Ecologically-oriented model for determining factor dependence in assessing the optimality of financing preventive measures in forest areas

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Abstract. In modern scientific research, more and more attention is paid to the mechanisms for maintaining the environmental situation in cities of various types. Forestry in many countries of the world is affected by various factors, among them, forest fires can be noted, which have a negative impact on the environmental situation both in large urban agglomerations and in vast territories occupied mainly by forest areas. The scientific work reflects the problem associated with the optimality and effectiveness of measures taken to prevent and extinguish forest fires. It is proposed to form 7 key macro regions based on the approach to ecological and economic zoning, which are territorially zoned according to homogeneous characteristics, where forestry production and forestry are separated. A distinctive feature can be noted in the proposed author's model of business processes in the system of forestry and forestry enterprises, in the context of zoning of territories. This model is based on the process approach and typology of forest areas in the context of ecological and economic zoning. Where the final eco-oriented processes at the output are a reduction in the number of forest fires, accelerated forest restoration using innovative methods and a transition to waste-free production. Based on the results of the study, a matrix of the general impact of intersections of ongoing processes on the financing of environmental measures in the forest industry and forestry is proposed. In this matrix, all eco-oriented processes are divided into group "A" and group "B", and have a corresponding level of optimality (from 2 to 3).

1 Introduction

On the territory of the Russian Federation there are certain conditions for maintaining the ecological environment in the regions in forest areas, as a rule, associated with the approaches used to assess the effectiveness of environmental measures taken to prevent and extinguish forest fires, and further reforestation. In the context of the need to maintain the ecological environment in the regions, it is necessary to combine all available resources: environmental, natural, financial, social. The most optimal would be the use of an integrated approach based on the ecological and economic zoning of forest areas, taking into account the basic principles

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of natural and climatic conditions, environmental standards, conditions for the implementation of rational use of natural resources and forestry. On the territory of the Russian Federation there are more than 85 territorial regional units, where the implementation of forestry and forest industry production can be unique from the position of territorial location and certain geographic conditions.

Based on this, each region can be divided into a number of specific areas, or several regions can be grouped into one specific area [4,11]. The basis for the study is a specific area located in certain territories occupied by forests or requiring rapid reforestation. All forest areas can be divided into ecological and economic regions based on the types of forestry and forest industry activities carried out by enterprises and organizations engaged in this area.

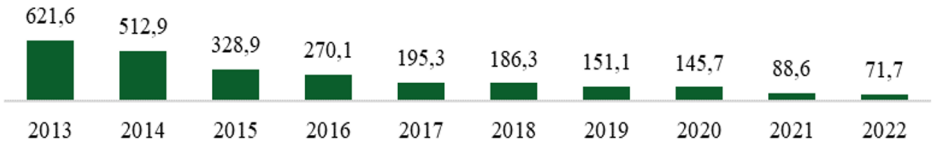

Fig. 1. Dynamics of forest stands lost due to various reasons on the territory of the Russian Federation, thousand hectares [2,3]. Source: Rosleskhoz data, Ministry of Natural Resources report.

Analysing the data of the Federal Forestry Agency, it can be noted that in 2022, 71.7 thousand hectares were destroyed for various reasons, which is significantly less than the same period in 2021 (88.6 thousand hectares). But in comparison with 2013, there is a significant decrease, almost ninefold. There are many reasons why forest resources are destroyed, let's consider the most common of them (Figure 2).

