market impacts; indirect losses of timber; costs of assessment of the damaged areas; harvesting costs; timber conservation costs; forest infrastructure costs (mainly forest roads); forest protection costs.

Several methodologies have been developed and are applied in European countries to assess the costs and losses. These methodologies demonstrate some common features, however, they can greatly differ in terms of local conditions and forest management practices.

### 2.1.3 Calculation methodology for economic costs related to natural disasters

Either universal or specific methodologies are applied to assess economic costs of natural disasters in the forest sector of Europe. The universal methodology estimates costs and losses irrespective of risk factors. The specific methodology is aimed at assessing the damage done by a particular type of natural disaster.

A methodology developed by Croatian experts can be regarded as universal [3]. It is used to do a quick assessment of losses. It also designed to conduct a preliminary analysis of the scope, intensity and costs of damage. Final assessment is done only after data on recovery operations and forest regeneration are available.

Calculations are made based upon the preliminary data about the area and the intensity of damage. The assessment of the affected areas and stands can be done by remote sensing or surface

methods. The intensity of the damaged incurred to forest stands is established by The Methodology for Damage Assessment Caused by Natural Disasters [51].

Total damage from natural disasters covers the following losses and costs:

- **total losses of timber value.** The loss of timber value is defined as a difference between the values of standing forest before and after the natural disaster. The value of standing forest before the natural disaster is estimated depending upon the age and maturity stage of the stands as prescribed by The Regulations on Forest Management [52]. The total value of undamaged timber is multiplied by the degree of damage. The value of timber after the natural disaster is calculated in terms of average prices of the preceding year.

The total losses of timber value are supplemented by the increased costs of harvesting of damaged trees and lost wood increment [18];

- **forest regeneration costs.** These include: soil preparation; planting of new stands incl. estimation of the required planting material; protection of new stands; revision of forest management plans;

- **losses from forest road damage.** These include: clearing of forest roads from broken trees and debris; reconstruction of damaged road sections; construction of new hauling roads to ensure access to the damaged forest areas;

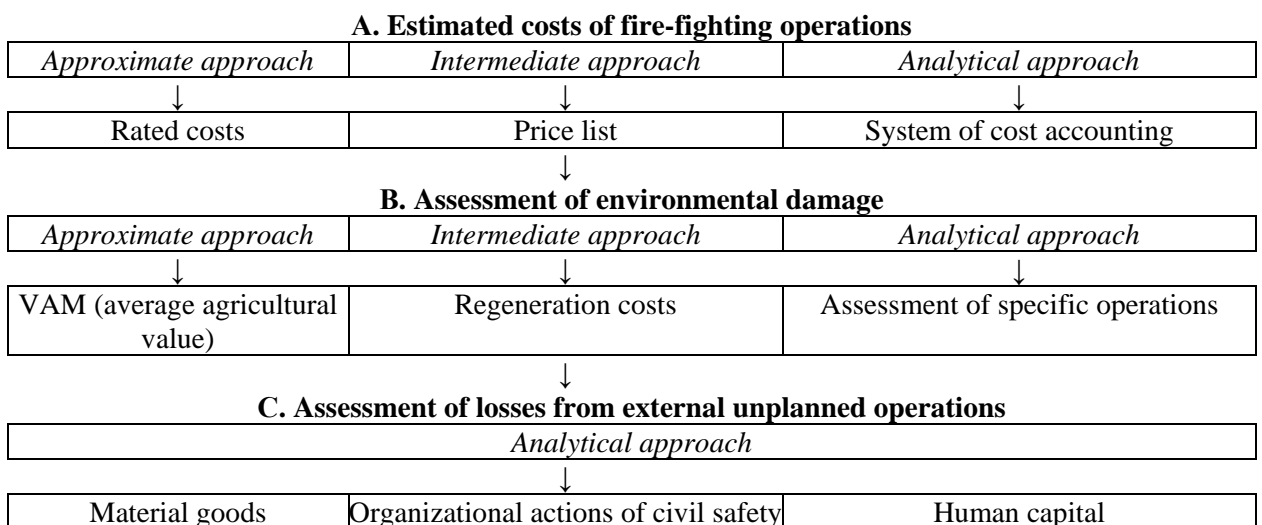
- **damage (losses if value) to forest ecosystem services.** Forest ecosystem services include both material (tourism, hunting, etc.) and immaterial (favourable effect on human health) benefits [53–55].

According to The Regulations on Forest Management [54] the value of forest ecosystem services is assessed at the compartment level and is dependent on: protection of soils, road and other structures against erosion and floods; hydropower impact on water regime; impacts on soil fertility and agriculture; climate and other environmental impacts, oxygen generation and cleaning of the atmosphere; recreation, tourism and healthcare effects; wildlife and game impacts.

Depending on the degree of damage the average value of forest ecosystem services went down by 40% for some compartments (heavily damaged forests), by 20% – for less damaged stands. If the stands were completely destroyed, the total value of forest ecosystem services was registered as damage.

The total damage incurred by natural disasters was calculated as a sum up of all estimated costs.

Specific methodologies of assessing the consequences of various natural disasters include a methodology of calculating losses from forest fires in Italy [56]. This methodology is based on a sequential and profound analysis of costs and losses based on modular approach and the scope of loss (Figure 50).



**Figure 50 – Modular methodology for assessing losses from forest fires**

Source: Ciancio O., et al. 2007

As can be seen from Figure 50, the total damage includes three components:

- A. Fire-fighting costs (machinery, equipment, workforce);
- B. Environmental losses of several goods and services;
- C. External emergency losses (accidents, infrastructure damage, general organizational costs of fire-fighting and subsequent forest regeneration).

**Fire-fighting costs** can be divided into two categories: general costs of fire control and specific fire-fighting costs.

To estimate the costs both rated (standard) calculation formulas and common cost values of equipment of workforce can be used.

Actual values (reporting data) can be applied to provide more accurate economic assessment.

**Assessment of environmental impact** can be based on the average agricultural values per 1 ha (VAM). The values of this indicator are assessed for all types of agricultural crops and forested lands.

This component can also include forest regeneration costs and specific operations.

It covers the following indicators as well:

- timber losses;
- non-timber losses;
- losses of tourism and recreational activities;
- hunting losses;
- hydrogeological protection ;
- climate change protection;
- biodiversity protection or naturalistic function.

**External emergency losses** cover infrastructure damage [57–63], civil safety measures, as well as costs of reimbursement to the people injured during forest fire fighting and recovery operations [64].

The review of the methodologies for calculation of economic costs of natural disasters allows us to conclude that both universal and specific methodologies can be equally efficient. The assessment has been based on the review of international practices of natural disaster management and economic costs assessment. Thus, it is possible to apply certain calculation mechanisms and suggest recommendations to improve a methodology for assessment of full economic costs of catastrophic forestry events in the Republic of Belarus.

## **2.2 Analysis of economic costs of windblows, fires, droughts, snow, ice and other adverse climate change related impacts in the Republic of Belarus**

Hydrometeorological observations over the past 20 years in Belarus show that the annual average temperature has increased by 1.1°C whereas the amount of precipitation has changed only inconsiderably. Climate change in Belarus results in the increasing number and extreme character of such adverse weather effects as frost, stormy winds, rain, snow and fires that cause damage to both the economy of the country and welfare of its population. Thus, the World Bank experts estimate that annual damage from the adverse weather effects amounts to 90 million USD in the Republic of Belarus [65].

According to the National Weather Service Belarus experiences 10–30 adverse weather events a year. Their number is growing only inconsiderably, however the intensity of such negative impacts is becoming higher due to climate change. Most natural disasters are of local effect. However, such adverse weather events as stormy winds, incl. windblows and whirlwinds, heavy rains, snow, fire hazards affect large areas of the country each year [65].

The adverse weather effects can be classified as follows [65]:

- meteorological: stormy winds, squalls, tornadoes, fog, hail, thunderstorms, heavy rain-fall, snow, blizzards, emergency fire hazards, etc.
- agrometeorological: droughts, frosts, extreme high and low temperatures, etc.
- hydrological: flood, extremely low and high water levels, early freeze-up, etc.

Approximately 80% of such weather effects occur during warm seasons. The most catastrophic events in the forest sector are such meteorological effects as fires, stormy winds and their aftereffects, i.e., forest pests and diseases [65].

Long-term estimations of climate change effects are based on regionalization of the climate scenarios resulting from the atmosphere general circulation model HadCM2 (Great Britain). According to the HadCM2 data for Belarus, the average temperatures across all months are expected to increase by 0.6–1.9°C in the period of 1990–2039 and by 1.0–2.9°C in the subsequent years of XXI century. The average annual precipitation will increase only inconsiderably in winter months. However, during the winter months the precipitation plays only a minor role as a moisture source for the current vegetation [65].

As can be derived from the model calculations, the temperature increase in Belarus can mostly be expected in summer months as well as in winter. This scenario is generally favourable to vegetation. However, the largest precipitation is expected in summer and winter whereas spring months, which are known as active vegetation period, will be characterized by lack of moisture. It is also expected that southern regions will suffer from insufficient precipitation and northern parts from moisture excess [65].

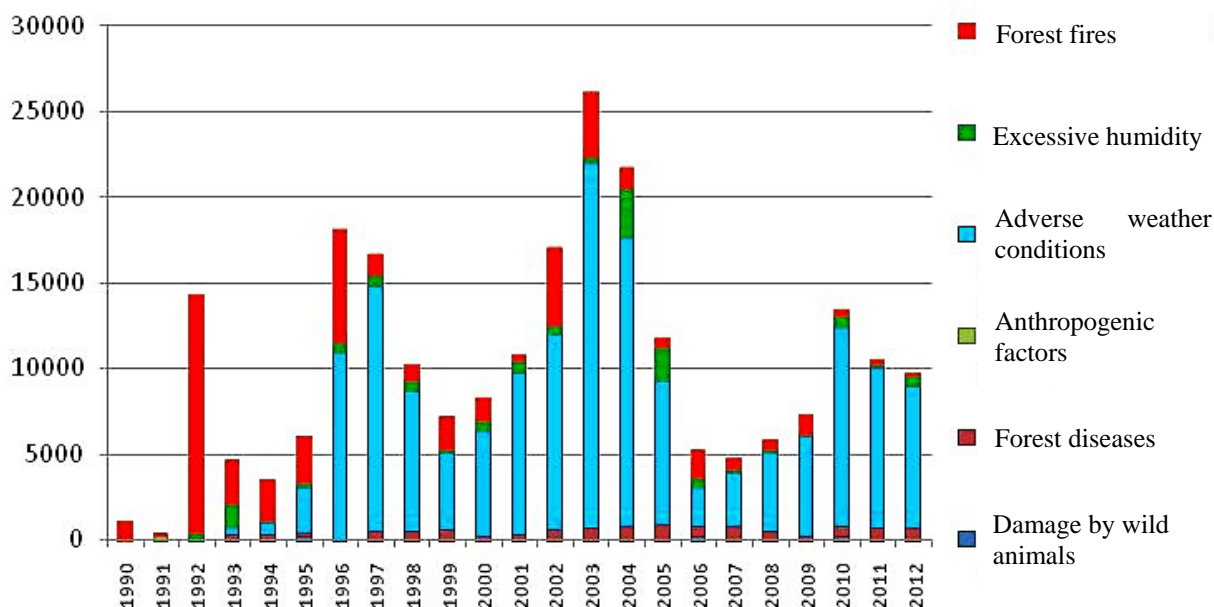
Early vegetation due to climate change can lead to higher probability and harmfulness of late spring frosts that can negatively affect the current wood increment, damage blooms and young fruits of trees and forest berries [65]. Droughts severely weaken the pest resistance of forests [66].

Other estimates of Intergovernmental Panel on Climate Change (IPPC) show that climate change in the Republic of Belarus will lead to changes in species composition and general bioproductivity of vegetation cover calculated by CSIRO-Mk3-b2 regression model can decline [65].

The aftereffects of climate change in the forest sector of the Republic of Belarus are shown as movement of ranges of some forest vegetation, more frequent forest disease and fires, changes in hydrological regime in some regions. Increasing losses of standing wood will occur from windblows. The efficiency of harvesting operations will badly be affected by shorter cut periods on boggy areas in winters as soils will freeze only moderately and the access by heavy logging machinery will be made rather difficult [65].

Figure 51 illustrates the impacts of adverse weather on the forest fund of the Republic of Belarus in 1990–2012 [65].

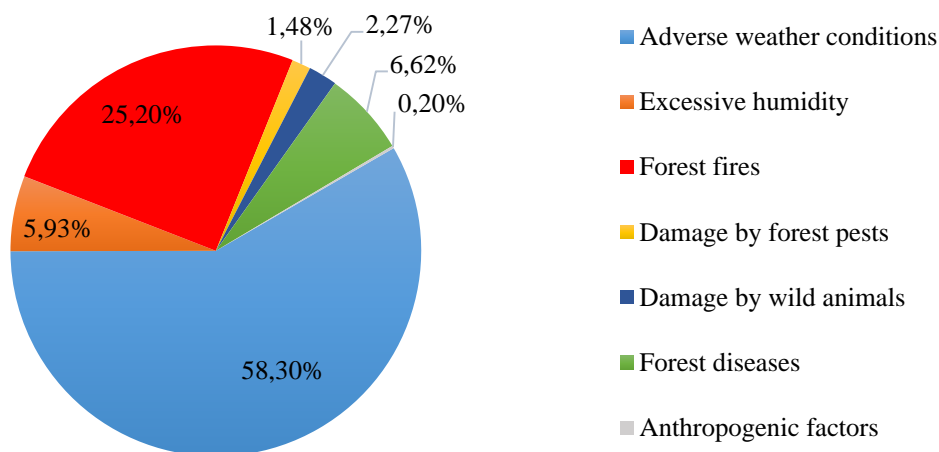




**Figure 51 – Forest damage by different factors, ha**

Source: National report on vulnerability and adaptation to climate change in Belarus

Figure 52 shows averaged impacts of certain adverse weather effects on the forest fund of the Republic of Belarus in 1990-2012 [65].



**Figure 52 – Damage to the forest sector of the Republic of Belarus by different adverse factors in 1990-2012, %**

Source: National report on vulnerability and adaptation to climate change in Belarus

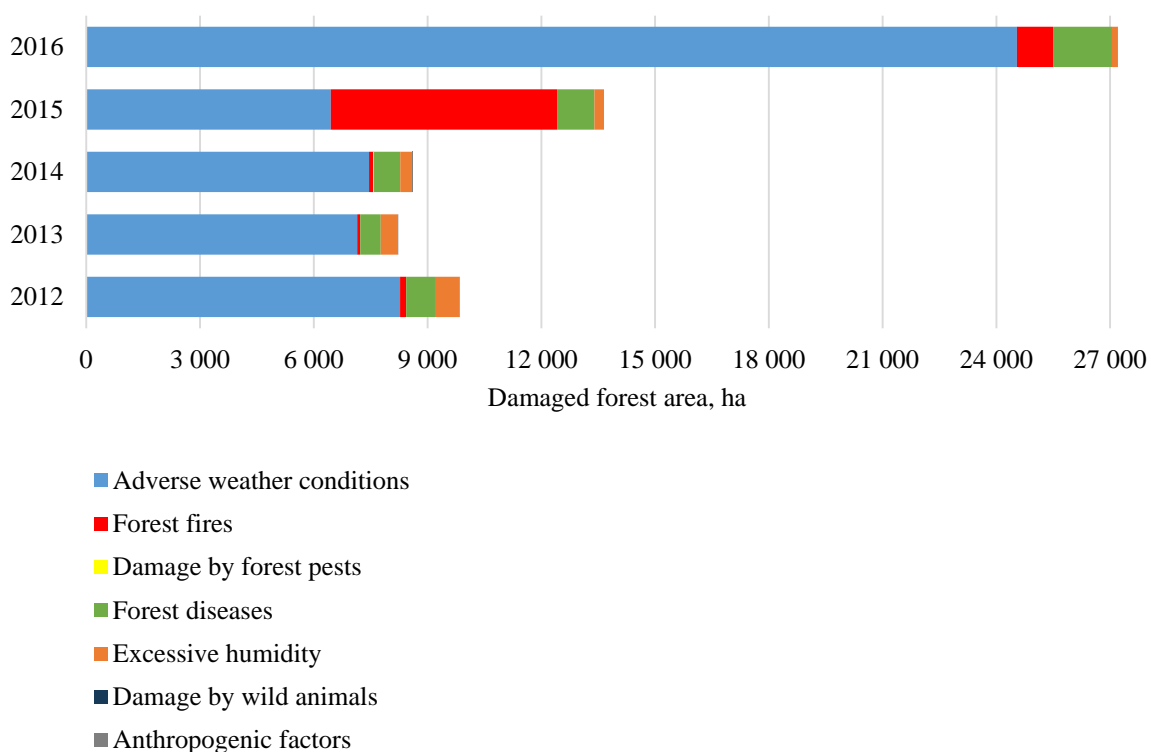
As can be seen from Figure 52, forest fires and adverse weather had the most negative impacts.

Table 28 and Figure 53 illustrate the impacts of adverse weather on the forest fund of the Republic of Belarus in 2012–2016 [64–71].

**Table 28 – Forest damage by different adverse weather effects in 2012–2016**

Year		2012	2013	2014	2015	2016
Area of destroyed forest stands, ha:	total	9 848	8 222	8 594	13 660	27 206
	incl. coniferous species	8 808	7 689	7 746	12 206	24 457
– forest fires	total	160	79	105	5 968	957

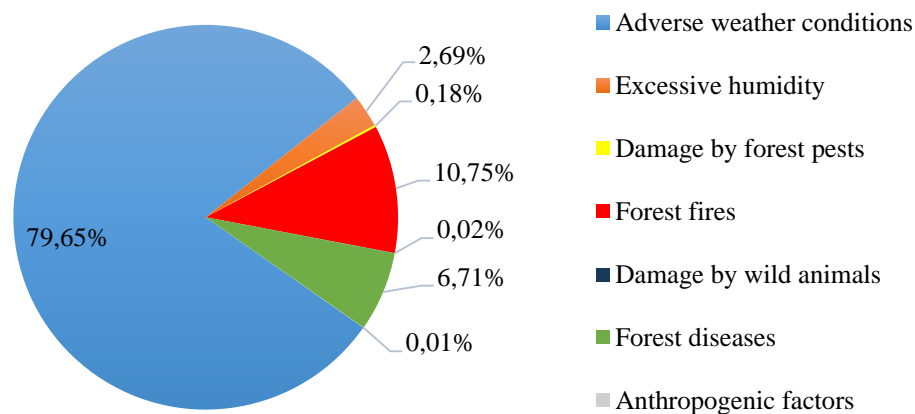
Year		2012	2013	2014	2015	2016
	incl. coniferous species	153	78	104	5 061	921
– adverse weather	total	8 274	7 145	7 455	6 446	24 540
	incl. coniferous species	7 607	6 806	6 781	5 974	21 900
– pests	total	–	–	24	–	–
	incl. coniferous species	–	–	24	–	–
– forest diseases	total	760	541	697	985	1 554
	incl. coniferous species	641	487	634	962	1 533
– excessive moisture	total	652	454	310	253	150
	incl. coniferous species	405	315	199	201	103
– wild animals	total	2	2	2	–	5
	incl. coniferous species	2	2	2	–	–
– anthropogenic factors	total	–	–	1	–	–
	incl. coniferous species	–	–	1	–	–



**Figure 53 – Forest damage by different adverse weather effects, ha a**

Source: Forest regeneration, protection and forest fires in the Republic of Belarus: statistical bulletin for 2012–2016

Figure 54 shows averaged impacts of certain adverse weather effects on the forest fund of the Republic of Belarus in 2012–2016 [67–71].



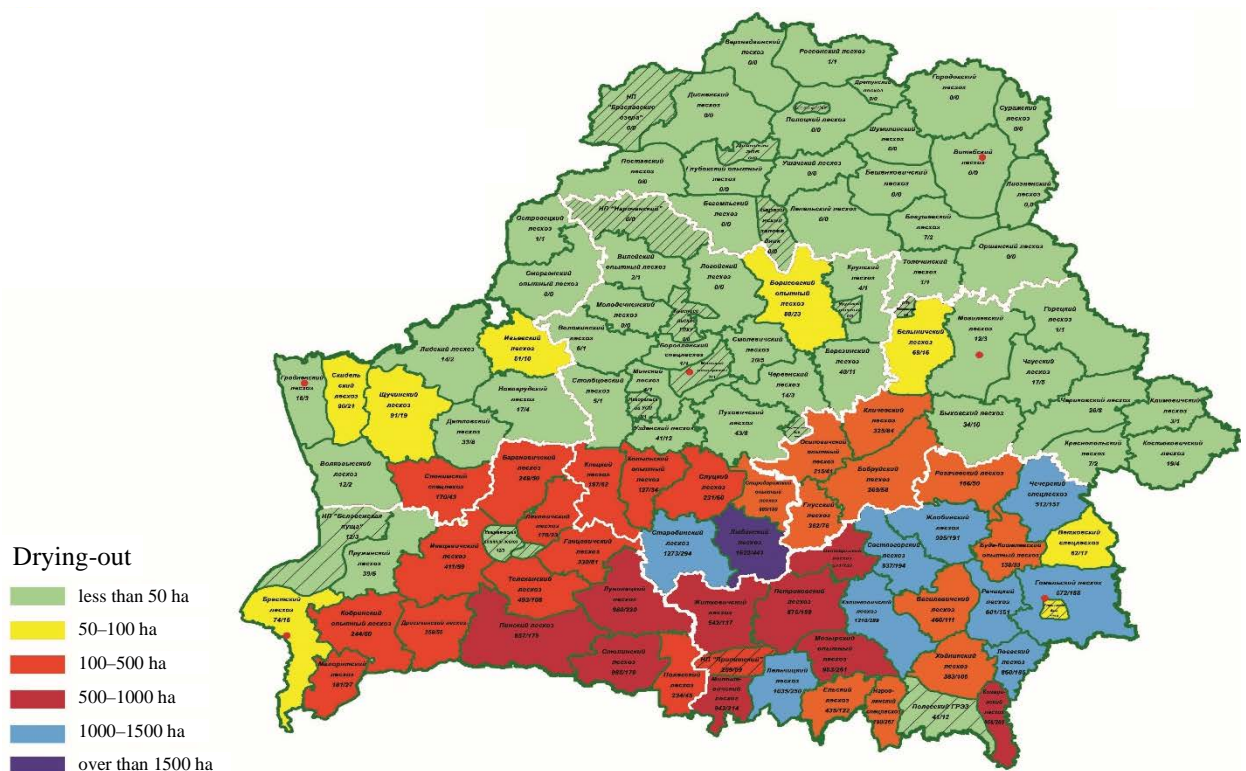
**Figure 54 – Damage to the forest sector of the Republic of Belarus by different adverse factors in 2012-2016, %**

Source: Forest regeneration, protection and forest fires in the Republic of Belarus: statistical bulletin for 2012–2016

As can be seen from Figure 54, forest fires and adverse weather had the most negative impacts in 2012-2016. The share of adverse weather effects has dramatically increased from 58% to 80% as compared to the period of 1990–2012.

The review of data given in Table 28 and figure 54 makes us conclude that the most serious damage to the forest sector of the Republic of Belarus in 1990-2016 was incurred by adverse weather effects of June 17, June 21, July 12-13, 2016. The windblow of July 2016 heavily damaged the Belarusian forests on the area exceeding 110 thousand ha. The timber losses amounted to over 6 million m<sup>3</sup>.

Apart from windblows, other adverse weather events, i.e., fires, drying-out, snowbreaks, pests, have been increasingly registered in the forest sector. Figure 55 illustrates the volumes of sanitary cuts done in the areas of drying-out stands in the Republic of Belarus.