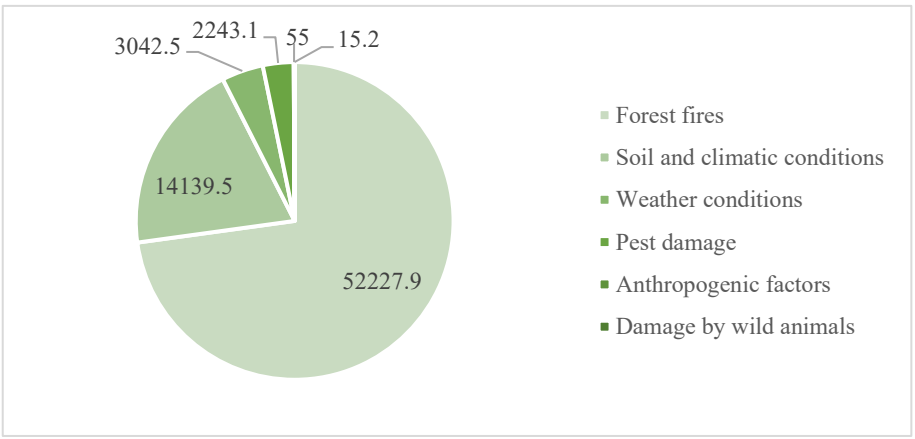

Fig. 2. The impact of environmental and natural factors on forestry in the Russian Federation, for 2022, ha.

Analysing the possibility of innovative development of the forest industry complex, it can be noted that, as in many forest countries of the world (Russia, Brazil, Canada, China, Africa and others), on the territory of the Russian Federation there is a problem of a natural and ecological nature associated with annual forest fires. Forest fires have a detrimental effect on the entire forest industry complex as a whole, in which thousands of hectares have been lost annually for more than 10 years. But forest fires are not the only source of forest loss. If we consider it in dynamics, the area of forest loss is decreasing, but overall, a significant volume of forest loss is observed. Figure 1 shows the dynamics of forest resource loss in the territory of the Russian Federation.

Today, it is worth paying special attention to forest fires, which are one of the most common and strategically dangerous reasons for the destruction of large areas of forests. But an equally important reason is the influence of soil and climatic conditions, damage to trees by pests and various forest diseases. Considering the dynamics of the causes of forest death, it was revealed that according to the results of 2022, the greatest impact was exerted by forest fires, due to which more than 52 thousand hectares of forest died, due to natural and climatic conditions, more than 14 thousand hectares died, from damage to trees by pests - 2243.1 hectares.

Considering the loss of forest resources in the context of ecological and economic zoning, it was concluded that an integrated approach to organizing forestry in a particular region primarily depends on the interaction of key elements in the entire chain of processes, including economic and territorial components of the regions, taking into account regional specifics (exploitable forest resources, various types of forest industry activities, the need for forest industry products in the region).

Table 1. Dynamics of forest fires in the territory of the Russian Federation, for 2023. Source: Compiled by the authors based on data posted by the relevant forest protection service for 2023 and the State Statistics Committee of the Russian Federation [1].

Names of territories in the context of Federal Districts	Number of forest fires, units	Size of forest area engulfed in fire, ha	Amount of forest area lost due to forest fires, ha		
			Total, ha	Of these, coniferous forests, ha	% of total volume
Northwestern Federal District (NWFD)	831	2978.9	1484.9	1449.9	97.64
In % of the total	6.51	0.07	1.60	1.76	110.00
Central Federal District (CFD)	358	631.35	1044.8	883.5	84.56
In % of the total	2.80	0.01	1.12	1.07	95.54
Southern Federal District (SFD)	661	32618.62	1304.3	987.7	75.73
In % of the total	5.18	0.72	1.40	1.20	85.71
North Caucasian Federal District (NCFD)	11	31.09	104.3	104.3	100.00
In % of the total	0.09	0.001	0.11	0.13	118.18
Volga Federal District (VFD)	990	6045.93	2373.5	1393.8	58.72
In % of the total	7.76	0.13	2.55	1.69	66.27
Ural Federal District (UFD)	3438	530143.6	15254.4	11916.8	78.12
In % of the total	26.93	11.66	16.42	14.43	87.88
Siberian Federal District (SFD)	2750	192519.24	18927.9	17890.3	94.52
In % of the total	21.54	4.23	20.37	21.66	106.33
Far Eastern Federal District (FEFD)	3726	3780956.9	52420.5	47956.2	91.48
In % of the total	29.19	83.17	56.42	58.07	102.92
Total on the territory of the Russian Federation	12765	4545925.7	92914.6	82582.5	88.88

Let us consider in more detail the dynamics of forest fires in the territory of the Russian Federation for 2023, according to the necessary data posted by the relevant forest protection service, presented and grouped in Table 1.