**Figure 55 – Volumes of sanitary cuts in the drying-out forested areas**

Source: data of the Ministry of Forestry of the Republic of Belarus

The largest damage from drying-out was registered in the following forestry enterprises:

- SFE “Lyuban leskhoz” – damaged area of 1692 ha, timber loss of 441 thousand m<sup>3</sup>;
- SFE “Starobin leskhoz” – damaged area of 1273 ha, timber loss of 294 thousand m<sup>3</sup>;
- SFE “Lelchitsy leskhoz” – damaged area of 1035 ha, timber loss of 250 thousand m<sup>3</sup>;
- SFE “Kalinkovichy leskhoz” – damaged area of 1210 ha, timber loss of 289 thousand m<sup>3</sup>;
- SFE “Svetlogorsk leskhoz” – damaged area of 937 ha, timber loss of 194 thousand m<sup>3</sup>;
- SFE “Zhlobin leskhoz” – damaged area of 905 ha, timber loss of 191 thousand m<sup>3</sup>;
- SSFE “Chechersk spetsleskhoz” – damaged area of 512 ha, timber loss of 157 thousand m<sup>3</sup>;
- SEFE “Rechitsa opytnyi leskhoz” – damaged area of 601 ha, timber loss of 151 thousand m<sup>3</sup>;
- SFE “Gomel leskhoz” – damaged area of 672 ha, timber loss of 188 thousand m<sup>3</sup>;
- SFE “Loev leskhoz” – damaged area of 860 ha, timber loss of 186 thousand m<sup>3</sup>.

As can be seen from Figure 54, the drying-out forested areas are concentrated in southern and central regions of the country which can be attributed to climate change impacts on forest ecosystems.

Apart from windblows other negative factors have been affecting the forest sector, i.e., fires, drying-out, snowbreaks, pests. If we analyze economic costs of the damage by these factors, windblows will have the highest damage rate. Snowbreaks have impacts of similar types but of lower rate.

Forest fires incur major losses, but costs of fire-fighting and recovery operations differ from other catastrophic events (Table 29).

Table 29 – Characteristics of forest fires impacts in the Republic of Belarus

Indicator	2011	2012	2013	2014	2015	2016
Number of forest fires						
Total:	433	544	272	687	1 218	319
Area affected by forest fires, ha						
Total:	156	189	73	359	16 947	251
Losses from forest fires, million BYN						
Total:	78,0	368,4	131,9	817,3	432 317	41 979
burnt standing wood	65,8	308,9	60,7	710,6	372 653	12 077
burnt timber harvest	–	–	34,0	7,5	12 263	–
burnt or damaged structures and other property	–	3,3	34,0	7,5	12 740	525
other losses	12,2	56,3	37,2	97,9	34 661	29 377
Costs of fire-fighting and recovery operations						
Total:	380,3	314,5	154,3	783,7	1 705 995	183 761
forest regeneration	8,2	7,3	5,3	55,2	21 191	9 669
clear-up	24,0	25,9	2,9	47,8	258 918	2 779
forest fire fighting	346,7	281,3	146,1	671,3	1 187 122	170 313
other costs	1,4	–	–	9,3	238 764	1 000

The 2017 data for all factors are currently not available. However we are credibly informed that in 2017 the national forest fund experienced a heavy attack by eight-toothed bark beetle with the damaged area of more than 30 thousand ha. The pest attack was largely attributed to climate change effects such as droughts in southern regions which negatively affected the forest resistance to bark beetle [66].

## 2.3 Development of a methodology for the assessment of full economic losses from forestry catastrophic events in the Republic of Belarus

### 2.3.1 Algorithm of assessment of natural disasters aftereffects

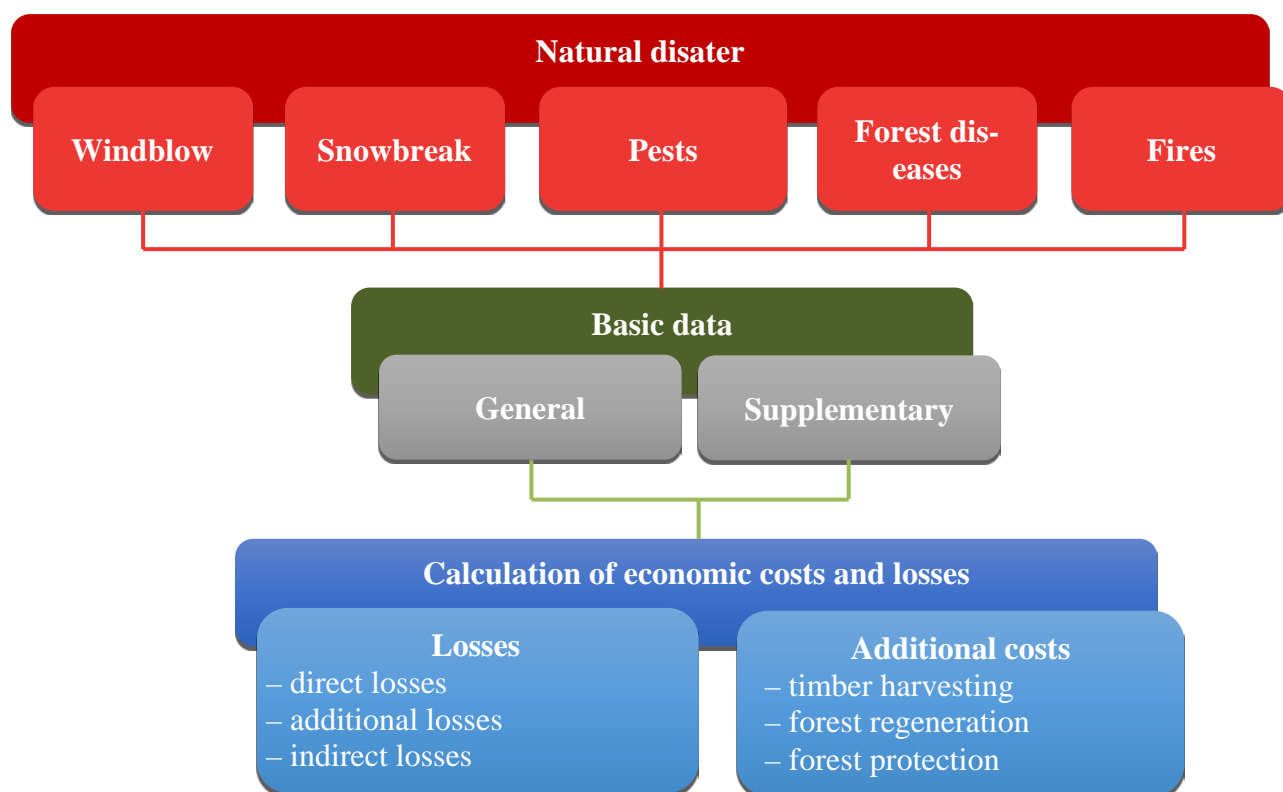
Forestry enterprises are recommended to take the following actions after the forestry catastrophic events:

1. Allocation of damaged forest sites to determine the area of damage and mensurational characteristics of the stands;
2. Timber harvesting and clear-up operations in the damaged areas;
3. Timber transportation and conservation;
4. Preparation of the damaged area for future forest regeneration;
5. Care and protection of young forests;
6. Monitoring and control over the new stands.

Forest fire events require fire-fighting operations and evacuation of people, valuable assets, etc.

During the allocation of damaged sites the area and mensurational characteristics of the damaged stands are determined. This makes it possible to obtain basic data for economic assessment of costs and losses.

Figure 56 illustrates the algorithm of assessment of economic losses and additional costs from natural disasters in the forests of Belarus.



**Figure 56 – The algorithm of assessment of economic losses and additional costs from natural disasters**

*Source:* authors' development

As can be seen from Figure 56, the basic data are divided into general and supplementary ones.

*General basic data* are data that are determined for all types of natural disasters (territorial boundaries of the damaged stands, their mensurational characteristics, etc.)

*Supplementary basic data* are determined for a specific type of natural disasters. For instance, the degree of trees damage, area of burn-out forest floor, etc. are determined in case of forest fires.

### 2.3.2 Assessment of costs and losses from windblows and snowbreaks

Methodological scheme of economic assessment of losses and additional costs related to recovery operations after adverse weather effects is shown in Figure 57.

Economic losses can be categorized as follows:

– ***direct losses*** include increased volumes of wood waste; degraded assortment pattern of timber; average price drops; losses of stand increment;

– ***additional losses*** related to non-timber products that are harvested and sold by an enterprise as well as infrastructure and facilities of the enterprise;

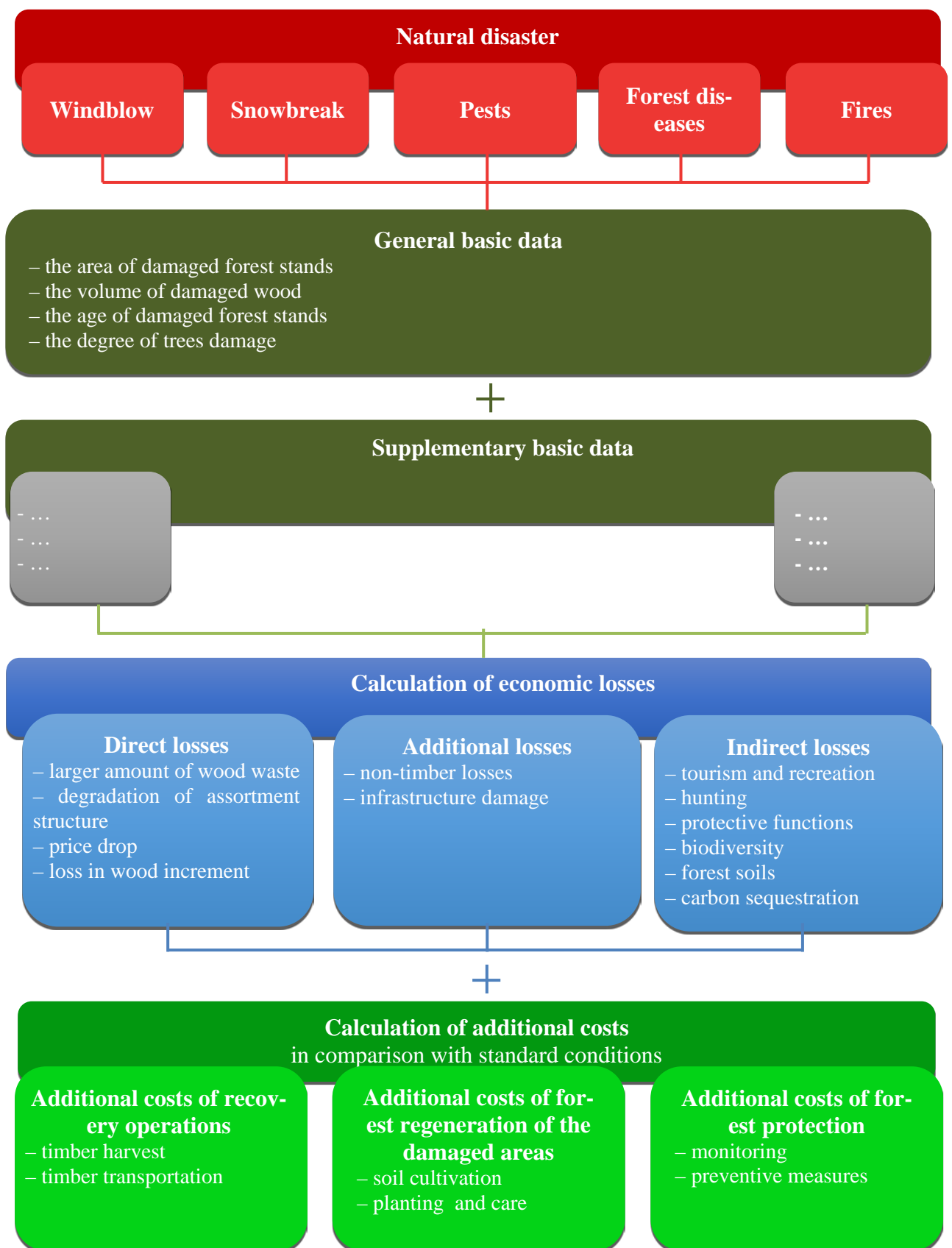
– ***indirect losses*** that are connected to forest ecosystem services (tangible and intangible benefits from forested areas), damage to soil, water bodies, etc. These also include losses in tourism, recreation, biodiversity, carbon sequestration, protective functions of forests, etc.

Additional costs are understood as:

– ***additional costs of damaged trees harvest and clear-up operations on affected areas*** as compared to standard conditions of timber harvest. These costs arise from reduced rates of performance, increased fuel consumption rates and maintenance costs of machinery, increased costs of relocation of machines, workforce and expert personnel, subsistence expenses, etc.;

– ***additional costs of forest regeneration on affected areas*** that include additional costs of soil cultivation, planting and care of young forest as compared to standard conditions. These costs also include costs of relocation of machines, workforce and expert personnel, subsistence expenses, etc.;

– ***additional costs of forest protection*** that include costs measures to prevent secondary and tertiary damage by pests, invasive species and forest diseases that occur and dynamically develop in the forests affected by adverse weather effects.



**Figure 57 – Methodological scheme of economic assessment of losses and additional costs related to recovery operations after adverse weather effects**

\* Non-timber products are products of secondary forest use, i.e., berries, mushrooms, sap, honey, etc.

Source: authors' development

**Direct losses.** Any natural disaster leads to the damage of forest stands and the resulting increase in the amount of wood waste from timber harvesting operations. **Economic losses associated with larger amount of wood waste** are calculated by multiplying the difference between the timber amount in the damaged areas and the actual amount of timber transportation by the timber price:

$$L_{ww} = (Q_{da} - Q_{tr}) \cdot I_{BW}, \quad (11)$$

where  $L_{ww}$  – losses associated with larger amount of wood waste, BYN;

$Q_{da}$  – amount of timber in the damaged areas, m<sup>3</sup>;

$Q_{tr}$  – actual amount of timber transportation, m<sup>3</sup>;

$I_{BW}$  – average income from sales of 1 m<sup>3</sup> of round timber on the affected area before windblow, BYN/m<sup>3</sup>.

**Calculation of economic losses from the degraded assortment pattern of the harvested timber** is made by comparison of monetary valuation from forest inventory in the damaged areas with actual timber output.

Losses from degraded commodity pattern of harvested timber [16]:

$$L_{ass} = (P'_{AW} - P_{AW}) \cdot Q_{tr}, \quad (12)$$

where  $L_{ass}$  – losses from the degraded assortment pattern of the harvested timber, BYN;;

$P_{AW}$  – average price of 1 m<sup>3</sup> of round timber in the damaged area after the windblow event, BYN/m<sup>3</sup>;

$P'_{AW}$  – average price of 1 m<sup>3</sup> of round timber in the damaged area after the windblow event in terms of the commodity pattern before the windblow, BYN/m<sup>3</sup>.

**Economic losses from round timber price drops** can be determined based on their excessive market supply by the formula:

$$L_{pd} = (P_{BW} - P'_{AW}) \cdot Q_{tr}, \quad (13)$$

where  $L_{pd}$  – losses from market price drops of timber, BYN;

$P_{BW}$  – average price of 1 m<sup>3</sup> of round timber in the damaged area before the windblow event, BYN/m<sup>3</sup>.

The average price of 1 m<sup>3</sup> of round timber before and after the windblow event can roughly be calculated as a weighted average:

$$P_{BW} = \frac{P_{1BW} \cdot S_{1BW} + P_{2BW} \cdot S_{2BW} + \dots + P_{nBW} \cdot S_{nBW}}{100}, \quad (14)$$

$$P_{AW} = \frac{P_{1AW} \cdot S_{1AW} + P_{2AW} \cdot S_{2AW} + \dots + P_{nAW} \cdot S_{nAW}}{100}, \quad (15)$$

where  $P_{1-nBW}$ ,  $P_{1-nAW}$  – average price of an  $n$ -type of round timber with regard to its grade, size, length and tree species before and after the windblow event, BYN/m<sup>3</sup>;

$S_{1-nBW}$ ,  $S_{1-nAW}$  – share of an  $n$ -type of round timber in the commodity pattern of the harvested timber before and after the windblow event (ranging from 0 to 100).

The average price of 1 m<sup>3</sup> of round timber in the damaged area after the windblow event in terms of the commodity pattern before the windblow can roughly be calculated as a weighted average:

$$P'_{AW} = \frac{P_{1AW} \cdot S_{1BW} + P_{2AW} \cdot S_{2BW} + \dots + P_{nAW} \cdot S_{nBW}}{100}. \quad (16)$$

In some cases calculations can be simplified and facilitated by the formula that directly considers economic losses *from the degraded assortment pattern of the harvested timber and market price drops of timber*:

$$L_{ass-pd} = (P_{BW} - P_{AW}) \cdot Q_{tr}. \quad (17)$$

One of the serious aftereffects of a natural disaster is the damage (destruction) of forest stand that have not reached their maturity age. The removal of damaged trees leads to the decline



in total annual increment of the forest stands. In view of this, **losses in the increment of forest stands** can be calculated by the formula:

$$L_{incr} = Q_{incr} \cdot S_{dam} \cdot P_{incr} \cdot N_{years}, \quad (18)$$

where  $L_{incr}$  – losses from decline in annual increment in the damaged areas, BYN;  
 $Q_{incr}$  – average annual increment of forest stands, m<sup>3</sup>/ha;  
 $S_{dam}$  – area of the forest fund damaged by natural disaster, ha;  
 $P_{incr}$  – stumpage value of 1 m<sup>3</sup> of wood increment in a forest stand, BYN/m<sup>3</sup>;  
 $N_{years}$  – number of years until the maturity age of a stand.

Thus, **total direct losses** from a forestry catastrophic event can be determined by the formula:

$$L_{dir} = L_{ww} + L_{ass} + L_{pd} + L_{incr}, \quad (19)$$

where  $L_{dir}$  – direct losses from a forestry catastrophic event, BYN.

**Additional losses.** Economic assessment of **non-timber losses** in the damaged forest stands can be calculated by the formula:

$$L_{nt} = S_{dam} \cdot P_{av.a} \cdot \frac{(1+E)^{N_{years}} - 1}{E \cdot (1+E)^{N_{years}}}, \quad (20)$$

where  $S_{dam}$  – damaged area, ha;

$P_{av.a}$  – average annual profit from non-timber products, BYN/ha;

$N_{years}$  – number of years required for a stand to recover its sustainability and capacity to yield non-timber products

$E$  – discount rate, in shares.

Economic losses from **forest road damage** ( $L_{fr}$ ) are attributed to the reconstruction of the damaged road sections to ensure their trafficability for logging machinery. This indicator is determined by the actual data taken from an enterprise. Generally, the calculation formula for the costs of forest road reconstruction will involve the total length of damaged road sections multiplied by the reconstruction costs of 1 m<sup>3</sup> of forest road:

$$L_{fr} = L \cdot C_{1km}, \quad (21)$$

where  $L_{fr}$  – losses from forest road damage, BYN;

$L$  – length of damaged road sections, km;

$C_{1km}$  – reconstruction costs of 1 km of forest roads, BYN.

The reconstruction costs of 1 km of forest road comprise the payroll budget, operation costs of machines and equipment, materials and other costs (transportation of people, machines and equipment, subsistence allowances, etc.):

$$C_{1km} = PB + C_{soc} + C_{mnt} + C_m + C_{other}, \quad (22)$$

where  $PB$  – payroll budget of main workforce, BYN;

$C_{soc}$  – social security contributions, BYN;

$C_{mnt}$  – operation and maintenance costs of machines, BYN;

$C_m$  – costs of materials, BYN;

$C_{other}$  – other costs (transportation of people, machines and equipment, subsistence allowances, etc.), BYN.

The suggested approach towards the assessment of reconstruction costs of forest roads can be applied to assess losses from damaged buildings, facilities and other assets of the forestry enterprises. On the whole the costs will depend upon the number of damaged facilities and the degree of their damage.

Thus, **total additional losses** from a forestry catastrophic event can be determined by the formula:

$$L_{add} = L_{nt} + L_{fr} \quad (23)$$

where  $L_{add}$  – additional losses from a forestry catastrophic event, BYN.

**Indirect losses.** Economic losses from forestry catastrophic events in *tourism and recreation* can be calculated by the formula:

$$L_{t/r} = n_{vis} \cdot P_{vis} \cdot \frac{(1+E)^{N_{years}} - 1}{E \cdot (1+E)^{N_{years}}}, \quad (24)$$

where  $L_{t/r}$  – losses in tourism and recreation, BYN;

$n_{vis}$  – average number of visitors a year, person;

$P_{vis}$  – average profit from a visit, BYN/person;

$N_{years}$  – number of years required for a stand to recover its sustainability and tourism and recreation capacities.

The following formula can be used to assess economic losses in *hunting sector* of an enterprise:

$$L_{hunt} = S_{dam} \cdot P_{ava.hunt} \cdot \frac{(1+E)^{N_{years}} - 1}{E \cdot (1+E)^{N_{years}}}, \quad (25)$$

where  $L_{hunt}$  – losses in hunting sector, BYN;

$P_{ava.hunt}$  – average annual profit from the hunting sector of an enterprise, BYN/ha;

$N_{years}$  – number of years required for a stand to recover its sustainability and game management capacity.

Economic losses from *degraded protective functions* of forest can be determined by the formula:

$$L_{prot} = S_{dam} \cdot \left( C_{plant} + C_{care} \cdot \frac{(1+E)^{N_{years}} - 1}{E \cdot (1+E)^{N_{years}}} \right), \quad (26)$$

where  $L_{prot}$  – losses from degraded protective functions of forest, BYN;

$C_{plant}$  – costs of planting new stands, BYN;

$C_{care}$  – costs of care and protection of forest stands (incl. improvement fellings, etc.), BYN/ha.

Economic losses from *degraded biodiversity* can be determined by the formula:

$$L_{bio} = k_{bio} \cdot S_{dam} \cdot k_{dam} \cdot C_{reg} \cdot (1+E)^{N_{years}}, \quad (27)$$

where  $L_{bio}$  – losses from degraded biodiversity, BYN;

$k_{bio}$  – degree of naturalness ( $k_{bio} = 0-1$ );

$k_{dam}$  – degree of damage to the forested areas;

$C_{reg}$  – costs of regeneration of forested areas, BYN/ha.

Losses from *forest soil damage*. In the course of the study no special methodology was identified in Belarus that would make it possible to determine indirect losses from the effect of catastrophic events on the forest soils. At the same time there are effective Regulations on the Procedure for Calculating the Reimbursable Amount of Environmental Damage and Making a Report on the Factual Environmental Damage No.1042 dated 17.07.2008 [72, Appendix 5]. The Regulations establish charges for various soil types, incl. forest soils. These charges serve as a basis for calculating the reimbursable amount of the degradation of forested lands (Table 30) [73, Appendix 5]. The document is intended to determine the amount of damage incurred not by natural disasters but by anthropogenic activities and is applied to raise damage claims against individuals and legal persons that have incurred the damage. If no specialized methodology is available, the following formula is suggested to make the calculations:

$$L_{f.s.} = Ch \cdot P \cdot Ch_i \cdot B, \quad (28)$$

where  $L_{f.s.}$  – losses from forest soil damage;

$Ch$  – charges established by Presidential Decrees in basic units per one ton, one kilogram, thousand cubic metres, one square metre, one hectare, one piece [73];

*P* – quantitative indicator: weight of pollutants, fuel, byproducts of the industry, wild animals (and their embryos), mushrooms, wild plants and (or) their parts in tons, kilograms respectively; volume of compressed gas in thousand cubic metres; areas of lands (incl. soils), lawns, flower beds in square metres, hectares; number of animals (their embryos), trees, shrubs, seedlings in pieces;

*Chi* – respective charges established by the Presidential Decrees of the Republic of Belarus [73];

*B* – basic unit as of the date of Report on the Factual Environmental Damage, BYN.