According to the data in Table 1 and the dynamics of the indicators, it is clear that the largest number of fires by their quantity was in the Far Eastern Federal District (FEFD),

Siberian and Ural Federal Districts, where 3726 (29.2% of all forest fires in the territory of the Russian Federation), 2750 (21.5%) and 3438 (26.9%) forest fires were recorded in 2023. In other federal districts, the number of forest fires did not exceed 990 units (7.8%) in the Volga Federal District. The smallest number of forest fires was recorded in the forested areas of the North Caucasian Federal District (NCFD), a total of 11 fires (0.09%) were noted. In the Central Federal District and the Northwestern Federal District, the total share of forest fires by area was 2.8 and 6.51, respectively.

2 Material and methods

The application of the ecological and economic zoning approach is carried out mainly when studying territories where large industrial, mechanical engineering and agricultural enterprises are located [5,6,10]. This approach can be applied comprehensively in forestry and in the forest industry, based on the main indicators reflecting the specifics of the activity and complexity of forest areas in different territories.

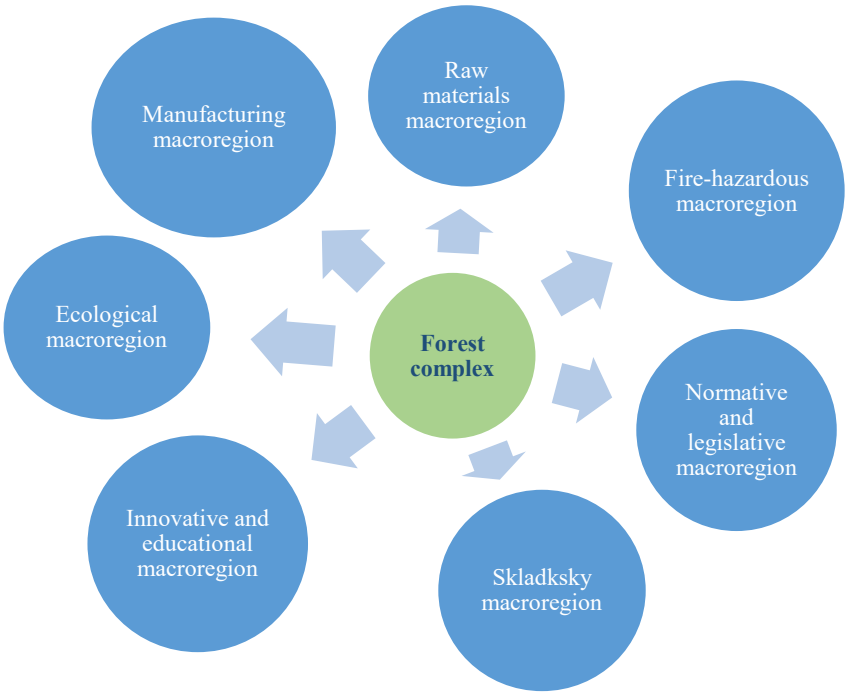

Fig. 3. Results of typology and zoning of territories occupied by forestry and timber industry production.

Today, forest areas can be divided by territorial features into those occupied by logging, wood processing, forest industry production, pulp and paper industry regions, and forest areas. In order to attract investment in the forestry complex and reduce the negative impact on the environment by reducing the number of forest fires, it is necessary to carry out optimal ecological and economic zoning for forestry and the forest industry complex. This approach is based on the basic principle of territorial division, in which forest and forest industry areas are subject to zoning, i.e. into specific zones, according to their functional purpose. In this case, it will be much more accessible and informative to assess the consequences of forest fires and develop measures to prevent them, since the main indicators necessary for calculations and detailing the current situation in forest regions will be reflected. Based on

the optimal key characteristics grouped above, we will define the typology of business processes in assessing the damage and the significance of the necessary measures aimed at preventing and extinguishing forest fires, in terms of territorial zoning: social and public type, economic and industrial, ecological and natural, business and commercial type. The principle of territorial division involves zoning forest areas into separate macro-regions based on the similarity of forest fires that have occurred and the possibility of using identical measures to prevent and extinguish them. In total, it is proposed to identify seven macro-regions taking into account ecological and economic zoning and territorial zoning (Figure 3).