Table 30 – Charges for calculating the reimbursable amount of the degradation of forested lands (Appendix 5 [73])

Forest type on the degraded lands, degraded non-forested lands of the forest fund	Degree of degradation	Charge, basic unit per one square metre of degraded lands	
		Conservation, recreational and protective forests	Commercial forests
Degraded forested lands			
Sphagnum, sedge-sphagnum, cotton-grass-sphagnum	low	0,08	0,04
	medium	0,12	0,06
	high	0,16	0,08
	very high	0,24	0,12
Sedgy, willow	low	0,10	0,06
	medium	0,16	0,08
	high	0,20	0,10
	very high	0,30	0,16
Spirea, sedge-grassy, iris, boggy-grassy, boggy-ferny	low	0,14	0,08
	medium	0,22	0,10
	high	0,28	0,14
	very high	0,42	0,22
Ledum	low	0,18	0,10
	medium	0,28	0,14
	high	0,36	0,18
	very high	0,54	0,28
Lichenous, heathy	low	0,20	0,10
	medium	0,30	0,16
	high	0,40	0,20
	very high	0,60	0,30
Long-mossy, riverine-grassy, vaccinium	low	0,24	0,12
	medium	0,36	0,18
	high	0,48	0,24
	very high	0,72	0,36
Mossy, myrtillus, riverine-floodplain, grassy-floodplain	low	0,30	0,16
	medium	0,46	0,22
	high	0,60	0,30
	very high	0,90	0,46
Urticaceous	low	0,34	0,18
	medium	0,52	0,26
	high	0,68	0,34
	very high	1,02	0,52
Bracken, grassy, green-mossy	low	0,40	0,20
	medium	0,60	0,30
	high	0,80	0,40
	very high	1,20	0,60
Aegopodium, ferny, hairgrassy, alder-floodplain, ash-floodplain,	low	0,42	0,22
	medium	0,64	0,32

Forest type on the degraded lands, degraded non-forested lands of the forest fund	Degree of degradation	Charge, basic unit per one square metre of degraded lands	
		Conservation, recreational and protective forests	Commercial forests
broad-leaved grassy-floodplain	high	0,84	0,42
	very high	1,26	0,64
Sorrel	low	0,46	0,24
	medium	0,70	0,34
	high	0,92	0,46
	very high	1,38	0,70
Degraded non-forested lands of the forest fund			
	low	0,30	0,16
	medium	0,46	0,22
	high	0,60	0,30
	very high	0,90	0,46

Economic losses from *degraded carbon sequestration* of forest can be determined by the formula:

$$L_{cs} = V \cdot W \cdot BEF_2 \cdot (1 + R) \cdot CF \cdot P_c, \quad (29)$$

where  $L_{sc}$  – losses from reduced carbon sequestration, BYN;

$V$  – timber volume, m<sup>3</sup>;

$W$  – volume-weighted average density of wood, tons of completely dry wood, t / m<sup>3</sup>;

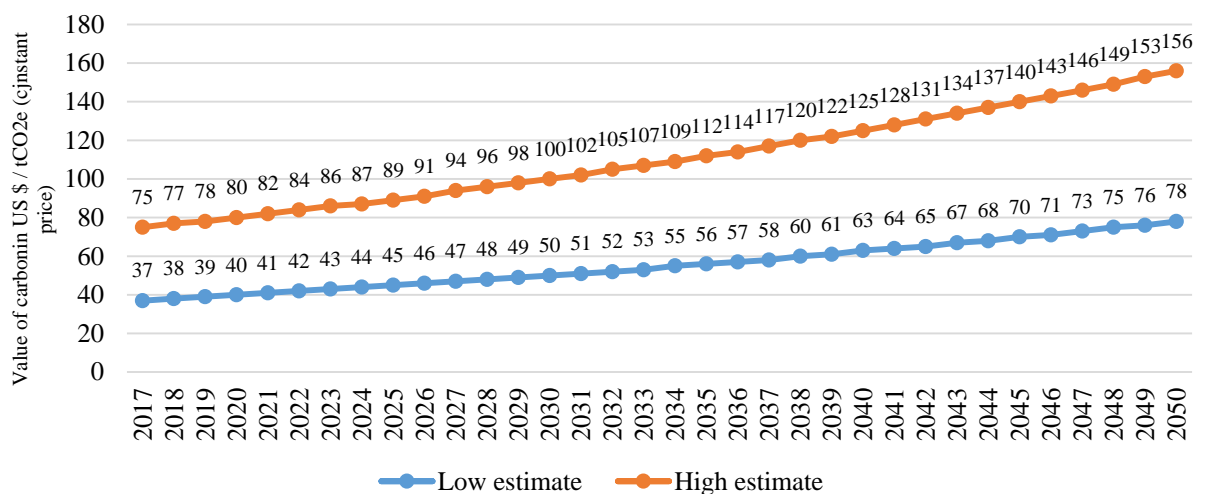
$BEF_2$  – phytomass coefficient for conversion of the total stock of plantings (i.e. volume of stem wood) to the value of phytomass of all components of the aboveground part of the stand, dimensionless value;

$R$  – the ratio of the mass of roots, including stump, stem wood, the dimensionless quantity;

$CF$  – fraction of carbon in dry matter (in the absence of local data it is allowed to accept equal to 0,5);

$P_c$  – carbon price, BYN.

The High-Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern, concluded based on an extensive review that a range of US\$40-80 per ton of CO<sub>2</sub>e in 2020, rising to US\$50-100 per ton of CO<sub>2</sub>e by 2030, is consistent with achieving the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, provided a supportive policy environment is in place. Figure 57 shows the low and high values of shadow price of carbon that all projects are recommended to use for the period 2017-2050 period.



**Figure 58 – Recommended shadow price of carbon in US\$ per 1 metric ton of CO<sub>2</sub> equivalent (constant prices)**

Source: Guidance note on shadow price of carbon in economic analysis (Word Bank)

Thus, **total indirect losses** from a forestry catastrophic event can be calculated by the formula:

$$L_{indir} = L_{t/r} + L_{hunt} + L_{prot} + L_{bio} + L_{f.s.} + L_{cs}. \quad (30)$$

where  $L_{indir}$  – indirect losses from a forestry catastrophic events, BYN.

Apart from economic losses, natural disasters result in **supplementary costs** related to:

- damaged trees harvest and clear-up operations on affected areas;
- forest regeneration on affected areas;
- forest protection.

**Additional costs of damaged trees harvest and clear-up operations on affected areas** are calculated by the formula:

$$\Delta C_{harv} = C_{harv}^w - C_{harv}^{st} \quad (31)$$

where  $\Delta C_{harv}$  – additional costs of damaged trees harvest and clear-up operations on affected, BYN;

$C_{harv}^w$  – costs of timber harvest on windblow affected cutting areas, BYN;

$C_{harv}^{st}$  – costs of timber harvest under standard conditions, BYN;

The structure of costs that are included in the prime cost is established by Guidelines for Planning, Recording and Calculation of Prime Cost of Products (Works, Services) within the system of the Ministry of Forestry of the Republic of Belarus [74]. Roughly the methodology for calculation of economic costs of timber harvest can be presented as follows:

$$C_{harv} = PB + C_{soc} + C_{mntn} + C_{other}, \quad (32)$$

where  $C_{harv}$  – costs of timber harvest, BYN;

$PB$  – payroll budget for main workforce, BYN;

$C_{soc}$  – social security contributions, BYN;

$C_{mntn}$  – maintenance costs of machines and equipment, BYN;

$C_{other}$  – other costs (transportation of workforce, machinery, subsistence allowance, etc.), BYN.

The payroll budget for the main workforce is calculate by the formula:

$$PB = \sum_{i=1}^n R_{pci} \cdot Q_i, \quad (33)$$

where  $PB$  – payroll budget for the workforce, BYN;

$R_{pci}$  – piece rate of harvesting of 1 m<sup>3</sup> for an  $i$ -operation, BYN/m<sup>3</sup>;

$Q_i$  – wood harvest volume for an  $i$ -operation, m<sup>3</sup>.

The adjusting factors  $k_2$  and  $k_3$  can be applied for cutting operations on windblow affected areas.

The piece rate of harvesting of 1 m<sup>3</sup> for an  $i$ -operation (logging, hauling, transportation of timber) is

$$R_{pci} = \frac{WR_1 \cdot TI \cdot k_1}{R_{perf} \cdot k_2}, \quad (34)$$

where  $WR_1$  – first class wage rate established by an enterprise, BYN;

$TI$  – tariff increase;

$R_{perf}$  – performance rate, m<sup>3</sup>/shift;

$k_1$  – coefficient of tariff increase for the length of service, complexity and intensity of work, overtime hours;

$k_2$  – coefficient of decreased performance rate (0.5–1) can be calculated by the data in Table 31.

Social security contributions (social protection fund and Belgogsstrakh) are

$$C_{soc} = \frac{PB \cdot R_{contr}}{100}, \quad (35)$$

where  $C_{soc}$  – social security contributions, BYN;

$R_{contr}$  – rate of social security contributions (34.69%), %.

Maintenance costs of machinery and equipment involved in the recovery operations are calculate by the formula:

$$C_{mntn} = \sum_{i=1}^n C_{m-shf_i} \cdot n_i, \quad (36)$$

where  $C_{m-shf_i}$  – maintenance costs of a machine-shift for an  $i$ -operation, BYN;

$n_i$  – number of machine-shift for an  $i$ -operation.

Maintenance costs of a machine-shift for an  $i$ -operation can be calculated by the formula:

$$C_{m-shf} = C_f + C_r + C_{wg} + C_{contr} + D + S_{os}, \quad (37)$$

where  $C_{m-shf}$  – costs of a machine-shift for an  $i$ -operation, BYN;

$C_f$  – fuel costs per a machine-shift, BYN;

$C_r$  – costs of repair parts, BYN;

$C_{wg}$  – wage costs of repair workers, BYN;

$C_{contr}$  – social security contributions from wage costs of repair workers, BYN;

$D$  – depreciation cost, BYN;

$S_{os}$  – outsources services of repair and maintenance, BYN.

Fuel costs can be calculated by the formula:

$$C_f = \sum_{i=1}^n R_{cons_i} \cdot P_f \cdot k_3, \quad (38)$$

where  $R_{cons_i}$  – fuel consumption rate for an  $i$ -operation, l/machine-shift;

$P_f$  – price of a l of fuel, BYN;

$k_3$  – coefficient of increased fuel consumption rate for recovery operations in the damaged areas can be calculated by the data in Table 31.

Table 31 – Dependence of decreased performance rate for recovery operations in the windblow areas for various degrees of damage

Degree of damage	Type of damage							
	wind-blow	% of decreased performance rate ( $a_i$ ) and increased fuel consumption rate ( $b_i$ )	wind-break	% of decreased performance rate ( $a_i$ ) and increased fuel consumption rate ( $b_i$ )	combined (windblow and wind-break)	% of decreased performance rate ( $a_i$ ) and increased fuel consumption rate ( $b_i$ )	snow-break	% of decreased performance rate ( $a_i$ ) and increased fuel consumption rate ( $b_i$ )
Minor	up to 20 %	5 and 2,5	up to 25 %	10 and 5	up to 20 %	10 and 7,5	up to 25 %	15 and 10
Low	21–40 %	15 and 2,5	26–45 %	20 and 5	21–30 %	20 and 10	26–45 %	25 and 10
Medium	41–65 %	25 and 5	46–70 %	30 and 7,5	31–50 %	35 and 15	46–70 %	40 and 15
Heavy	over 65 %	35 and 7,5	over 70 %	40 and 10	over 50 %	50 and 15	over 70 %	50 and 20

The number of machine-shifts a year for each operation can be expressed as:

$$n = \frac{Q_{year}}{R_{cons} \cdot k_2}, \quad (39)$$

where  $n$  – number of machine-shifts a year for each operation;

$Q_{year}$  – annual timber harvest volume in damaged areas, m<sup>3</sup>.