One of the proposed types of macro regions are raw materials macro regions, where enterprises carrying out logging operations are concentrated [7,12]. A fire-hazardous macro region can be represented by hard-to-reach forest areas, where, according to statistics from previous years, forest fires most often occur and where there are difficulties associated with extinguishing and preventing forest fires.

Warehouse macro regions are represented by timber warehouses, where forest timber is stored for further shipment for processing, and transport hubs, where harvested timber is transported from the felling area along branches and tendrils [8,9,13]. As a rule, they are located near freight railway stations and water bodies suitable for timber rafting.

The regulatory and legislative region is concentrated on the territory of large megalopolises, where the forest complex is regulated at the state level based on the development and amendments to regulatory and legal acts in the direction of forestry and the forest industry complex. An important role is given to innovation and educational macro-regions, which form the fundamental basis for providing forest industry enterprises with innovative infrastructure, where the necessary scientific and methodological foundations for increasing the level of innovation in the forest industry complex are developed.

The ecological macro-region contains forest areas for protective, compensatory tree planting, including for carbon deposition and the generation of carbon units in the direction of reducing emissions and absorption of carbon dioxide [14,15,16].

The production macro-region, in which forest industry products are manufactured, is characterized by the concentration of production systems in certain industrial areas for the production of wood products, cellulose and paper and cardboard products, furniture products, wooden structures for construction purposes. This macro-region has its own specific territorial features and can be divided into categories by the complexity and heterogeneity of the products manufactured.

3 Results and Discussion

In the entire chain of interaction of participants in the production process of forest industry production, it is possible to identify processes that hinder the innovative development of business entities. First of all, the growth in the number of inefficient business processes is associated with the conditions of functioning under the sanctions policy of unfriendly states and the need to implement import substitution in the production of products. In addition to economic and geopolitical circumstances, annual forest fires have an important impact on the development of the entire forest complex. Based on the ecological and economic zoning, zoning and typology were carried out, where all production systems, including participants in the production process in the forest complex, are proposed to be grouped, as mentioned above, into seven accessible macro-regions.