Coefficients  $k_2$  and  $k_3$  can be calculated in terms of the complexity of operations and the degree of damage to the cut areas by the data given in the reference source [75]. The percentage of decreased performance rate and increased fuel consumption rate has been developed by the respective orders of the Ministry of Forestry as well as by orders of the forestry enterprises affected by the 2016 windblow (Cherven leskhoz and Mozyr leskhoz).

In each case  $k_2$  and  $k_3$  can be calculated as follows:

$$k_2 = \frac{100 - a_i}{100}, \quad (40)$$

$$k_3 = \frac{100 + b_i}{100}, \quad (41)$$

where  $a_i, b_i$  – table values of the percentage of decreased performance rate and increased fuel consumption rate.

**Additional costs of forest regeneration after adverse weather effects** can be calculated by the formula:

$$\Delta C_{for} = C_{for}^w - C_{for}^{st} \quad (42)$$

where  $\Delta C_{for}$  – additional costs of forest regeneration after adverse weather effects, BYN;

$C_{for}^w$  – costs of forest regeneration on windblow affected cutting area, BYN;

$C_{for}^{st}$  – costs of forest regeneration under standard conditions, BYN.

Forest regeneration costs can roughly be calculated as follows:

$$C_{for} = C_{s.c.} + P_{pl.m.} + C_{plant} + C_{b.up} + C_{cfp}, \quad (43)$$

where  $C_{for}$  – forest regeneration costs, BYN;

$C_{s.c.}$  – soil cultivation costs, BYN;

$P_{pl.m.}$  – price of planting material, BYN;

$C_{plant}$  – planting costs, BYN;

$C_{b.up}$  – costs of beating up, BYN;

$C_{cfp}$  – costs of care of forest plantation, BYN.

**Costs of forest protection** ( $C_{prot}$ ) include costs of measures to prevent secondary and tertiary damage of stands by forest pests, invasive species and forest diseases that occur and dynamically develop in the forests affected by adverse weather effects.

**Total additional costs** of adverse weather effects can be calculated by the formula:

$$C_{add} = \Delta C_{harv} + \Delta C_{for} + C_{prot}, \quad (44)$$

where  $C_{add}$  – total additional costs of adverse weather effects, BYN.

Thus, **total costs** of adverse weather effects can be calculated by the formula:

$$\sum CandL = L_{dir} + L_{add} + L_{indir} + C_{add}. \quad (45)$$

where  $\sum CandL$  – total costs and losses from adverse weather effects, BYN.

### 2.3.3 Assessment of indirect losses from ground fires of various intensity

Ground fires in the Belarusian forests are usually considered as a natural disaster. They are one of the main ways of reentry of carbon, nitrogen and other mineral constituents from the ecosystem into the atmosphere or inaccessible soil layers.

The aftereffects from ground fires are diverse in the depth of impact on the condition and further development of both the environment and economic processes. Many foreign and international experts suggest that indirect losses from ground fires can not only be comparable to indirect losses but exceed them considerably. Therefore, a comprehensive assessment of losses from ground fires is of vital social and economic importance in the modern context.

Current methodologies involve nothing else but assessment of direct losses from ground fires. These include costs of fire-fighting, clear-up of the burnt areas, forest regeneration, timber losses, buildings, facilities and other tangible assets. However, they do not involve losses of the basic substance of forest floor and forest live cover.

At the same time it should be considered that indirect losses unlike direct ones cannot be economically assessed with high accuracy because they are highly diverse, take some time to reveal themselves, are highly dynamic and are very difficult to assess in terms of quality and quantity.

In view of this, the assessment of ecological and environmental losses should differentiate between:

- losses from one or several forest fires when drafting and bringing in a lawsuit against the liable parties (a legal concept);
- losses from one or several forest fires when recording by forestry enterprises (an economic concept).

The sum total of losses to bring in a lawsuit against the liable party must be beyond any doubt. Therefore, apart from direct losses it can include indirect losses as well. Their natural and economic indicators can be considered with a high legal accuracy.

In view of the above, complex losses from ground fires ( $L_c$ ) are to be calculated by the following general formula:

$$L_c = L_d + L_{id}, \quad (46)$$

where  $L_d$  – direct losses, BYN;

$L_{id}$  – indirect losses, BYN.

Direct losses ( $L_d$ ) include costs of fire-fighting, damaged timber, creation of new plantations, recovery/clear-up operations and can be expressed as follows [76]:

$$L_d = (C_{timber} + C_f + C_{fr} + C_{op}) \cdot S, \quad (47)$$

where  $C_{timber}$  – costs of damaged or lost standing timber, BYN/ha;

$C_f$  – fire-fighting costs, BYN/ha;

$C_{fp}$  – costs of new forest plantations, BYN/ha;

$C_{op}$  – costs of recovery/clear-up operations and other works, BYN/ha;

$S$  – ground fire area, ha.

Indirect losses are shown through;

- disturbed oxygen balance in the fire area;
- large losses of organic substances, nitrogen, ash constituents, and hence declined current increment of the existing and new stands;
- large or complete damage of mossy cover and biological diversity of forest vegetation;
- invasion of fire affected trees by insect and phytopests and diseases;
- degradation of social, environmental, recreational and other indirect functions of forests (water and soil protection, sanitary and hygiene, etc.).

Besides, the significance of indirect losses is largely dependent on the intensity of ground fires.

At the same time, modern methodologies and guidelines for determination of losses from forest fires do not make it possible to assess complex losses for the following reasons;

- a large amount of various basic data and specifications is required which makes calculations complicated, is time-consuming and requires high professionalism of the experts involved;
- the results obtained can hardly be repeated, so various agencies allow for flexible rendering and conditionality when assessing the environmental costs.

Therefore the following formula can be suggested to determine indirect losses from ground fires [76]:

$$L_{id} = \sum_{t=1}^T \sum_{i=1}^n \sum_{j=1}^m (C_{it} \cdot K_{it} \cdot K_{jt}) \cdot S, \quad (48)$$

where  $t = 1, 2, 3, \dots, T$  – time period of negative aftereffects that can be assessed with high accuracy;



$i = 1, 2, 3, \dots, n$  – number of types of the resources lost that can be assessed with high accuracy;  
 $j = 1, 2, 3, \dots, m$  – relative share of each resource lost that can be assessed with high accuracy;  
 $C_{it}$  – value of losses of an  $i$  indirect resource (nitrogen, carbon, ash constituents) in a  $t$  year BYN/ha;

$K_{it}$  – relative share of an  $i$  indirect resource depending on the tree species, age of stands and growth conditions in a  $t$  year;

$K_{jt}$  – coefficient of losses in a  $t$  year which depends on the intensity of a ground fire;

$S$  – ground fire area, ha.

In order to make full use of the suggested approach, it is required to create a multi-level and accurate database about the losses of each element and depending on mensuration characteristics of stands, their growth conditions and intensity of ground fires.

According to the Kyoto Protocol and UN Framework Convention on Climate Change (including commitments of Belarus) a global market has emerged for greenhouse gases emissions trading. By the above conventions, the value of CO<sub>2</sub> emissions quota can be regarded as a value of carbon loss from ground fires. Currently the suggested quota is 3-4 USD/t or 6-8 BYN/t (exchange rate – 2.03 BYN/USD) for the countries with transition economy (incl. Belarus). A kilogram of nitrogen is about 1.6 BYN, ash constituents (depending on the share of P, K, Ca, Mg, etc.) can be estimated within the range from 0.21 BYN/kg to 1.06 BYN/kg.

So, for a first approximation the indirect losses from ground fires can be expressed in monetary terms by means of Table 32 [76].

Table 32 – Natural and economic assessment of indirect losses from ground fires of various intensity

No.	Characteristics of stands	Intensity of fires	Losses, kg/ha			Losses, thousand BYN/ha
			carbon	nitrogen	ash constituents	
1	C heathy; 10P; 50 years; H-16,3 m; D-18,0 cm; G-21,15 m <sup>2</sup> /ha; V-210 m <sup>3</sup> /ha	low	up to 2920	up to 59	up to 299	up to 180
		medium	2921–6540	60–134	300–755	180–420
		heavy	6541–10570	135–219	756–1352	420–715
2	C vac; 10P; 100 years; H-21,8 m; D-25,5 cm; G-31,07 m <sup>2</sup> /ha; V-328 m <sup>3</sup> /ha	low	up to 2920	up to 59	up to 299	up to 360
		medium	2921–6540	60–134	300–755	360–670
		heavy	6541–10570	135–219	756–1352	670–1150
3	C bracken-vac; 10P+S; 120 years; H-25,9 m; D-32,1 cm; G-23,86 m <sup>2</sup> /ha; V-293 m <sup>3</sup> /ha	low	до 2920	up to 59	up to 299	up to 350
		medium	2921–6540	60–134	300–755	350–680
		heavy	6541–10570	135–219	756–1352	680–1120
4	C mossy; 10P+S; 65 years; H-23,2 m; D-22,8 cm; G-31,54 m <sup>2</sup> /ha; V-358 m <sup>3</sup> /ha	low	up to 2920	up to 59	up to 299	up to 514,0
		medium	2921–6540	60–134	300–755	370–780
		heavy	6541–10570	135–219	756–1352	780–1150
5	C bracken-myrt; 9P1S+B; 120 years;	low	up to 2920	up to 59	up to 299	up to 400
		medium	2921–6540	60–134	300–755	400–790

No.	Characteristics of stands	Intensity of fires	Losses, kg/ha			Losses, thousand BYN/ha
			carbon	nitrogen	ash constituents	
	H-29,5 m; D-34,2 cm; G-27,11 m <sup>2</sup> /ha; V-375 m <sup>3</sup> /ha	heavy	6541–10570	135–219	756–1352	790–1300

Based on the data in Table 32 we can conclude that depending on the mensuration characteristics of the stands and the intensity of fires the total economic losses from ground fires vary from 175 BYN/ha to 1280 BYN/ha which is a prevailing sum as compared to the losses in the preceding year.

### 2.3.4 Testing of the developed methodology

The suggested methodology for economic assessment of losses and costs of natural disasters consequences makes both predictive and factual assessment possible. Calculation of main indicators after the recovery operations will provide more accurate data and detailed analysis of consequences of catastrophic weather events. The methodology can be applied to assess forestry losses and costs at both national and local levels (for individual forestry enterprises and stations). The calculation will be of higher accuracy for individual organizations and their units.

The suggested methodology served as a basis for assessing losses from the 2016 windblow. The calculations were made for the affected forest area (various damage degree, including small damage) of 110 thousand ha. The volume of timber loss was considered as 6 million m<sup>3</sup>. The obtained values were compared to the results of assessment by the existing methodology. The calculation results are given in Table 33.

Table 33 – Results of the assessment of the 2016 windblow effects by the existing and the suggested methodologies, BYN.

Indicators	Methodology	
	existing	suggested
<b>Direct losses</b>		
- formation of additional volume of wood waste	–	1 140 000
- aggravated commodity structure of timber	–	44 175 840
- price drop of round timber	–	-14 143 200
- decreased wood increment in damaged stands	–	13 398 000
<b>Total</b>	–	<b>44 570 640</b>
<b>Additional losses</b>		
- non-timber losses	–	127 015
- damage to forest roads	1 500 000*	1 500 000*
<b>Total</b>	<b>1 500 000</b>	<b>1 627 015</b>
<b>Indirect losses</b>		
- tourism and recreation	–	93 625
- game management	–	58 427
- protective functions of forest	–	–
- biodiversity	–	–
- forest soils damage	–	–
<b>Total</b>	–	<b>152 052</b>
<b>Recovery operations costs</b>		
- timber harvesting	109 053 061	109 053 061
- timber transportation	57 207 857	57 207 857
- other costs (subsistence, relocation of people and machinery)	19 782 617	19 782 617
<b>Total</b>	<b>186 043 535</b>	<b>186 043 535</b>
including additional costs:		

Indicators	Methodology	
	existing	suggested
- harvesting of damaged trees and clear-up of damaged areas	–	40 929 680
<b>Additional costs</b>		
- forest regeneration after natural disaster	–	1 914 000
- forest protection	–	
<b>Total</b>	–	<b>1 914 000</b>
<b>Total costs and losses from natural disaster</b>	<b>187 543 535</b>	<b>234 307 242</b>

\* – Borovlyany spetsleskhoz, state forestry enterprise «Smolevichi leskhoz», state forestry enterprise «Cherven leskhoz»

Analysis of the calculations shows that salvage/clear-up operation costs after the 2016 windblow amounted to 186 044 thousand BYN, road reconstruction costs to 1 500 thousand BYN, which is 187 543 thousand BYN in total. These costs were determined by the existing methodology.

The suggested methodology makes it possible to assess direct, additional and indirect losses as well as additional costs of recovery operations after adverse weather effects. Thus, the salvage/clear-up operation costs (186 044 thousand BYN) include additional costs arising from the severe conditions of machinery operation (reduced rates of performance, increased fuel consumption rates and maintenance costs of machinery, increased costs of relocation of machines, workforce and expert personnel, subsistence expenses totaling 40 930 thousand BYN (22%)).

Besides the suggested methodology makes it possible to assess other indirect losses and additional costs that amounted to nearly 46 764 thousand BYN or 25% of the total costs of recovery operations after the catastrophic event. The most considerable losses are from aggravated commodity structure of timber (44 176 thousand BYN), decreased wood increment in damaged stands (13 398 thousand BYN), additional amount of wood waste (1 140 thousand BYN), additional costs of forest regeneration (1 914 thousand BYN). Nevertheless, it should be noted that prices of timber increased for main stock items (including exported timber) that resulted in the reduction of direct losses by 14 143 thousand BYN.

Thus the calculations made by the suggested methodology allow us to conclude that total losses and costs of the 2016 windblow amounted to 234 307 thousand BYN. As compared to normal conditions of timber harvest and forest regeneration, additional costs and losses amounted to 89 193 thousand BYN. The existing methodology records only 40 930 thousand BYN thereof. So, about 48 263 thousand BYN was not recorded. This sum can be attributed to either direct losses from aggravated commodity structure of timber or additional costs of forest regeneration or future lost income from non-timber products, tourism and recreation, game management, etc.

It is worth mentioning that it is still not possible to assess losses from reduced forest protective functions, biodiversity, forest soil damage, etc. that occur as a result of natural disasters. These losses can be a focus of further studies.

The outcomes of the study prove that the consequences of adverse weather effects may be rather large-scale. It can be recommended to establish a natural disasters impact fund within each state production forestry association. The fund will provide timely assistance to the forestry enterprises that are affected by forestry catastrophic events and will reduce their financial losses.

## Conclusions on Part 2

1. The most devastating natural disaster for forestry in Europe has long been a strong wind activity. In addition to strong winds, other types of natural disasters also have a significant negative impact: fires, pests, diseases, excessive humidity. In recent years, their number and intensity are increasing, which, first of all, is due to climate change.

2. In the Republic of Belarus, adverse weather events include:

- meteorological: strong winds, squalls, tornado, fogs, hail, thunderstorms, heavy rainfall, snowfalls, snowstorms, extreme fire danger etc .;

- agrometeorological: droughts, frosts, low and high temperatures, etc .;

- hydrological: floods, low and high water levels, early freeze-ups.

The greatest damage to the forest fund of Belarus over the period from 1990 to today has been caused by fires and hurricanes, to a lesser extent pests, forest diseases, excessive humidity, wild animals.

3. In Belarus, there is no specialized methodology for assessing the losses and costs arising from natural disasters, so in most cases, losses from natural disasters were determined in kind, and costs determined for the work performed. All calculations in forestry organizations are conducted in accordance with the Methodological Guidelines for the planning, accounting and calculation of the cost of production (works, services) in the system of the Ministry of Forestry of the Republic of Belarus. In these guidelines, the composition of costs included in the cost of production is determined, and their classification according to articles, elements and other characteristics of groupings is cited.

However, after the devastating consequences of the hurricane in 2016, the organizations of forestry in the Republic of Belarus faced the need to take into account the various types of losses and additional costs associated with the elimination of the consequences of natural disasters, since they all have a significant impact on the financial performance of organizations in short- and long-term period of time.

4. European methodologies analysis for assessing the consequences of natural disasters in forestry and their comparison with the Belarusian methodology showed their differences and allowed to identify a number of factors that are necessary for a more complete and accurate assessment of damage. Thus, many European methods take into account the loss of forest ecosystem services, assess the costs of protecting soil, roads and other structures from erosion, floods and floods, take into account losses from future growth of wood in forest stands and the costs of their restoration.

5. Based on the analysis of international and Belarusian experience in eliminating the consequences of natural disasters in forests, as well as taking into account modern methods and approaches to assessing economic losses, an improved methodology has been developed that allows to take into account a complex of influencing factors and to improve the accuracy of the assessment. When developing the domestic methodology, the most effective foreign practices and the specifics of forest management in the Republic of Belarus were taken into account.

An improved methodology was developed based on the review of international and Belarusian practices of rectification of natural disaster aftereffects and modern methodologies and approaches towards assessment of economic losses. The suggested methodology takes into account the variety of affecting factors and makes more accurate assessment possible:

- direct losses (increase in the volume of wood waste, deterioration of the commodity structure of harvested assortments, lower average prices for timber, loss of increment of forest stands);

- additional losses (related to the procurement and sale of mushrooms, berries, honey, infrastructure and facilities);

- indirect losses (related to losses in hunting, tourism, recreation, biodiversity, protective functions of forests, etc.);

- additional costs for harvesting damaged trees and cleaning damaged areas;

- additional costs for reforestation of damaged areas;
- additional costs for protecting the planted forest.

The suggested methodology for economic assessment of losses and costs of natural disasters consequences makes both predictive and factual assessment possible. Calculation of main indicators after the recovery operations will provide more accurate data and detailed analysis of consequences of catastrophic weather events. Moreover, the accuracy of calculations will increase with the transition from the level of the damaged area to the level of forestry.

6. Thus the calculations made by the suggested methodology allow us to conclude that total losses and costs of the 2016 windblow amounted to 234 307 thousand BYN. As compared to normal conditions of timber harvest and forest regeneration, additional costs and losses amounted to 89 193 thousand BYN. The existing methodology records only 40 930 thousand BYN thereof. So, about 48 263 thousand BYN was not recorded. This sum can be attributed to either direct losses from aggravated commodity structure of timber or additional costs of forest regeneration or future lost income from non-timber products, tourism and recreation, game management, etc.

7. It is worth mentioning that it is still not possible to assess losses from reduced forest protective functions, biodiversity, forest soil damage, etc. that occur as a result of natural disasters. These losses can be a focus of further studies.

8. The outcomes of the study prove that the consequences of adverse weather effects may be rather large-scale. In this regard, it is recommended to establish a natural disasters impact fund within each state production forestry association. The fund will provide timely assistance to the forestry enterprises that are affected by forestry catastrophic events and will reduce their financial losses.

## Recommendations

The study can serve as the basis for **the following recommendations** for assessment and recovery operations after natural disasters under the conditions of the forest sector in the Republic of Belarus:

1. The required measures and actions of rectification of natural disaster aftereffects must be laid down in relevant regulatory documents and guidelines. The experience gained by the organizations of the Ministry of Forestry of the Republic of Belarus during the recovery operations after the windblow of July 2016 must be incorporated and taken advantage as the review shows that all the arrangements and planning were performed at a high level. International practices should be used in such fields as prediction of risks and damage to forest stands affected by adverse weather effects; development of recovery action plans; development and use of various insurance packages; long-term conservation of the harvested timber; decision-making approaches to restoration of forest stands; communication with stakeholders; monitoring and control of future forest damage, etc.

2. The documents must contain the points related to planning, organization, coordination and control of the proper operations:

- creation of command centres for logging operations in the most affected forestry enterprises/daily briefings of command centres;
- planning of harvesting operations;
- creation of temporary checkpoints of forest guards;
- creation of maintenance and repair stations for machinery;
- ongoing monitoring of damaged and neighboring areas, determination of logging deadlines;
- involvement of forest workers from other forestry enterprises in logging operations in windblow affected cutting areas;
- overtime work of forest workers of the most affected forestry enterprises;
- necessity for additional funding due to more complicated technology of the operations, reduced productivity rates, increased fuel consumption rates, degraded assortment pattern of timber. Additional costs (subsistence and other costs arising from relocation of people and machinery and workers' accommodation) must also be accounted for.

3. Practices of restricting timber harvest volumes during final fellings must be taken into consideration. This will prevent timber price drops due to suddenly bringing large volumes of timber onto the market.

4. In spite of the existing round timber export ban, it is advisable to allow exports of round timber coming from the windblow affected areas. It is the export sales of round timber from the 2016 windblow that made it possible to compensate for the increased expenditures and minimize the amount of public funding.

5. It can be effective to establish a special compensation fund for disaster damage under each state production forestry association. The funds will provide prompt assistance to forestry enterprises affected by forestry catastrophic events and minimize their financial losses.

6. Crisis management should be seen as a cyclic process. Larger efforts and costs at one stage can save time and money over the remaining parts of the cycle. Namely, more profound analysis of the past catastrophic events, proper training of personnel and implementation of preventive measures will ensure lower damage, costs and shorter time required to recover from the natural disasters.

7. It is recommended to use the universal methodology developed in the course of the study. Losses and additional costs arising from various natural disasters are very similar, demonstrate their effects during long periods of time and can considerably affect forestry, timber harvesting and timber sawing operations. At the same time, the methodology is not time-consuming because it uses the data collected and available at forestry enterprises to make calculations.

8. It is necessary to do further studies into more accurate assessment of damage such as weakened protective functions of forests, degraded biodiversity, soil impacts, etc. that are incurred by forestry catastrophic events and are of great importance.

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## APPENDICES

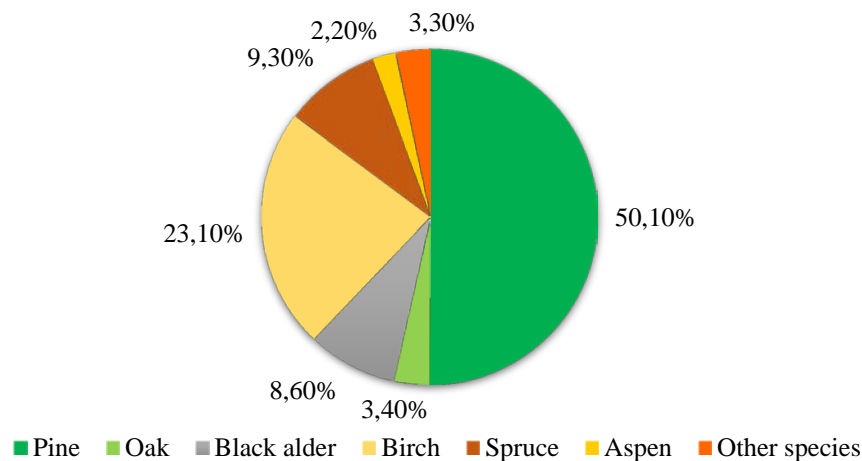
### A1 Current state and development prospects of the forest sector in the Republic of Belarus

Forestry of Belarus is of crucial importance to the sustainable operation of the national forest sector. It encourages further development of the related economic sectors and makes a vital contribution to the implementation of the international conventions signed by the Republic of Belarus in the field of environmental protection and climate change mitigation. Its economic, ecological and social roles are constantly growing in importance. This fact provides all grounds to conclude that the forestry is being turned from a traditional resource-based industry into an infrastructural one. Besides it has become a key industry in the rural areas of the country.