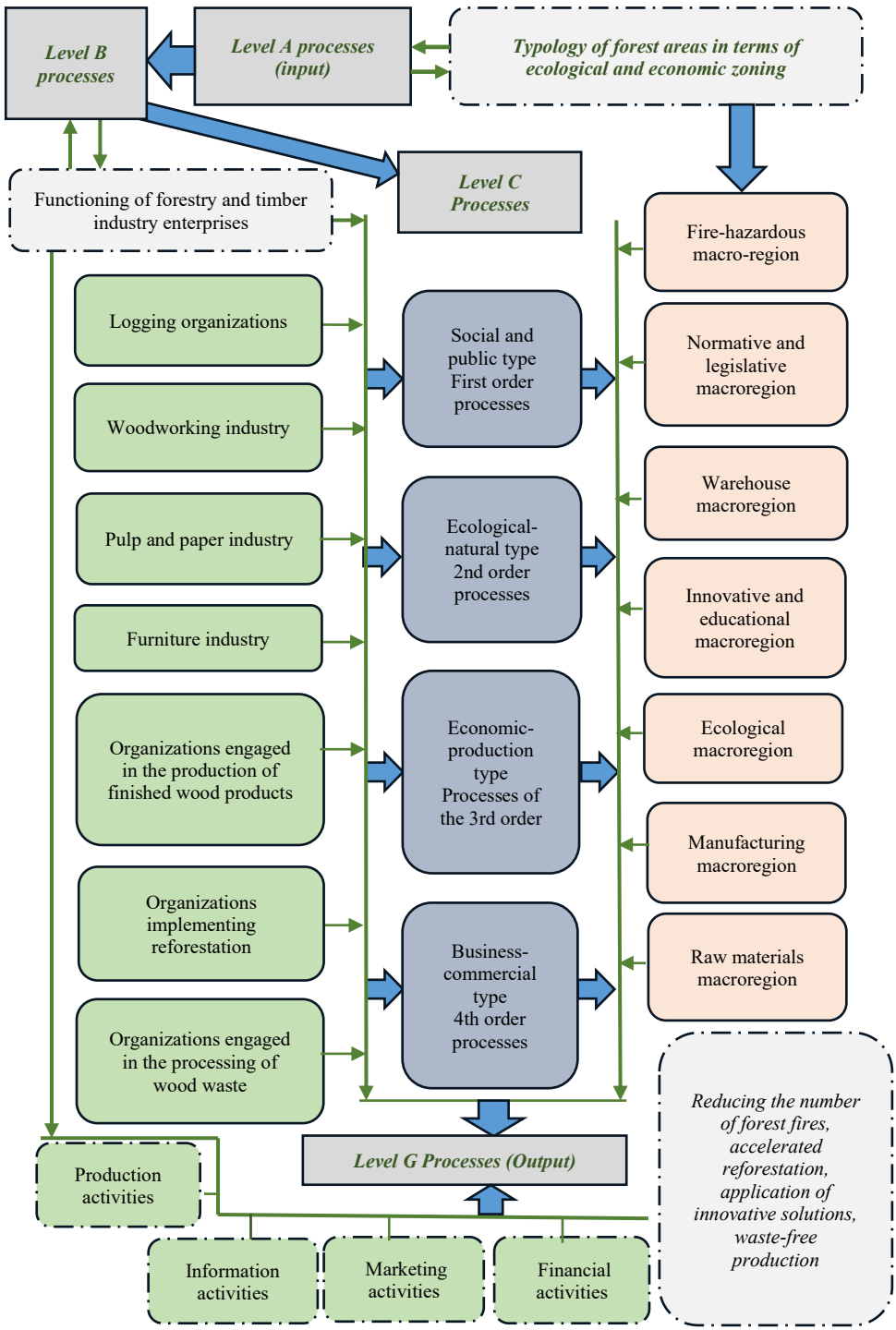

Fig. 4. Model of business processes in the forestry and timber industry enterprises system, in terms of territorial zoning (Generalized model).

The study modelled and typologized the flow of business processes aimed at reducing the number of forest fires and the importance of the necessary measures aimed at preventing and extinguishing forest fires, in the context of zoning of territories. A generalized model of business processes in the system of forestry and forest industry enterprises is proposed, which reflects all seven zoning groups - forest macro-regions (Figure 4).

From the presented model in Figure 4, it can be seen that the entire set of ongoing business processes is reflected, taking into account the interaction of key elements in the forestry and forest industry production system, in the context of zoning of territories in a generalized form, where business processes are formed into four main groups. This model implements an approach to the typology and zoning of forest and forest industry territories, which takes into account all areas of operation of forest industry enterprises and organizations, taking into account the entities of forestry. All areas of activity of forest industry enterprises are also taken into account. At the output, the presented model assumes a transition to a decrease in the number of forest fires based on the use of effective and rational fire extinguishing means, as well as the use of effective measures to prevent and extinguish forest fires. An important role is given to accelerated reforestation, which should use genetically resistant seedlings. The use of optimal innovative solutions is fundamental in the forest complex.

Table 2. Optimal values of the intersection matrix of ongoing business processes in the forestry complex.

Level A processes / **Level B processes**	**Fire-hazardous macroregion**	**Normative and legislative macroregion**	**Warehouse macroregion**	**Manufacturing macroregion**	**Ecological macroregion**	**Innovative and educational macroregion**	**Raw materials macroregion**
Forest complex		10	10	12	16	9	21
Logging organizations	2		3	0	7	0	2
Woodworking industry	1	1		2	2	2	7
Pulp and paper industry	0	3	3		3	4	5
Furniture industry	0	1	0	2		1	1
Organizations engaged in the production of finished wood	0	2	2	5	0		4
Organizations implementing reforestation	4	1	0	0	3	1	
Organizations engaged in the processing of wood	6	2	2	3	1	1	2

In the model, all processes are grouped into four main process blocks (A, B, C, G). The flow of processes begins with the typology of forest areas in the context of ecological and economic zoning, where the output of the model is the task of reducing the number of forest fires through the use of economically sound effective measures for their prevention, accelerated reforestation by innovative methods and the use of genetically stable planting material, the introduction of the latest innovative technologies in the activities of economic entities, as well as the implementation of waste-free production. Next, directly using the process approach and the identified business processes in the forestry system and forest

industry enterprises, in the context of zoning of territories, in the context of assessing the optimality of financing measures aimed at preventing and extinguishing forest fires, we will build a matrix of intersections of ongoing processes (Table 2). The presented matrix takes into account all types of activity in each industry segment: production, financial, marketing and information activities.