All the forests in Belarus are state-owned, there is no private forest ownership. The forest management bodies are the Ministry of Forestry of the Republic of Belarus (88.0% off the total forested area), the Department of Presidential Affairs of the Republic of Belarus (7.9%), the Ministry of Emergencies (2.3%), the National Academy of Sciences of Belarus (0.4%), the Ministry of Education (0.3%) as well as local authorities (0.2%). The forests are managed by 118 legal entities, 98 of which are under the jurisdiction of the Ministry of Forestry. The Ministry employs about 36 000 people.

As of 01.01.2017 the forest fund of the Republic of Belarus covers 9 565.8 thousand ha. The forested lands amount to 8 259.4 thousand ha, including 6 575.7 thousand ha of exploitable lands (79.6%). The total wood stock is 1 772.5 million m<sup>3</sup>, including 1 439.0 million m<sup>3</sup> of exploitable wood stock (81.2%). The per capita share of wood is 183 m<sup>3</sup>.

Coniferous forests are the prevailing ones (66.7%), more than a half of these is represented by common pine (50.1%). Figure 59 shows the distribution of forest stands by tree species.



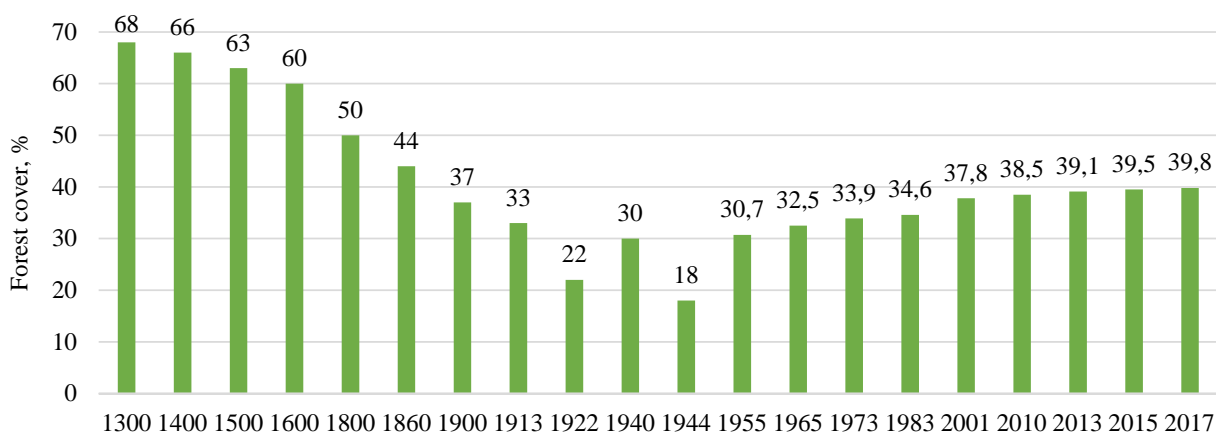
**Figure 59 – Species composition of forest stands**

*Source:* data of the Ministry of Forestry of the Republic of Belarus

Pure stands (composed of one tree species) occupy 27.4%, whereas mixed stands composed of two or species prevail (57.8%). Main forest types series are mossy, bracken, ferny, sorrel, myrtillus, long-mossy.

Mixed forest stands often contain maple, ash, linden, willows, hornbeam, elms, however, the share of the stands dominated by these aboriginal tree species hardly amounts to 1%. Local vulnerable tree species are silver fir and durmast oak. The areas dominated by common ash have considerably decreased recently which can be explained by the fact of its wide-scale dieback.

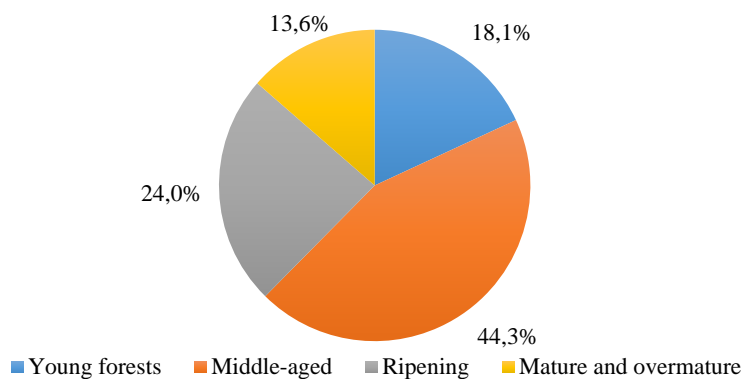
The area covered by forests is 39.8% (Figure 60). The wood stock per one hectare of forested lands is 264 m<sup>3</sup>/ha. The prevailing species, i.e., common pine, has the average wood stock of 238 m<sup>3</sup>/ha.



**Figure 60 – Forest cover dynamics in the Republic of Belarus**

Source: data of the Ministry of Forestry of the Republic of Belarus

The age structure of the national forests is uneven and needs to be optimized (Figure 61). Young forests account for 18.1%, middle-aged – 44.3%, ripening – 24.0%, mature and over-mature – 13.6%. Average age of the forest stands is 55 years, average density is 0.71.



**Figure 61 – Age structure of the forest stands**

Source: data of the Ministry of Forestry of the Republic of Belarus

Nature protection areas occupy 1179.8 thousand ha of forested lands (14.3%), including reserves – 75.9 thousand ha, national parks – 265.3 thousand ha, national and local preserves – 831.5 thousand ha, nature monuments – 7.1 thousand ha.

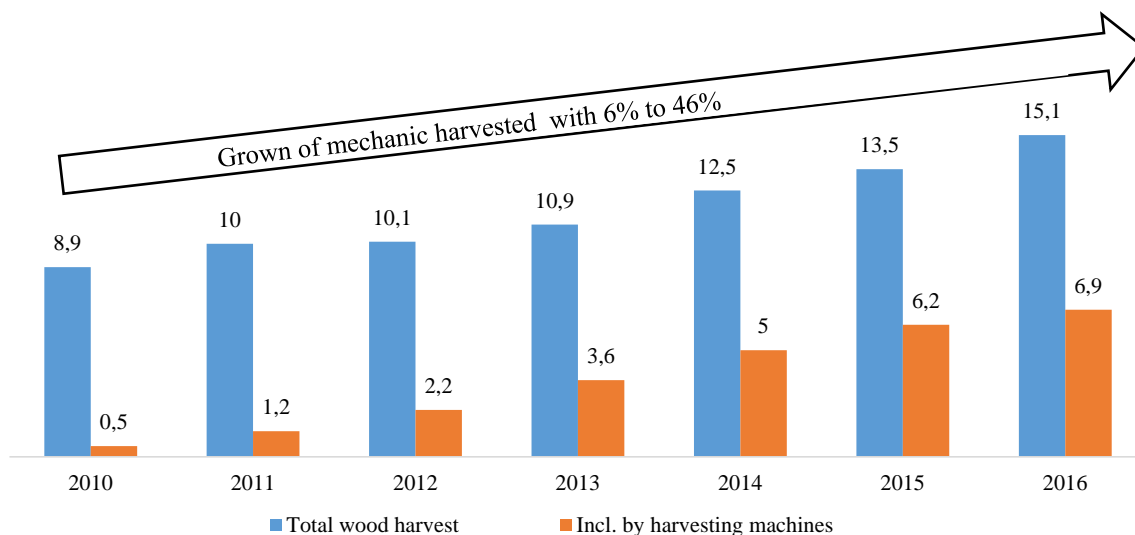
As of 01.01.2017, experts estimated the total cost of forest resources at 11.6 billion USD, including the stemwood cost of 5.1 billion USD (44%). The cost of 1 ha of forested lands amounted to 1.4 thousand USD, that of 1 ha of the total forest fund area – 1.2 thousand USD. The forest sector GDP ratio was estimated at approximately 2.7%.

Annual wood increment provides enough primary products for the national economy of the Republic of Belarus. At the same time the total volume of forest stands remains stable. The annual wood increment is estimated at 32.1 million m<sup>3</sup> whereas the annual cut accounts for 19 million m<sup>3</sup>.

Since 2013 only harvested wood has been marketed in order to increase the profit-making capacity of the forest sector. The sales of harvested wood make the main profit share of the forestry enterprises. Woodworking factories buy round timber at the timber exchange. All forestry enterprises are obliged to trade their timber at the timber exchange.

Private and foreign companies as well as joint ventures have the opportunity to render logging services to forestry enterprises.

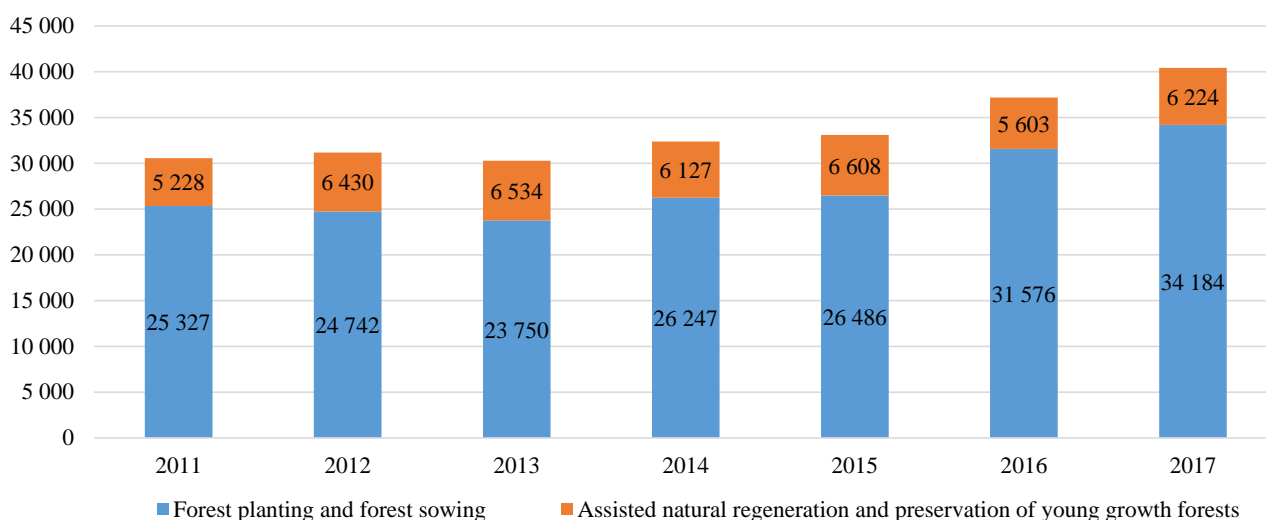
18.2 million m<sup>3</sup> of wood was harvested from the forests of the Ministry of Forestry in 2016. 15.1 million m<sup>3</sup> (78%) of the wood was harvested by forestry enterprises with 46% of the wood harvest done by multifunction machinery (Figure 62).



**Figure 62 – Wood harvested in 2010–2016 years**  
*Source:* data of the Ministry of Forestry of the Republic of Belarus

81 forestry enterprises (81.6% of the total forest fund area under the Ministry of Forestry) hold Forest Stewardship Council certificates. 95 forestry enterprises under the Ministry of Forestry have been certified by the Pan European Forest Council (PEFC).

Artificial forest regeneration is common for the forest sector of the Republic of Belarus (Figure 63).



**Figure 63 – Forest regeneration in the Republic of Belarus, ha**  
*Source:* data of the Ministry of Forestry of the Republic of Belarus

Over the recent years the forest sector has made a lot of investment in soil cultivation machinery, forest plantation care, technical reequipment and infrastructure development of forest nurseries, creation of new nurseries and greenhouses to grow planting stock for future forest plantations, decorative plants growing, closed-root planting materials. As a result of these measures, the forest sector possesses its own planting materials and is able to export 33 million pieces annually. In general, the nursery economy is considered to be cost-efficient.