As can be seen from the presented matrix, the largest number of processes intersect in the raw materials and ecological macro-region, 21 and 16, respectively. In these conditions, we observe that the number of ongoing processes in the activities of forestry enterprises and forestry is characterized by unevenness, due to which in certain areas difficulties may arise associated with both extinguishing forest fires and further reforestation of lost forest areas. A large number of processes also hinders the efficient operation and innovative development of forestry enterprises.

Table 3. Matrix of the overall impact of intersections of ongoing processes on the financing of environmental measures in the forest industry and forestry.

Level A processes / **Level B processes**	**Fire-hazardous macro region**	**Normative and legislative macro region**	**Warehouse macro region**	**Manufacturing macro region**	**Ecological macro region**	**Innovative and educational macro region**	**Raw materials macro region**
Forest complex		7.672	7.672	9.206	12.274	6.904	16.110
Logging organizations	1.534		2.301	0.000	5.370	0.000	1.534
Woodworking industry	0.767	0.767		1.534	1.534	1.534	5.370
Pulp and paper industry	0.000	2.301	2.301		2.301	3.069	3.836
Furniture industry	0.000	0.767	0.000	1.534		0.767	0.767
Organizations engaged in the production of finished wood	0.000	1.534	1.534	3.836	0.000		3.069
Organizations implementing reforestation	3.069	0.767	0.000	0.000	2.301	0.767	
Organizations engaged in the processing of wood	4.603	1.534	1.534	2.301	0.767	0.767	1.534

Woodworking enterprises face the largest number of intersections in the raw materials macro-region, which is reflected in the cost of supplied raw materials and the duration of the production cycle. In the same macro-region, a significant number of ongoing processes are observed in the activities of pulp and paper mills, but it is worth noting that this is primarily due to the complexity of technological processes in the production of paper and cardboard products. Having calculated and assessed all four types of influence, we will construct a general matrix of influence on the possibility of attracting financial resources to environmental projects by forest industry enterprises and organizations engaged in forestry (Table 3). The calculations were carried out using the necessary software and mathematical

apparatus using the function for determining the average value for each intersection of the identified processes.

According to the calculations in the presented matrix, we see that in those cells where the same values are marked, these processes are homogeneous and proceed according to a single regulatory documentation, therefore, it is necessary to eliminate ineffective business processes in the entire chain of their flow and develop additional internal local regulations that contribute to the acceleration of interaction between processes. Most indicators are outside the optimal value range (from 2 to 3). All indicators corresponding to the optimal range are highlighted in green in the matrix. It can be seen that in the entire chain of business processes of forestry and forest industry, the largest number of optimal processes is noted in the pulp and paper industry in four macro-regions out of seven. The remaining production and forestry areas are distinguished by a low number of optimal values. Considering the processes of group "A", we see that the warehouse and environmental macro-regions are in the greatest degree of optimality, accordingly, the optimal number of interruptions of ongoing processes should vary from 10 to 16 for each group of processes "B".

4 Conclusion

Today, forest industry enterprises need to develop environmental measures to preserve natural resources. It may be important to use effective innovative developments that contribute to the production of higher-quality forest industry products and take into account the possibility of minimizing the impact on the environment. It is also worth paying attention to the fire-hazardous macro region and ensuring more rational interaction of all participants in forest industry production. For example, only 3 out of 7 groups of industrial production are involved in this macro-region, of which only organizations involved in reforestation (optimality index 3.069) meet the required level of optimality, since they are provided with all the necessary and well-established processes. But at the same time, organizations that ensure the removal of logging residues experience difficulties associated with a large number of intersections of ongoing business processes (optimality index 4.603), here more attention should be paid to the innovative-educational and environmental macro region.

Acknowledgments

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